Chula Med J Vol. 49 No. 4 April 2005

Quality assurance for the alignment of the field of radiotherapeutic treatment of cancer in of head and neck

Prayuth Rojpornpradit*
Sivalee Suriyapee* Saranya Lapanich*

Rojpornpradit P, Suriyapee S, Lapanich S. Quality assurance for the alignment of the field of radiotherapeutic treatment of cancer in of head and neck. Chula Med J 2005 Apr; 49(4): 225 - 40

Purpose : *To evaluate the accuracy of the alignment of treatment field in radiotherapy for cancer of head and neck region, in order to evaluate the precision of the field alignment which relates to the increase of survival and the reduction of side effects.*

Setting : *Division of Radiation Oncology, Department of Radiology, King Chulalongkorn Memorial Hospital.*

Research design : *Prospective observational descriptive study.*

Patients and methods : *15 patients with cancer in the head and neck region, who were treated with linear accelerator at King Chulalongkorn Memorial Hospital from 1 February 2003 - 31 July 2003, were recruited. Weekly portal film was done; localized film was compared with first portal film which was then measured up to the consequent portal films. Inaccuracy parameters were evaluated from entrance field location, beam direction, movement, block and field edge. Excel program was implemented to identify the value of maximum, minimum, mean and standard deviation.*

* Department of Radiology, Faculty of Medicine, Chulalongkorn University

Results : *In total, 182 films (53 localized films and 129 portal films) and 1,510 were evaluated, and points were analyzed. The inaccuracy of entrance field location, beam direction, patient movement, block and filed edge were 0.23, 0.27, 0.26, 0.24 and 0.17 cm, respectively. The result shows the similar inaccuracy for all parameters studied and technique used. According to these data, the discrepancy in the means and standard deviations of localized and first portal film were a little bit higher than those of first portal and consequent portal films. This means the transition from simulation to treatment set up yielded larger deviations than repeated treatment set up.The maximum inaccuracy was 1.95 cm resulted from the difference between simulation and treatment at the field edge location, but it is only 0.12 % of all evaluated points.*

Conclusion : *The error was less than 1.00 cm and standard deviation was less than 2 cm. Therefore, international standard radiotherapy of King Chulalongkorn Memorial Hospital was approved and confirmed that role of radiation technician is important in setting the field.*

Keywords : *Quality assurance, Accuracy, Treatment field alignment, Radiotherapy, Head and neck cancer, King Chulalongkorn Memorial Hospital.*

Reprint request: Rojpornpradit P. Department of Radiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand.

Received for publication. June 30, 2004.

ประยุทธ์ โรจน์พรประดิษฐ์, ศิวลี สุริยาปี, สรัญยา ฬาพานิช. การควบคุมคุณภาพของการฉายรังสีในผู้ป่วยมะเร็งบริเวณศีรษะและลำคอ. จุฬาลงกรณ์เวชสาร 2548 เม.ย; 49(4): 225 – 40

วัตถุประสงค์ : *เพื่อวัดความคงที่ของขอบเขตการฉายรังสีในผู้ป่วยมะเร็งบริเวณศีรษะและลำคอ โดยการเปรียบเทียบตำแหน่งของจุดอ้างอิงต่าง ๆ จาก Localized film และ Portal film เพื่อให้การรักษาด้วยรังสีมีความแม่นยำ เพิ่มประสิทธิภาพของการรักษาผู้ป่วย ทำให้อัตรารอดชีวิตเพิ่มขึ้นในขณะที่อาการจากผลข้างเคียงน้อยลง*

สถานที่ทำการศึกษา : *สาขารังสีรักษา ฝ่ายรังสีวิทยา โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย*

รูปแบบการวิจัย : *การวิจัยเชิงพรรณนาแบบไปข้างหน้า*

วิธีการศึกษา : *ศึกษาในผู้ป่วยมะเร็งบริเวณศีรษะและลำคอจำนวนทั้งหมด 15 ราย ที่เข้ารับการรักษาด้วยรังสีรักษาที่ห้อง Linear accelerator ตึกเอลิสะเบธ สาขารังสีรักษา ฝ่ายรังสีวิทยา โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย ช่วงระหว่างวันที่ 1 กุมภาพันธ์ 2546 ถึง 31 กรกฎาคม 2546 การศึกษาวิจัยทำโดยการถ่ายภาพ Localized film และ Portal film ทุกสัปดาห์ หลังจากนั้นนำ Localized film มาเปรียบเทียบกับ Portal film ครั้งแรก, Portal film ครั้งแรก มาเปรียบเทียบกับ Portal film แผ่นต่อ ๆ ไปในทุกสัปดาห์ พิจารณาค่าความคลาดเคลื่อนจากตำแหน่งลำรังสีเข้า (Entrance field location) ทิศทางที่ลำรังสีออก (Beam direction) การเคลื่อนไหวของผู้ป่วย (Patient movement), ตำแหน่งของแท่งกำบังรังสี (Block) และขอบเขตของพื้นที่ฉายรังสี (Field edge) โดยใช้โปรแกรม Excel เพื่อคำนวณหาค่า Maximum, Minimum, Mean และ Standard deviation*

ผลการศึกษา : *จำนวน Film ทั้งหมด 182 films แบ่งเป็น Localized film 53 films และ Portal film 129 films จำนวนจุดอ้างอิงทั้งหมด 1,510 จุด พบว่าค่าความคลาดเคลื่อนเฉลี่ยของ Entrance field location, Beam direction, Patient movement, Block และ Filed edge มีค่าเท่ากับ 0.23, 0.27, 0.26, 0.24 และ 0.17 เซ็นติเมตร ตามลำดับ ค่า Mean และ SD ของความแตกต่างระหว่าง Localized film กับ Portal film ครั้งแรกมีค่ามากกว่าค่า Mean และ SD ของความแตกต่างระหว่าง Portal film ของการฉายรังสีครั้งแรกกับ Portal film ในครั้งต่อ ๆ ไป ซึ่งแสดงว่าเมื่อมีการย้ายผู้ป่วยจากเครื่อง Simulation มายังเครื่องฉายรังสีค่าความคลาดเคลื่อนเกิดมากกว่าการฉายรังสีผู้ป่วยในเครื่องเดียวกันครั้งต่อ ๆ ไป ค่าความคลาดเคลื่อนที่พบมากที่สุดคือความแตกต่างระหว่าง Localized film กับ Portal film ครั้งแรกของ Field edge location มีค่าเท่ากับ 1.95 เซ็นติเมตร ซึ่งเป็นเพียง 0.12 % ของจำนวนจุดอ้างอิงทั้งหมด*

บทสรุป : *ค่าความคลาดเคลื่อนเฉลี่ยมีค่าอยู่ในเกณฑ์มาตรฐานที่ยอมรับได้คือมีค่าความคลาดเคลื่อนน้อยกว่า 1.00 เซ็นติเมตร และมีค่า Standard deviation (SD) น้อยกว่า 2 จึงสรุปได้ว่ามาตรฐานการฉายรังสีของสาขารังสีรักษา ฝ่ายรังสีวิทยา โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย อยู่ในเกณฑ์มาตรฐานสากลที่ยอมรับได้*

คำสำคัญ : *การควบคุมคุณภาพ, การฉายรังสี, มะเร็งบริเวณศีรษะและลำคอ*

According to the statistics of the Division of Radiation Oncology, Department of Radiology, King Chulalongkorn Memorial Hospital, the number of patients with cancer has been increasing every year, mostly with the malignancy of the head and neck region.[1]

The preferred model of treatment for most cases of cancer is multimodality approach consisting of radiation, surgery, chemotherapy, etc. In daily radiation therapy, there are substantial inaccuracies of the field alignment for radiation that occur due to a number of factors.[2]

Many researches were conducted, on the assurance of the field alignment for radiotherapy such as:

- Herring *et al.*[3] documented that the change of radiation dose for patient at +/- 10 % could result in the decrease of tumor control and the increase of normal tissue necrosis.

- Sue E *et al.*[4] identified that the accuracy of reference points between localized and portal film of pelvic irradiation were below acceptable standard points.

- C.L. Creutzberg *et al.*[5] identified portal film and summarized that the inaccuracy of reference points in radiotherapy of breast cancer are below the acceptable standard points.

Therefore the accuracy of radiation dose and alignment of radiation field in radiotherapy are necessary for the improvement of the efficiency of treatment.[3-6]

Populations and methods

This study was conducted at the Division of Radiation Oncology, Department of Radiology, King Chulalongkorn Memorial Hospital. Time frame of the study is 1.3 years, from October 2002- December 2003. Fifteen patients (7 males and 8 females) were treated with Linear Accelerator from 01 February-31July 2003. Their median age was 49.80 years (23-76 years). Total radiation dose of 60-70 Gy, in 30-35 fractions in 6-7 weeks, 5 fractions per week was used. This study was approved by Ethics Committee for Research of the Faculty of Medicine, Chulalongkorn University, registered number 090/2003.

Inclusion criteria

To be qualified for recruitment into the study, the subject needs to fit in with the following criteria, namely:

1. Age equal or more than 18 years
2. Histopathology proved for head and neck cancer
3. Karnofsky performance status (KPS) equal or more than 70%.
4. Submitted written informed consent
5. Psychologically healthy
6. No previous history of irradiation
7. Prescribed for Linear accelerator

Exclusion criteria

The criteria for exclusion of the candidate for the study are as follows:

1. Second primary carcinoma found
2. Pregnancy
3. Radiation therapy planned with non-conventional dose prescription
4. Incomplete schedule of radiation treatment

Research materials

1. Simulator: Varian Ximatron CX
2. Linear accelerator: Varian Clinac 1800

3. Cassette: Kodak Lanex for Localized film

4. Cassette: Kodak EC-L Cassette/ Screen for verification 14 x 17 inch for Portal film

5. Diagnostic film for Localized film

6. Kodak EC film for oncology 14 x 17 inch for portal film

Procedure in the Simulation Room

Markers were attached bilaterally on the fixation mask. Simulation was done. Localized film was taken bilaterally.

Procedure in the Linear Accelerator Room

Portal film of the radiation field was done on the first day of radiotherapy, both right and left lateral field, anterior-posterior field and anterior-posterior face field (Figure 1-13). After that, portal film was taken weekly.

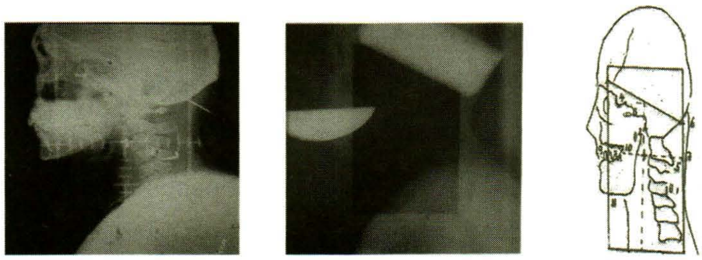

Figure 1. Points of evaluation of lateral field of simulation film and portal film. 1=Marker 1, 2= Marker 2, 3=Marker 3, 4=Anatomical point 1 (Lowest point of sella), 5=Anatomical point 2 (Tip of transverse process of C1), 6=Block 1 (The most lateral point of cranial block), 7=Field edge 1 (Field edge of treatment field; left), 8=Field edge 2 (Field edge of treatment field; inferior), 9=Field edge 3 (Field edge of treatment field; right), 10=Block 2 (The most lateral point of oral mucosa block), 11=Anatomical point 3 (Tip of middle mandible)

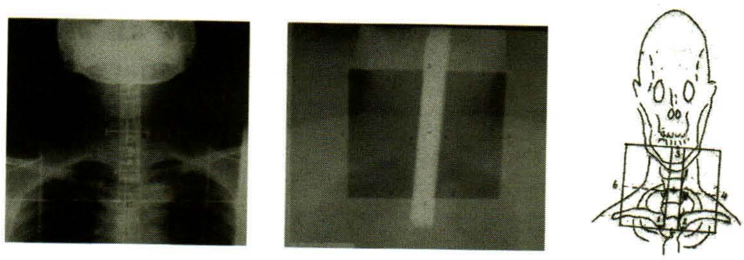

Figure 2. Points of evaluation of AP field of simulation film and portal film. 1=Anatomical point 1 (The most inferior point of left clavicle head), 2=Anatomical point 2 (The most inferior point of right clavicle head), 3=Field edge 1 (Field edge of treatment field; superior), 4=Field edge 2 (Field edge of treatment field; left), 5= Field edge 3 (Field edge of treatment field; inferior), 6=Field edge 4 (Field edge of treatment field; right), 7=Block 1 (Right lateral of middle of block edge), 8=Block 2 (Left lateral of middle of block edge)

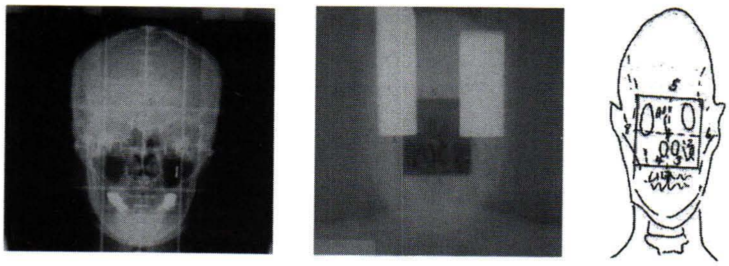

Figure 3. Points of evaluation of AP face field of simulation film and portal film.
1=Marker 1, 2=Marker 2, 3=Anatomical point 1(The most lateral point nasal cavity wall; left), 4=Anatomical point 2 (The most lateral point nasal cavity wall; right), 5=Field edge 1 (Field edge of treatment field; superior), 6=Field edge 2 (Field edge of treatment field; left), 7=Field edge 3 (Field edge of treatment field; inferior), 8=Field edge 4 (Field edge of treatment field; right).

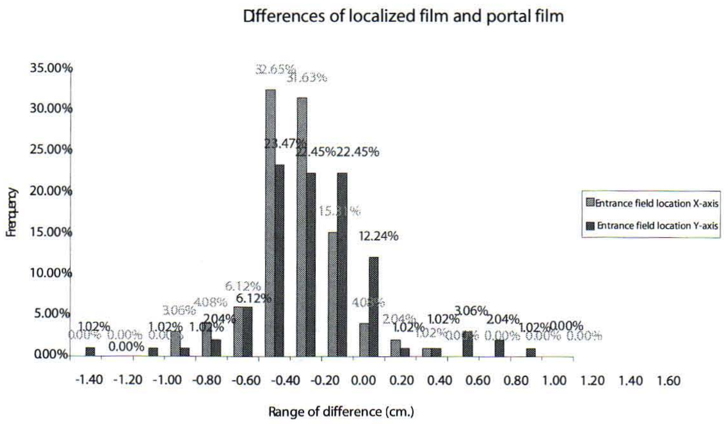

Figure 4. Differences of entrance field location on X and Y axis, comparing between the first Localized and Portal film.

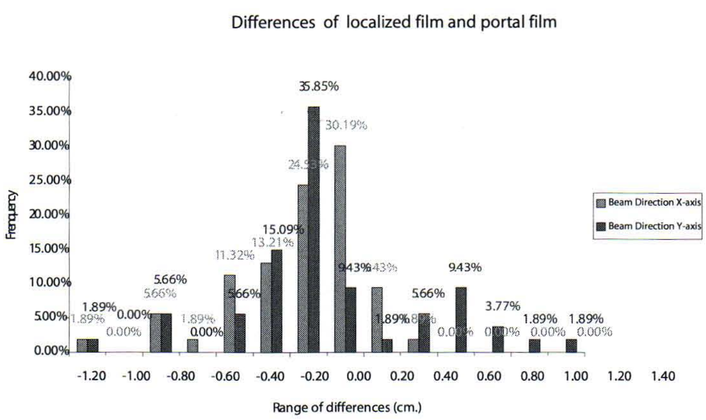

Figure 5. Differences of beam direction on X and Y axis, comparing between the first localized and portal film.

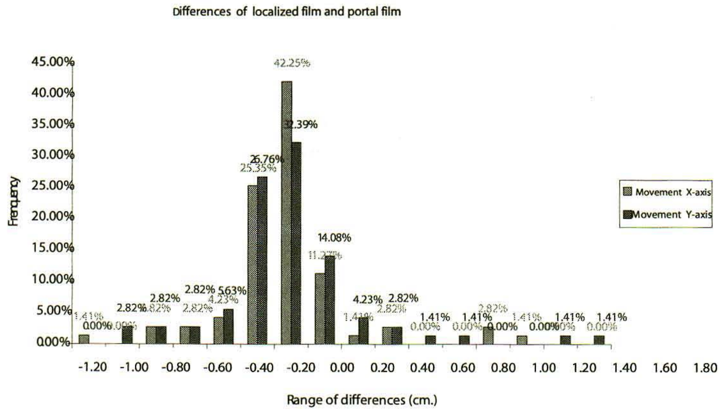

Figure 6. Differences of movement on X and Y axis, comparing between the first localized and portal film.

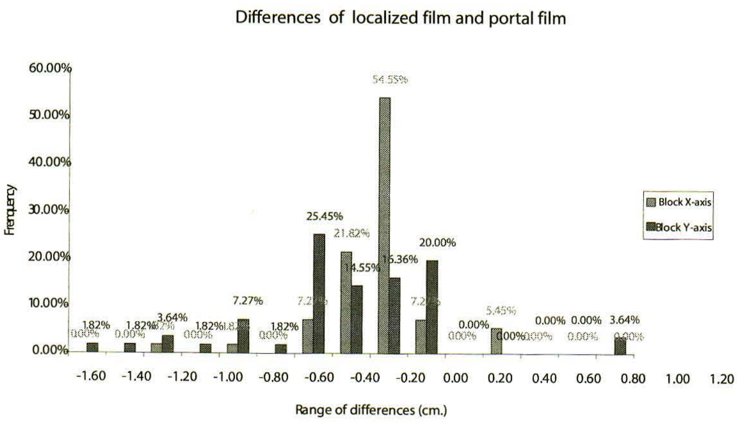

Figure 7. Differences of Block on X and Y axis, comparing between the first localized and portal film.

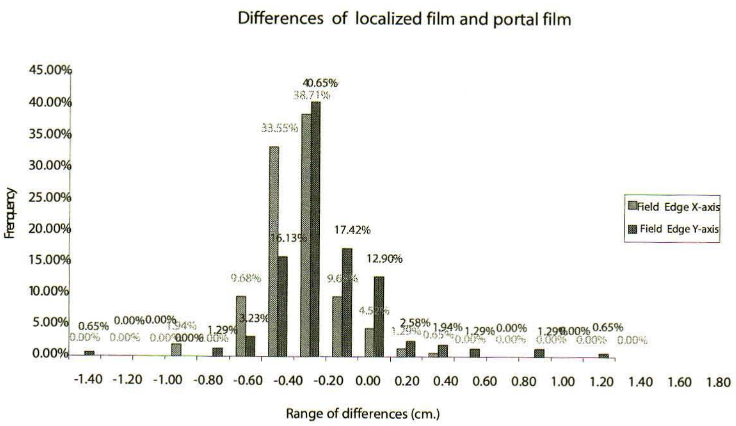

Figure 8. Differences of field edge on X and Y axis, comparing between the first localized and portal film.

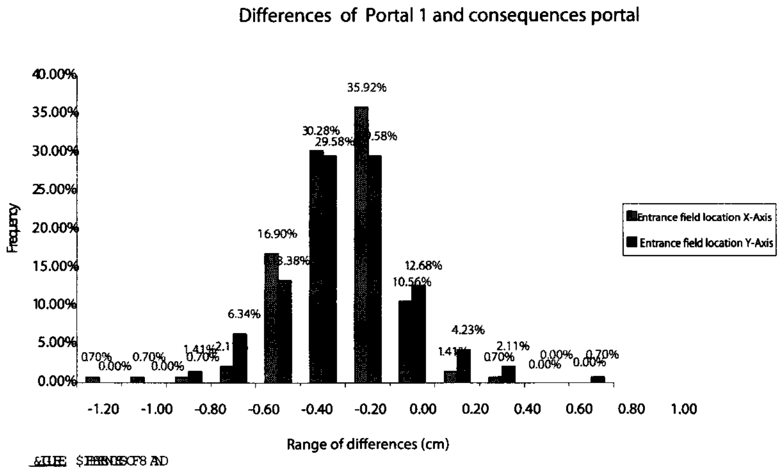

Figure 9. Differences of X and Y axis, comparing between the first and consequent portal films.

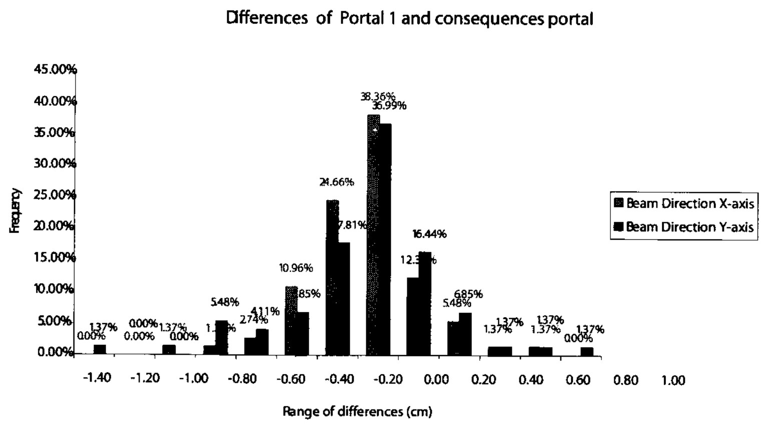

Figure 10. Differences of beam direction on X and Y axis,comparing between the first and consequent portal films.

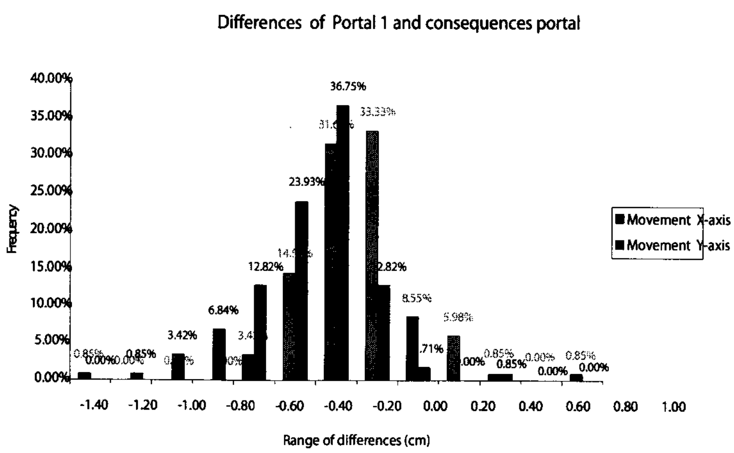

Figure 11. Differences of movement on X and Y axis, comparing with first and consequence portal film.

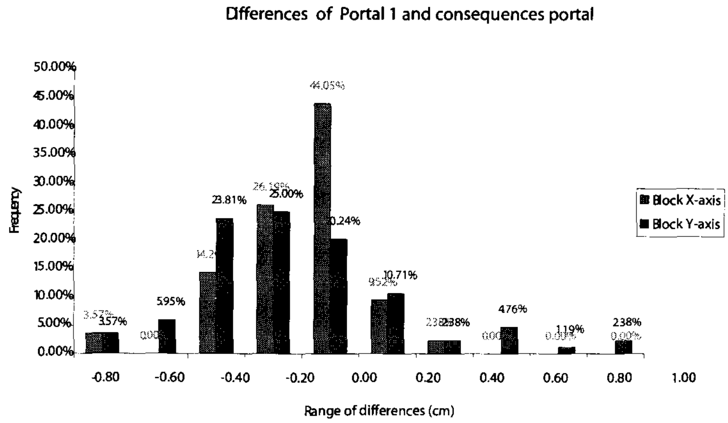

Figure 12. Difference of block on X and Y axis, comparing between first an consequence portal film.

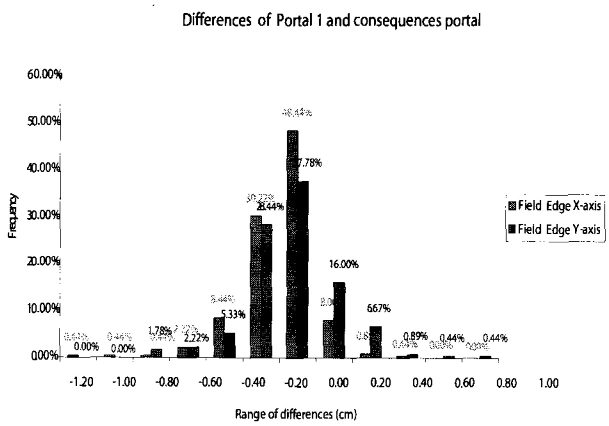

Figure 13. Differences of field edge on X and Y axis, comparing between first and consequence portal film.

Data collection and analysis

Differences of reference points on both the X and Y axis were identified by comparing localized to first portal film, and first portal film was measured up to the consequent portal films based on the same alignment as anatomical landmarks, field edges, blocks and markers.

1. X and Y axis were set up with the origin at the center of treatment field.

2. Measured distance between reference points and the origin on both the X and Y axis of localized and first portal film. The results were divided by magnification each films.

3. Differences of reference points on the X and Y axis were identified by comparing localized and first portal films.

4. Measured distance between reference points and the origin on both the X and Y axis of first and consequent portal films. The results were divided by magnification each films.

5. Differences of reference points on the X and Y axis were identified by compared first and consequent portal films.

6. Identified the maximum, the minimum, mean and SD by Excel program.

Differences in each reference points would be used in each parameter as follows:

1. Entrance field location consists of markers on the entrance of radiation beam
2. Beam direction consists of markers on the exit of radiation beam
3. Movement consists of anatomical points
4. Block consists of block alignment
5. Field edge consists of treatment field edge

Results

Totally, 182 films (53 localized films and 129 portal films) and 1,510 points were analyzed. Differences of reference points on localized films and first portal films have shown differences of radiation plan and the first radiotherapy on the first day. Differences of reference points on first and consequent portal film have shown differences of radiotherapy between the first and consequent weeks. Details are as follows:

Statistical evaluation was commenced with the use of Microsoft Excel program for the calculation of the maximum, the minimum, mean and standard deviation of parameters in each group. They are shown in table 1 as follows:

Table 1. The inaccuracy in tem of Maximum, Minimum, Mean and Standard deviation of each parameter of this study.

Statistical evaluation	Entrance field location	Beam	Movement	Block	Field edge
Maximum (cm)	1.52	1.59	1.83	1.88	1.95
Minimum (cm)	0.00	0.00	0.00	0.00	0.00
Mean (cm)	0.23	0.27	0.26	0.24	0.17
SD (cm)	0.23	0.29	0.29	0.26	0.22

Table 2. Maximum, Minimum, Mean and Standard deviation of each parameter were considered on the difference of Localized and first Portal film, as well as first and consequence Portal film.

Statistical evaluation	Entrance field location		Beam direction		Movement		Block		Field edge	
	L	P	L	P	L	P	L	P	L	P
Maximum(cm)	1.52	1.17	1.59	1.38	1.83	1.34	1.88	1.10	1.95	1.33
Minimum(cm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean(cm)	0.26	0.19	0.34	0.21	0.30	0.23	0.27	0.22	0.21	0.15
SD(cm)	0.27	0.19	0.34	0.23	0.37	0.21	0.32	0.21	0.28	0.17

L = Differences of Localized and first Portal films.

P = Differences of first and consequence Portal films.

According to table 1, the maximums, minimums, means and standard deviations of each parameter in the study are as follows:

1. Entrance field location: maximum =1.52 cm, minimum=0.00 cm, mean=0.23 cm, SD=0.23 cm

2. Beam direction: maximum=1.59 cm, minimum=0.00 cm, mean=0.27 cm, SD=0.29 cm

3. Movement: maximum = 1.83 cm, minimum = 0.00 cm, mean = 0.26 cm, SD=0.29 cm

4. Block: maximum = 1.88 cm, minimum = 0.00 cm, mean = 0.24 cm, SD = 0.26 cm

5. Field edge: maximum = 1.95 cm, minimum = 0.00 cm, mean = 0.17 cm, SD= 0.22 cm

According to table 3 and 4, differences between localized and first portal film are shown in terms of maximum, minimum, mean and standard deviation with a little higher range than first and consequent portal film.

Table 3. Average of Maximum, Minimum, Mean and Standard deviation on each Treatment field have been shown in X and Y axis, comparing between differences of Localized and first Portal film.

Treatment field	Maximum (cm)		Minimum (cm)		Mean (cm)		SD (cm)	
	X	Y	X	Y	X	Y	X	Y
Right lateral	1.17	1.33	0.00	0.00	0.19	0.29	0.78	0.24
Left lateral	1.81	1.59	0.00	0.00	0.81	0.30	0.23	0.29
Right lateral reduced	1.44	1.88	0.00	0.00	0.26	0.55	0.25	0.56
Left lateral reduced	1.28	1.95	0.00	0.00	0.24	0.43	0.25	0.43
Anteroposterior	1.04	1.64	0.00	0.00	0.25	0.18	0.24	0.31
Anteroposterior face	0.11	0.54	0.00	0.00	0.03	0.11	0.03	0.01
All treatment fields	1.81	1.95	0.00	0.00	0.30	0.31	0.30	0.32

Table 4. Average of Maximum, Minimum, Mean and Standard deviation on each Treatmentfield have been shown in X and Y axis, comparing with differences of first and consequence Portal films.

Treatment field	Maximum (cm)		Minimum (cm)		Mean (cm)		SD (cm)	
	X	Y	X	Y	X	Y	X	Y
Right lateral	1.17	1.07	0.00	0.00	0.18	0.22	0.18	0.19
Left lateral	1.34	1.10	0.00	0.00	0.19	0.26	0.19	0.24
Right lateral reduced	0.50	1.38	0.00	0.00	0.17	0.36	0.14	0.34
Left lateral reduced	0.53	0.72	0.00	0.00	0.15	0.23	0.10	0.14
Anteroposterior	0.92	0.76	0.00	0.00	0.26	0.15	0.17	0.16
Anteroposterior face	0.34	0.24	0.00	0.00	0.05	0.05	0.06	0.06
All treatment fields	1.34	1.38	0.00	0.00	0.17	0.21	0.14	0.19

Discussion

ICRU (International Commission on Radiation Units and Measurements)[7] number 24 applied in the standard of uncertainty in dose to a patient at 5 % and inaccuracy value in radiation field edge at less than 1.00 cm. Uncertainty in dose to a patient = 5 %, consist of the followings:

1. Cumulative uncertainty in dose delivered to a tissue = 2.5 %

2. Uncertainty in the treatment planning computation of dose to a patient = 4.2 %

Uncertainty in dose to a patient is shown in figure 14.

Inaccuracy value of radiation therapy must be less than 1.00 cm (Details are shown in figure 15). It consists of machine inaccuracy of less than 0.50 cm; patient set up and patient motion is less than 0.80 cm.

In daily radiation therapy, there are substantial inaccuracies of the alignment of treatment field due to the machine. Therefore the machine should be maintained at the tolerance level.[8-10] Markers on entrance radiation beam for entrance field location which

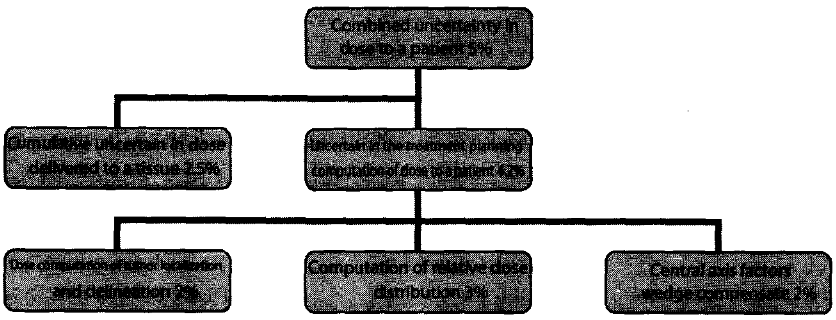

Figure 14. Dosimetric uncertainties in the process of radiation therapy. The uncertainties represent approximately 95 % of confidence level.

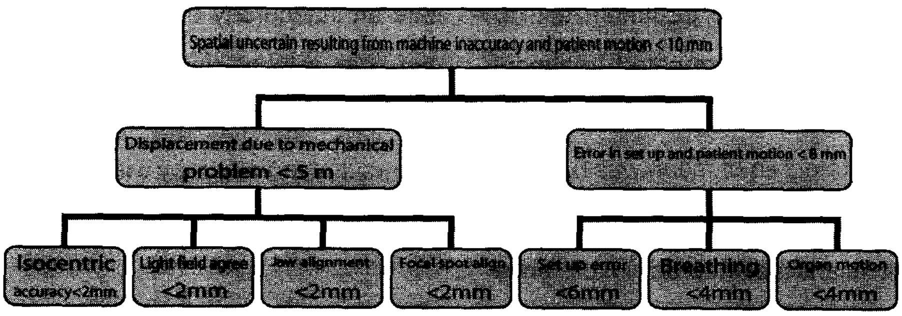

Figure 15. Spatial uncertainties (at the 95 % confidence level) in the radiation therapy process.

means the accuracy of entrance beam direction and mask positioning. Markers on exit beam direction for beam direction. Anatomical points for patient movement. Blocks for setting up and Field edge for field alignment of the treatment.

In conclusion:

1. References points were marked at the same position for both localized and portal film. After considering the inaccuracy on both the X and Y axis, the result are shown in the average inaccuracy of entrance field location, beam direction, movement, block, and field edge at 0.23, 0.27, 0.26, 0.24 and 0.17 cm, respectively.

2. Differences of localized and first portal film, and up to the consequent portal film: Reference point have shown entrance field location, beam direction, movement, block and field edge with different mean and SD as follows:

- Differences of localized and first portal film were identified with mean at 0.21-0.34 cm, SD at 0.27-0.37 cm. Differences of first and consequent portal film were identified with mean at 0.15-0.23 cm, SD at 0.17-0.23 cm.

- Differences of means and SD on localized and first portal film were identified with the higher rate than first and consequent portal film which means the transition from simulation to treatment set up yielded larger deviations than repeated treatment set up.

3. The highest degree of mean was 0.34 cm which is lower than 1.00 cm. Of ICRU 24's standard inaccuracy value, it means the accuracy in reference points between localized and first portal film were under acceptable standard points as Sue[11] and Creutzberg's study.[3]

4. SD is nearly or higher than mean of each parameter, compared between localized and first portal films. For the comparison between first and consequent portal films, SD was used to identify extreme value and abnormal data distribution. The majority of differences and inaccuracies were found at 0.00 - 0.40 cm, with the minority at 1.95 cm.

The inaccuracy in treatment field between localized and portal film is related to the following factors:[11-13]

1. Machine inaccuracy: the inaccuracy from simulation room to treatment room

2. The inaccuracy from daily radiotherapy, such as:

2.1 Patient's movement

2.2 Patient's positioning and treatment field set by radiation technician, considered from entrance field location, beam direction, block and field edge.

The inaccuracy of the filed of treatment between localized film and first portal film can be identified with the higher rate than between first and consequence portal films. The transition may result in machine inaccuracy. Hence, it is necessary to improve the accuracy by quality assurance.

After considering each parameter, we found that an inaccuracy degree could be decreased by the radiation technician, the accuracy of treatment field alignment and block. Also the result in this study shows that radiotherapy with different block sizes will result in different of outcomes on portal film.

Conclusion

From this study, the mean of each parameter and in total are under the acceptable standard point with an inaccuracy degree at equal or less than 1.00 cm and SD degree less than 2 cm. Radiation technique can be improved, if the cause of the inaccuracy is identified according to the following parameters:

1. Error rate from machine can be avoided by implementing quality assurance.

2. The inaccuracy of patient positioning:

2.1 Patient movement can be decreased by immobilizing device.

2.2 Technical factors can be improved: an inaccuracy degree can be decreased by the radiation technician.

Therefore the recommendation for improvement should be presented to radiation therapists in their daily practice in order to improve the technique of radiation. Daily radiotherapy on the filed of treatment is related to the inaccuracy of alignment of the filed of treatment due to the technique of radiation therapy, set up, immobilization device, patient motion and machine. Radiotherapy in King Chulalongkorn Memorial Hospital is below the acceptable standard, this may be because the radiation technicians were informed, pertaining the implementation of this study.

The results of this study will be used to evaluate the quality of radiation of Three Dimensional Conformal Radiation Therapy (3DCRT) and Intensity Modulated Radiation Therapy (IMRT), consist of real time film taken with portal imaging machine which resulted in the accuracy of radiotherapy on treatment field border.

The advantages from this study

1. Technique of treatment can be improved.

2. It achieved maximal precision in radiotherapy.

3. It maintained radiotherapy treatment of KCMH at acceptable standard.

4. It collected data and recommendation from patient and family for the next treatment.

5. It encouraged radiation technician to improve themselves in their daily positioning of treatment filed in order to achieve maximal precision in radiotherapy.

Suggestion for further work

Portal film should be taken routinely to identify the inaccuracy, precision and maximal achievement in radiotherapy. Collection of information can be advantage for the next treatment. The findings of this study should be presented to radiation technicians to empower them to do their best in daily practices.

Acknowledgements

Firstly, we would like to acknowledge with appreciation the following members of our medical team. Assoc. Prof. Prasert Lertsanguansinchai MD, Ass. Prof. Nopadol Asavametha MD, Ass. Prof. Chonlakiet Khorprasert MD, Ass. Prof. Kanjana Shotelersuk MD, Chawalit Lertbutsayanukul MD. for their kind assistance and cooperation.

Secondly, we would like to thank our radiation technicians, Mr. Wisut Wannawichit, Mr.Chutinan Nashin, Mr.Jamnong Khumkao, Ms. Amonwan Nasingkan, Ms. Aranya Ekwongsa, and Mr. Tinnakorn Boonrab for their wonderful works. Lastly, we would like to thank our physicists, Ms. Chulee Jaroonsantowong and Mr. Taweep Saenghangtham, and research assistance Ms. Sumada Lapanich and Dr. Wuttipong Tirakotai in their effort of making the research to its final conclusion.

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