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Analysis of the Inter- and Intra-treatment Isocenter Deviations in Pelvic Radiotherapy With Small Bowel Displacement System

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Purpose: To evaluate the extent and frequency of the inter- and intra-treatment isocenter deviations of the whole pelvis radiation field in using small bowel displacement system (SBDS).

Methods and Materials: Using electronic portal imaging device (EPID), 302 postero-anterior (PA) and 232 lateral portal images were prospectively collected from 11 patients who received pelvic radiation therapy (7 with cervix cancer and 4 with rectal cancer). All patients were treated in prone position with SBDS under the lower abdomen. Five metallic fiducial markers were placed on the image detection unit for the recognition of the isocenter and magnification. After aligning the bony landmarks of the EPID images on those of the reference image, the deviations of the isocenter were measured in right-left (RL), cranio-caudal (CC), and PA directions.

Results: The mean inter-treatment deviation of the isocenter in each RL, CC, and PA direction was 1.2 mm (±1.6 mm), 1.0 mm (±3.0 mm), and 0.9 mm (±4.4 mm), respectively. Inter-treatment isocenter deviations over 5 mm and 10 mm in RL, CC, and PA direction were 2, 12, 24%, and 0, 0, 5%, respectively. Maximal deviation was detected in PA direction, and was 11.5 mm. The mean intra-treatment deviation of the isocenter in RL, CC, and PA direction was 0 mm (±0.9 mm), 0.1 mm (±1.9 mm), and 0 mm (±1.6 mm), respectively. All intra-treatment isocenter deviations over 5 mm in each direction were 0, 1, 1%, respectively.

Conclusion: As the greatest and the most frequent inter-treatment deviation of the isocenter was along the PA direction, it is recommended to put more generous safety margin toward the PA direction on the lateral fields if clinically acceptable in pelvic radiotherapy with SBDD.

Key Words: Electronic portal imaging device, Pelvic radiotherapy

INTRODUCTION

In radiation therapy, treatment field deviation has been known to reduce local control and disease free survival.[1] Field movements of ±5 mm can lead to decrease 10~15% disease in tumor control probability according to the tumor dose-response models.[2] Increasing tumor margin would compensate setup errors of the radiation fields, but could increase normal tissue complications. Many devices have been developed to measure these deviations, and radiographic film is one of these devices and most commonly used worldwide. However film image needs complicated process including cassette preparation, film exposure, retrieval, processing, and viewing and makes huge film wastes. Recently, digital portal imaging system is growingly used with the convenience of viewing within seconds.

In our hospital, we have used small bowel displacement system (SBDS) in pelvic radiotherapy to reduce small bowel complications (Fig. 1).[3] But this may induce more unstable

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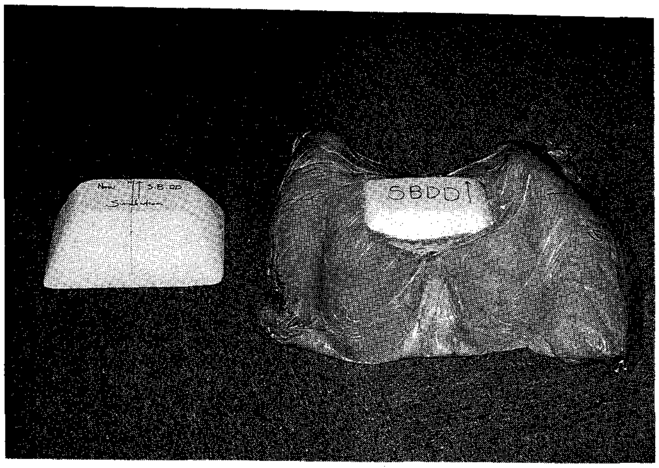

Fig. 1. The small bowel displacement system consists of a styrofoam compression device and a custom made immobilization abdominal board.

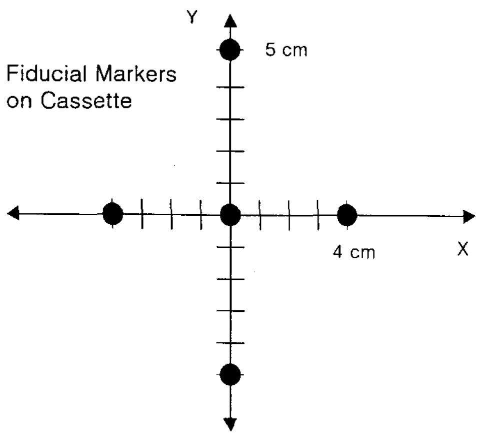

Fig. 2. Schematic picture showing five fiducial markers on cassette.

set-up positions. In order to verify these errors, we analysed inter-treatment and intra-treatment deviations by using electronic portal imaging device (EPID).

MATERIALS AND METHODS

Seven patients with cervix cancer and 4 patients with rectal cancer who received postoperative whole pelvis irradiation were evaluated by EPID (Portalvision™ V.3.5, Varian, USA). Pixel size is 1.27 mm×1.27 mm, spatial resolution is 2.3 mm×2.9 mm. All patients were treated in prone position with SBDS. The superior border was placed between the fourth and fifth lumbar spine or lumbosacral junction. The inferior border was the inferior margin of the obturator foramen. The lateral borders were 1~2 cm beyond the bony pelvic brim. The anterior border was at the level of the symphysis pubis. The posterior border was behind the second sacral spine in cervix cancer and 1.5~2 cm behind the anterior bony sacral margin in rectal cancer. Horizontal and sagittal laser marks on the skin were used to reproduce the daily position. 50.4 Gy with 1.8 Gy per fraction was delivered with conventional fractionation using four fields box technique (anteroposterior (AP) - posteroanterior (PA) and lateral opposed fields) in cervix cancer patients, and 45 Gy with 1.8 Gy per fraction was delivered using three fields technique (PA and lateral opposed fields) in rectal cancer patients. In patients with cervix cancer, the AP - PA and lateral fields were treated on alternate days.

Five metallic fiducial markers were placed on the image detection unit, one marker on the center, and two markers on the ±4 cm distances from the center along the X-axis (left-right direction), and two markers on the ±5 cm distances from the center along the Y-axis (cranio-caudal direction) (Fig. 2). Daily skin marks were adjusted in 23 cases of all 267 cases of they were deviated more than 5 mm. Two images were obtained during the daily treatment, just after beginning and just before finishing the treatment. Eight treatment images were not evaluated because of the poor image quality.

Five hundred and thirty four electronic portal images were compared to 20 digitized reference (simulation) images. The original reference radiograph images were digitized by an optic film scanner (Gammex Data Span DAS-730, USA). The portal images and the digitized reference images were downloaded to a workstation computer to measure the central displacements between the reference image and the portal images. After matching the magnifications by aligning the five metalic fiducial markers on the simulation films, more than three of the bony landmarks of EPID images were matched by those of the reference image (Fig. 3).[4] Pelvic brim and both obturator foramina were used as the bony landmarks for the PA fields. Femur head, and greater sciatic notch, and anterior aspect of the sacral promontory were used for the lateral fields. After adjustment, displacements of the radiation field centers in cranio-caudal (CC), right-left (RL), and PA directions were measured.

The CC deviations were recorded from both the PA and lateral fields. The RL deviations were recorded from the PA

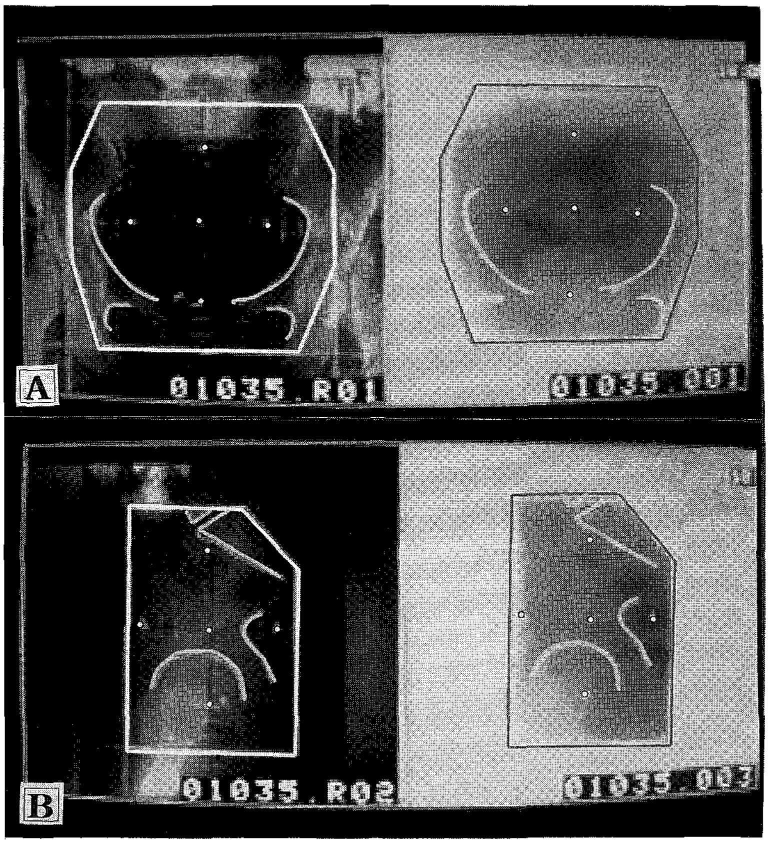

Fig. 3. Pictures showing how to match portal images to reference image by bony landmarks (**A.** postero-anterior image, **B.** lateral image).

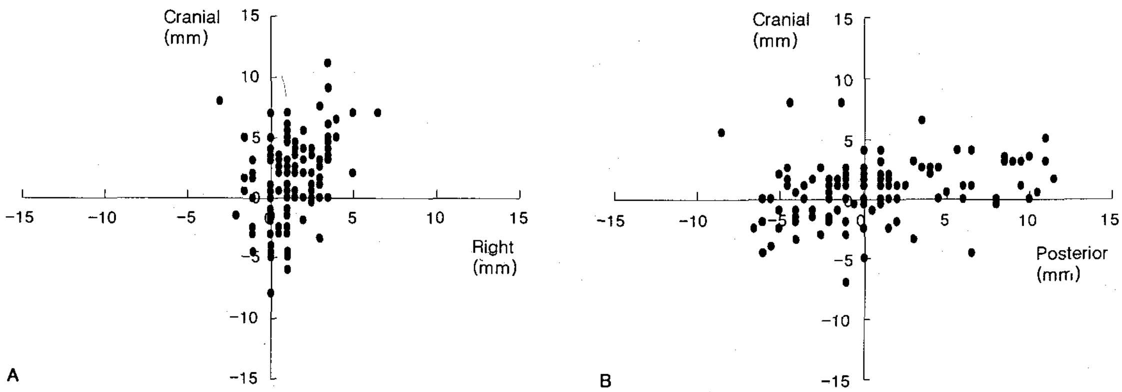

Fig. 4. Graphs showing inter-treatment deviations (**A.** postero-anterior image, **B.** lateral image).

fields, and the PA deviations were recorded from the lateral fields. The cranial, right, and posterior directions of the patient were defined as positive. For each daily treated field, the intra-treatment displacement was calculated by subtracting the displacement measured on the final image from the displacement measured on the initial image. The inter-treatment displacement was calculated by subtracting the displacement measured on the initial image of each day from the reference image.

RESULTS

Inter-treatment deviations (Fig. 4) and intra-treatment deviations (Fig. 4) in each PA and lateral fields are as follows. Maximal deviation was shown in PA direction (RL : 6.5 mm, CC : 11 mm, PA : 11.5 mm). The frequency of the inter-treatment displacements exceeding 5 mm in RL, CC, and PA direction was 2% (3/151), 12% (33/267), and 24% (28/116), respectively, and that exceeding 10 mm was 0% (0/151), 0% (0/267), and 5% (6/116), respectively. The intra-treatment displacement exceeding 5 mm in RL, CC, and PA direction was 0% (0/151), 1% (4/267), and 1% (1/116), respectively. There were no intra-treatment displacements exceeding 10 mm except 2 cases (1%) in CC direction (Table 1). Values within 90% of the inter-treatment deviations were within 1 cm in all directions (Table 2). The mean of the inter-treatment deviation was 1.2, 1.0, 0.9 mm, and that of standard deviation was 1.6, 3.0, 4.4 mm, in each RL, CC, and PA direction. The mean of the intra-treatment deviation was 0, 0.1, 0 mm, and that of standard deviation was 0.9, 1.9, 1.6 mm, in each RL, CC, and PA direction (Table 3). The absolute mean of the inter-treatment deviation was 1.3, 2.4, 3.4 mm, and that of the intra-treatment deviation was 0.5, 1.2, 1.4 mm, in each RL, CC, and PA direction.

DISCUSSION

Patient movement during a radiation treatment was first reported by Kelsey et al. in 1972.[5] With a modified closed-circuit television system (CCTV), 275 treatments in 37 patients were monitored, and movements were detected in 10% of the treatments. Norwood et al.[6] developed an extension of that CCTV system which was capable of detecting intra-treatment motion to an accuracy of 1 mm. They used a tile of 8×8 cm square as a target with a 13 mm black spot at the center, and the target was placed on the patients' skin. They monitored an average of each 12 sessions in 34 patients, and most of the displacements were within 1 mm. Meertens et al.[7] evaluated intra-treatment movement in various sites and reported that patient breathing, swallowing, or bowel motion was observed but severe

Table 1. Inter-treatment and Intra-treatment Deviations Exceeding 10 mm and 5 mm

	Inter-treatment		Intra-treatment	
	>10 mm (%)	>5 mm (%)	>10 mm (%)	>5 mm (%)
Right-Left (n=151)	0 (0)	3 (2)	0 (0)	0 (0)
Cranio-Caudal (n=267)	0 (0)	33 (12)	2 (1)	4 (1)
Postero-Anterior (n=116)	6 (5)	28 (24)	0 (0)	1 (1)

Table 2. Values within 10~90% of Inter-treatment Deviations

	Right-Left (mm)	Cranio-Caudal (mm)	Postero-Anterior (mm)
10th percentile	0.0	0.0	0.0
25th percentile	0.0	1.0	1.0
50th percentile	1.0	2.0	2.0
75th percentile	2.5	3.5	5.0
90th percentile	3.5	5.0	8.0

Table 3. Means and Standard Deviations of Inter-treatment and Intra-treatment Displacements

	Inter-treatment		Intra-treatment	
	Mean	SD*	Mean	SD
Right-Left	1.2	1.6	0	0.9
Cranio-Caudal	1.0	3.0	0.1	1.9
Postero-Anterior	0.9	4.4	0	1.6

*standard deviation

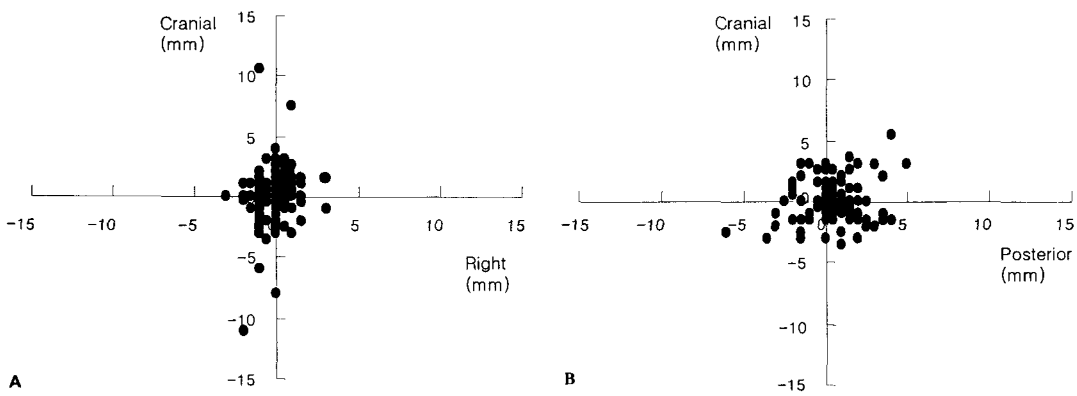

Fig. 5. Graphs showing intra-treatment deviations. (A. postero-anterior image, B. lateral image).

movement was seldom observed. The magnitude of the motions were not mentioned. Van Tienhoven et al.[8] also evaluated intra-treatment variation with an average of seven electronic portal images per fraction in five patients undergoing tangential breast radiotherapy. They concluded that respiration does not have a significant influence on the treatment volume in breast treatments. In our study, only 0~1.5% of the treatments showed deviations greater than 5 mm during the treatment, which means intra-treatment displacement of pelvic fields is not so important in clinical aspect of radiotherapy.

Byhardt et al.[9] reported using weekly port films that the frequency of center deviation greater than 5 mm was 15%, which was greatest in pelvis region (26%), and next in head and neck region (17%). Bone and cranial regions showed low frequency of deviations. Rabinowitz et al.[10] also evaluated inter-treatment variation in various sites using port films in routinely immobilized 71 patients. For the pelvis, the mean deviation between the port film and the simulation film was 5.6 mm, the deviation over 5 and 10 mm was 62% and 23%, respectively. Deviations of thoracic regions were greatest (mean : 5.8 mm), and those of head and neck regions were lowest (mean : 2.5 mm). Tinger et al.[11] also reported inter-treatment in pelvic irradiation without immobilization device. Inter-treatment deviations over 5 mm and 10 mm in RL, CC, and AP directions were 40, 52, 51%, and 3, 16, 23%, respectively. Kihlen and Ruden[12] evaluated daily port films in seven patients who had ovary, prostate, or kidney fields. In 125 films, inter-treatment deviations of 3~7 mm were detected. The average standard deviation was 4~5 mm for these sites. Richards and Buchler[13] reported that displacements more than 10 mm were greater in inferior and/or right lateral directions (28~31%) on weekly AP-PA port films in patients being treated with pelvic irradiation.

Several methods to evaluate anatomical alignment were developed. Using anatomical fiducial points and using anatomical template is the most popular method. Michalski et al.[14] reported fiducial point method was preferred in the head and neck site because it was fast and often easy to identify, and template method was preferred in the lung, abdomen, and pelvis because there were no discrete anatomical landmarks. But they proposed that these two methods are similar and compatible. In our study, we chose modified anatomical fiducial line technique using the line of the bony landmarks instead of the spot. Anatomical template method was not appropriate to us because the edge of the electronic portal images were too blunt to adjust to the reference film.

One difficulty in analyzing our data is matching the bony landmarks. More than three bony landmarks of EPID images were not always exactly matched to those of the reference image. This maybe due to a rotation, especially along the Y axis. In case of rotation, the evaluation of the magnitude by bony landmark alone leaves many chances of errors. In our study, after aligning five fiducial marks to adjust the magnitude and rotation, each bony landmarks were aligned. It may be a unique technique to adjust the magnitude and rotation easily by five fiducial marks.

In a clinical aspect, we can estimate the best margin of the treated field by analysing set-up displacement. But there was no data about the set-up displacement when a device was placed on the patient's lower abdomen such as SBDS. In our data, the greatest and the most frequent inter-treatment center deviation was along the PA direction, and most of the deviations were within 1 cm. This can be easily imagined, as the deviation would be greatest along PA direction according to the fitness to the device when the patient's body placed on the SBDS. With these regards, it is recommended to consider planning target volume more than 1 cm distance from the tumor, and to put more generous safety margin on the lateral field if clinically acceptable in pelvic radiotherapy with SBDS.

CONCLUSION

All intra-treatment center deviations over 5 mm in each direction were less than 1.5%, which means intra-treatment deviations are not so important in clinical aspect of radiotherapy. The greatest and the most frequent inter-treatment deviation of the center was along the PA direction, and most of the deviations were within 1 cm. So it is recommended to put more generous safety margin toward the PA direction on the lateral field if clinically acceptable in pelvic radiotherapy with small bowel displacement system.

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국문 초록

Small Bowel Displacement System을 이용한 골반부 방사선조사에서 치료간 및 치료중 중심점 위치변동에 관한 분석

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__목 적__ : small bowel displacement system (SBDS)을 이용한 골반부 방사선 치료시 치료간(intertreatment) 및 치료중(intratreatment) 중심점 위치변동의 편차를 분석하고, 그 결과를 임상적으로 이용하고자 하였다.

__대상 및 방법__ : 자궁경부암 7명, 직장암 4명의 총 11명의 환자를 대상으로 electronic portal imaging device (EPID)를 이용하여 302건의 후-전문(postero-anterior port) 영상과 232건의 측문(lateral port) 영상을 얻었다. 모든 환자는 복와위 자세로 하복부에 SBDS를 사용하였다. 방사선 조사야의 중심점과 배율을 맞추기 위하여 5개의 금속 기준점을 영상탐지판(image detection unit)에 부착시켰으며, EPID 영상의 골 기준점(bony landmark)을 정하여 모의치료시 촬영한 영상과 비교하여 정렬시킨 후 우-좌문, 두-미문, 그리고 후-전문 방향으로 중심점의 이동방향 및 거리를 분석하였다.

__결 과__ : 우-좌문, 두-미문, 그리고 후-전문 방향으로의 치료간 중심점 이동의 평균값은 각각 1.2 mm (±1.6 mm), 1.0 mm (±3.0 mm), 0.9 mm (±4.4 mm)이었으며, 각 방향으로의 5 mm 이상의 치료간 중심점 이동은 각각 2, 12, 24%, 그리고 10 mm 이상의 치료간 중심점 이동은 각각 0, 0, 5%이었다. 큰 폭의 위치변동을 보인 방향은 후-전문 방향이었으며, 최대값은 11.5 mm 이었다. 우-좌문, 두-미문, 그리고 후-전문 방향으로의 치료중 중심점 이동의 평균값은 각각 0 mm (±0.9 mm), 0.1 mm (±1.9 mm), 0 mm (±1.6 mm)이었다. 5 mm 이상의 치료중 중심점 이동은 각각 0, 1, 1%이었다.

__결 론__ : SBDS를 이용한 골반부 방사선 조사시 폭과 빈도가 가장 큰 치료간 위치변동은 후-전문 방향이므로, 측면의 후-전문 방향으로 추가적인 여유를 두는 것이 바람직할 것으로 판단된다.

핵심용어 : 전자포털영상장치, 골반 방사선 치료