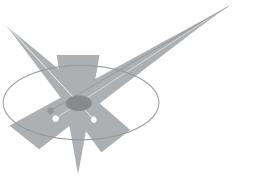
Rep Pract Oncol Radiother, 2007; 12(6): 323-328



Original Paper

Received: 2007.04.27
Accepted: 2007.10.19
Published: 2007.12.27

Reproducibility of tangential breast fields using online electronic portal images

Ramachandran Prabhakar[ABCDEF], Goura K. Rath[AG], Pramod K. Julka[ACD], Tharmar Ganesh[A], Rakesh C. Joshi[A]

Department of Radiation Oncology, Institute Rotary Cancer Hospital, All India Institute of Medical Sciences, New Delhi, India

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Background Treatment verification and reproducibility plays a major role in radiotherapy to achieve better tumour control. Small uncertainties in daily repositioning of the patients and internal organ motion can lead to discrepancies between the planned and delivered radiation treatments. A factor that influences dose homogeneity and treatment volume is the accuracy of treatment setup. Small deviations in positioning the patient with regard to the beam setup could have a relatively significant impact on the treatment volume and it is imperative to control the setup error during radiotherapy. This study focuses on the importance of inter- and intra-fraction error in tangential breast radiotherapy with an electronic portal imaging device.

Aim To study the variation in treatment setup due to intra-fraction and inter-fraction during tangential field breast irradiation.

Materials/Methods Twelve patients of carcinoma breast were selected for this study and CT based planning was performed with simple tangential fields. The patients were treated on a 6MV linear accelerator equipped with an electronic portal imaging device (EPID). Portal images were acquired for both medial and lateral tangential fields for 10 fractions and intra- and inter-fraction studies were performed for all the patients. Parameters such as central lung distance (CLD), central beam edge to skin distance (CBESD), central irradiated width (CIW) and cranio-caudal distances (CCD) were measured on the acquired portal image.

Results The average systematic differences observed for CLD, CBESD, CCD and CIW were 1.2mm, 2.8mm, 2.07mm and 3.30mm. For intra-fraction motion, the observed standard deviations for CLD, CBESD and CCD were 0.7mm, 0.73mm, and 1.36mm. Similarly the CLD, CBESD, CIW and CCD were analyzed for inter-fraction variation.

Conclusions The online portal imaging device is an important tool for ensuring the proper delivery of planned dose. Our results suggest that intra-fraction motion of the breast has less impact on the treatment volume. Regular treatment verification between treatment fractions will help in reducing the normal tissue toxicity and ensures proper dose delivery to the tumour volume.

Key words breast cancer • tangential field radiotherapy • setup error • EPID

Full-text PDF: http:/www.rpor.eu/pdf.php?MAN=11491

Word count: 1849
Tables: 2
Figures: 1
References: 19

Author's address: Ramachandran V. Prabhakar, Department of Radiation Oncology, Institute Rotary Cancer Hospital, All India Institute of Medical Sciences, New Delhi – 110 029, India, e-mail: prabhakar_smr@hotmail.com

Background

Radiation therapy following conservative surgery is the standard treatment of care in early breast cancer. Treatment verification and reproducibility plays a major role in radiotherapy to achieve better tumour control. Care should be taken to ensure the same dose is delivered to the same volume of irradiation. Small uncertainties in daily repositioning of the patients and internal organ motion can lead to discrepancies between the planned and delivered radiation treatments. Failing to characterize setup errors in three dimensions reduces the accuracy of the setup error measurements. Electronic portal imaging technique plays a vital role in accomplishing the above task by studying the setup error and correcting the same before the treatment delivery. Patient setup deviations can be measured during radiotherapy by comparing the portal images to simulator images. Setup error is defined as the difference between the actual and the intended position of the part of the patient that is irradiated, with respect to the treatment beam during treatment. The actual position is usually recorded on the portal image and the intended position is recorded on the reference image, digitally reconstructed radiograph (DRR) or simulator image. Setup error is classified as random or inter-fraction error, systematic error and intra-fraction error, which can occur during repositioning of the patient. PTV is derived by adding a margin to the CTV to compensate for these variations in patient position. However, with increasing interest in treatment such as 3D-CRT and IMRT, where the aim is to conform high dose volume more tightly to PTV, the effects of patient movement need to be investigated carefully. Setup error is likely to cause a large increase in volume outside 95–105% of the prescription dose than a change in breast volume [1]. A factor that influences dose homogeneity and treatment volume is the accuracy of treatment setup. Small deviations in the positioning of the patient with regard to the beam setup could have a relatively significant impact on the treatment volume and it is imperative to control the setup error during radiotherapy. Systematic patient position during treatment is very important in breast radiotherapy to achieve good quality of treatment [2]. Portal film evaluation plays an important role in detecting inadequate patient positioning or geometrical errors [3,4]. Geometrical uncertainties in external radiotherapy are mostly due to setup errors and internal organ motion. The magnitude of setup errors within the breast has been quantified by a large number of studies [5–9]. This study focuses on the importance of inter- and intra-fraction error in tangential breast radiotherapy with an electronic portal imaging device.

Aim

In this study, the variation in treatment setup due to intra-fraction and inter-fraction error is presented. Also, the significance of systematic error has been studied.

Materials and Methods

Twelve patients of early breast cancer after conservative surgery were selected for this study and CT based planning was performed with simple tangential fields using 6MV X-rays. The patient's arm on the treatment side was abducted to 90–110° during CT scanning. The CT images were transferred to the eclipse treatment planning system (Eclipse Version 6.5; Varian Medical System™). After contouring the external body, PTV and other normal structures, the gantry angles were chosen to achieve a non-divergent posterior beam edge. The dose was computed and DRRs were generated for both the tangential fields. The measurement employed was derived from van Tienhoven et al. Figure 1 [6]. Four linear measurements were taken for each DRR and portal image. The central lung distance (CLD) is the distance from the dorsal medial beam edge to the inner thoracic wall on the central plane of the beam. The central beam edge to the skin distance (CBESD) is the distance to the ventrolateral beam edge in the central plane of the beam. Central irradiated

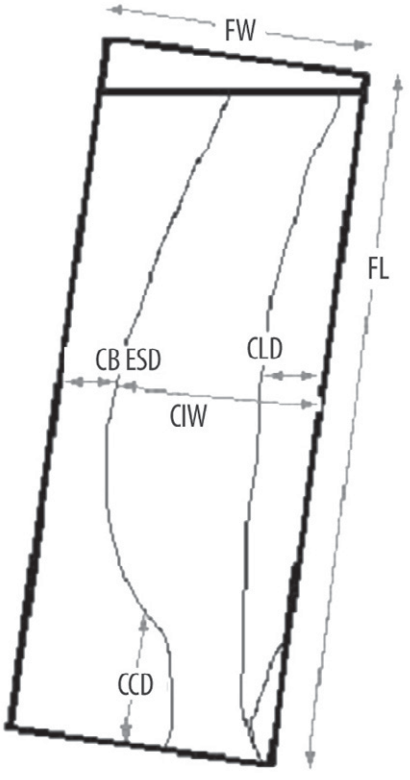


Figure 1. Definition of geometrical parameters. CCD – Cranio-Caudal Distance, CLD – Central Lung Distance, FL – Field Length, FW – Field Width, CIW – Central Irradiated Width, CBESD – Central Beam Edge to Skin Distance.

width (CIW) is defined as the distance from the dorsomedial beam edge to the skin. Cranio-caudal distance (CCD) is the distance from the skin to the caudal beam edge on the central plane of the beam. The treatment plans were transferred to a dual energy linear accelerator (Clinac 2300 C/D) equipped with a liquid ionization chamber based portal imaging device (Portal Vision™ LC250). Portal images were acquired for both medial and lateral tangential fields for 10 fractions and intra- and inter-fraction studies were performed for all the patients. Multiple portal images were taken for 10 fractions amounting to a total of 1200 images. Parameters such as CLD, CBESD, CIW and cranio-caudal distances measured on the acquired portal image were noted down for studying the inter-fraction and intra-fraction variation and were compared with the values measured from DRR for systematic deviations.

For each parameter, the standard deviation per fraction was calculated and averaged over all patients. Paired sample t-test was performed using SPSS Version 10.0 between the intra- and inter-fraction studies.

Results

Intra-fraction variations were analyzed for CLD, CBESD, CIW and CCD studied for all patients. For each parameter, the standard deviation per fraction was calculated and averaged over all patients. The resulting standard deviations (σ) are presented in Table 1. The observed standard deviations for CLD, CBESD and CCD were 0.7mm, 0.73mm and 1.36mm respectively. The maximum deviations observed in this study for CLD, CBESD and CCD during intra-fraction motion were 1.5mm, 1.6mm and 2mm respectively. For inter-fraction measurements, 10 fractions were analyzed to detect any day-to-day variation and the average standard deviation is shown in Table 1. The results of inter-fraction and intra-fraction variation are compared with the results of a similar study [6,7]. On applying the paired sample t-test for CLD, CBESD and CDD between intra- and inter-fraction variation, it was observed that the setup error with intra-fraction motion is less than with inter-fraction motion ($p<0.05$). The systematic error, which is the difference between the DRR and average position during treatment, is shown in Table 2. The table displays the average differences, average standard deviations and maximum deviations for these differences and compared with similar studies. The average systematic differences observed for CLD, CBESD, CCD and CIW were 1.2mm, 2.8mm, 2.07mm and 3.30mm. Similarly, the maximum systematic deviations observed for CLD, CBESD, CCD and CIW were 2.2mm, 8.60mm, 4.60mm and 7.60mm. The CLD value of our study was less than in other studies but CCD was found to be larger.

Discussion

Conventional portal films have their own disadvantages and lead to infrequent use in routine clinical radiotherapy. After the introduction of electronic portal imaging technique, it has become possible to get a real time picture of the delivered radiation that can be compared easily with the simulation films. Some of the sources of setup error are laser misalignment, movement of the skin mark, fixation device, patient mobility, internal organ motion and the accuracy with which the patient is set to the defined skin marks on the patient. Clinical portal images, which were until now only used for setup correction, might with a little extra effort also be used to correct field shape for internal organ motion [10]. Marks et al. have shown an important reduction in localization errors with increasing

Table 1. Intra- and inter-fraction variation.

	Intra-fraction variation (mm)					
	Present study		Van Tienhoven et al.		Lirette et al.	
	σ	Max. Deviation	σ	Max. Deviation	σ	Max. Deviation
CLD	0.70	1.5	0.8	2.0	1.8	13.1
CBESD	0.73	1.6	0.8	1.9	2.1	14.9
CCD	1.36	2.0	0.9	3.7	3.2	25.6
	Inter-fraction variation (mm)					
	Present study		Van Tienhoven et al.		Lirette et al.	
	σ	Max. Deviation	σ	Max. Deviation	σ	Max. Deviation
CLD	1.70	2.6	1.7	4.2	1.7	11.6
CIW	2.10	3.6		–	3.4	22.9
CBESD	2.50	3.05	2.2	4.9	2.8	15.6
CCD	4.00	8.2	1.8	3.6	3.4	22.9

Table 2. Systematic deviations.

	Systematic deviations							
	Present work			Van Tienhoven		Lirette et al.		
	Average difference	Sigma	Max.Dev	Average difference	Sigma	Average difference	Sigma	Max.Dev
CLD	1.20	0.7	2.20	–3.2	2.7	1.0	3.1	7.4
CBESD	2.80	2.8	8.60	2.1	2.8	3.4	4.3	12.7
CCD	2.07	1.6	4.60	–1.3	4.7	0.7	3.9	8.3
CIW	3.30	2.6	7.60			–1.7	4.5	11.2

frequency of portal films [11]. Portal setup films are an accurate representation of a patient's daily treatment setup. Inter- and intra-fractional variation reproducibility for tangential fields using an online portal imaging device has been studied by many authors [6–8,12–14]. CLD measured at the time of simulation provides a reasonable estimate of the percent of the ipsilateral lung treated by tangential fields [15]. Kron et al., in their study on evaluation of intra- and inter-fraction motion in breast radiotherapy, found inter-fraction variability to be about twice as large as intra-fraction variability [13]. The largest variability was detected in the cranio-caudal direction (intra-fraction: 1.3±0.4mm; inter-fraction: 2.6±1.3mm) while the lung involvement varied by 1.1±0.2 mm and 1.8±0.6 mm intra- and inter-fraction, respectively. They concluded that the effect of breathing motion on the amount of radiated lung was not of major concern in the patients studied. In a recent study by Smith et al., on the analysis of intra- and inter-fraction variation during breast tangential radiotherapy, they found that the effect of respiratory motion and movement during treatment was minimal: the maximum range in CLD for any patient on any day was 0.25cm [14]. The variation caused by day-to-day setup variation was greater, with CLD values for patients ranging from 0.59cm to 2.94cm, and they found similar findings for heart and lung areas. They concluded that there is very little change in CLD and the corresponding lung and heart area during individual radiation treatment fractions in breast tangential fields, compared with the relatively greater amount of variation that occurs between days. Hurkmans et al., in their study after reviewing many previously published papers, quoted that the standard deviation of the systematic and random errors for current breast technique were 1.0–4.7mm and 1.7–14.4mm [16]. Bohmer et al., in his study on setup deviations during irradiation of breast cancer using

EPID, concluded that intra-fractional deviations in breast cancer patients are negligible and they can be attributed to random errors due to patient movement and breathing [17]. Patient position during treatment also has a significant impact in cardiac dose during tangential field breast radiotherapy [18]. Dose inhomogeneities that result in overdosage to some regions in the breast and underdosage to other regions can occur because treatment setup differs from that prescribed in the treatment plan [19]. In our study, the CLD and CBESD values observed were 0.7mm and 0.73mm, which are the same as those observed by van Tienhoven et al. [6].

Bohmer et al. showed that intra-fractional setup deviations in breast cancer patients are negligible in clinical practice [17]. Our study also showed similar results, which may be due to breathing and movement of the patient. The CLD is closely related to the amount of lung irradiated in the corresponding field [15]. The CLD value of our study was lower than the values shown in Tables 1 and 2 for the other two studies. In our study, the CCD value was higher than the other two studies for inter-fraction and systematic deviations but the maximum deviation is less when compared to Lirette et al. [7]. This is due to the fact that between every fraction when the patient raises the hand, the ipsilateral breast also moved, and since no immobilization was used there are more chances that the hand reproducibility is altered. The main reasons for the systematic error observed are transfer errors from the planning system to the setup on the machine. The accuracy of the field alignment is influenced by various factors such as patient immobilization and positioning devices. Similarly, systematic deviation was also studied by comparing the DRR and online portal images and the results were similar to those in the published literature.

Conclusions

Setup errors may lead to decreased tumour control probability and increased normal tissue complication probability. The verification of the field alignment with portal films can increase the accuracy by identifying localization errors. Inter-fraction and intra-fraction variation were studied for parameters such as CLD, CBESD, CIW and CCD for tangential field portals using portal images. Our study shows that setup error with intra-fraction motion is less than for inter-fraction motion ($p<0.05$).

References:

1. Hector C, Webb S, Evans PM. A simulation of the effects of setup error and changes in breast volume on conventional and intensity-modulated treatments in breast radiotherapy. Phys Med Biol, 2001; 46: 1451–71
2. Baroni G, Garibaldi C, Scabini M et al: Dosimetric effects within target and organs at risk of interfractional patient mispositioning in left breast cancer radiotherapy. Int J Radiat Oncol Biol Phys, 2004; 59: 861–71
3. Kihlen B, Ruden BI: Reproducibility of field alignment in radiation therapy. A large-scale clinical experience. Acta Oncol, 1989; 28: 689–92
4. Rabinowitz I, Broomberg J, Goitein M et al: Accuracy of radiation field alignment in clinical practice. Int J Radiat Oncol Biol Phys, 1985; 11: 1857–67
5. Valdagni R, Italia C: Early breast cancer irradiation after conservative surgery: quality control by portal localization films. Radiother Oncol, 1991; 22: 311–3
6. van Tienhoven G, Lanson JH, Crabeels D et al: Accuracy in tangential breast treatment setup: a portal imaging study. Radiother Oncol, 1991; 22: 317–22
7. Lirette A, Pouliot J, Aubin M, Larochelle M: The role of electronic portal imaging in tangential breast irradiation: a prospective study. Radiother Oncol, 1995; 37: 241–45
8. Fein DA, McGee KP, Schultheiss TE et al: Intra- and interfractional reproducibility of tangential breast fields: a prospective on-line portal imaging study. Int J Radiat Oncol Biol Phys, 1996; 34: 733–40
9. Westbrook C, Gildersleve J, Yarnold J: Quality assurance in daily treatment procedure: patient movement during tangential fields treatment. Radiother Oncol, 1991; 22: 299–303
10. Stroom JC, Koper PC, Korevaar GA et al: Internal organ motion in prostate cancer patients treated in prone and supine treatment position. Radiother Oncol, 1999; 51: 237–48
11. Marks JE, Haus AG, Sutton HG, Griem ML: The value of frequent treatment verification films in reducing localization error in the irradiation of complex fields. Cancer, 1976; 37: 2755–61
12. Pouliot J, Lirette A: Verification and correction of setup deviations in tangential breast irradiation using EPID: gain versus workload. Med Phys, 1996; 23: 1393–8
13. Kron T, Lee C, Perera F, Yu E: Evaluation of intra- and inter-fraction motion in breast radiotherapy using electronic portal cine imaging. Technol Cancer Res Treat, 2004; 3: 443–9
14. Smith RP, Bloch P, Harris EE et al: Analysis of interfraction and intrafraction variation during tan-

gential breast irradiation with an electronic portal imaging device. Int J Radiat Oncol Biol Phys, 2005; 62: 373–8

15. Bornstein BA, Cheng CW, Rhodes LM et al: Can simulation measurements be used to predict the irradiated lung volume in the tangential fields in patients treated for breast cancer? Int J Radiat Oncol Biol Phys, 1990; 18: 181–7

16. Hurkmans CW, Remeijer P, Lebesque JV, Mijnheer BJ: Setup verification using portal imaging; review of current clinical practice. Radiother Oncol, 2001; 58: 105–20

17. Bohmer D, Feyer P, Harder C et al: Verification of setup deviations in patients with breast cancer using portal imaging in clinical practice. Strahlenther Onkol, 1998; 174 (Suppl.2): 36–9

18. Canney PA, Deehan C, Glegg M, Dickson J: Reducing cardiac dose in post-operative irradiation of breast cancer patients: the relative importance of patient positioning and CT scan planning. Br J Radiol, 1999; 72: 986–93

19. Das IJ, Cheng CW, Fosmire H et al: Tolerances in setup and dosimetric errors in the radiation treatment of breast cancer. Int J Radiat Oncol Biol Phys, 1993; 26: 883–90