Dosimetric Study of Inverse-Planed Intensity Modulated, Forward-Planned Intensity Modulated and Conventional Tangential Techniques in Breast Conserving Radiotherapy

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Objective: *The authors present the result of a dosimetric comparison of inverse-planed intensity modulated, forward-planned intensity modulated, and conventional tangential technique in breast conserving radiotherapy.*

Method and Material: *The breasts (Right side: Left side = 1:1), heart, and lungs of 28 patients were contoured on all the computed tomography (CT)-slice. Three different treatment plans were created: (1) inverse IMRT (iIMRT), (2) forward IMRT (fIMRT), and (3) conventional tangential technique (CVT). The total prescribed dose for all plans was 50 Gy/ 25 fractions. All treatment plans were normalized at 95% of the prescribed dose covered the entire PTV and used inhomogeneity corrections.*

Results: *For the entire group, the mean breast volume was 517 cc. The $V_{105\%}$ for iIMRT, fIMRT and conventional plans was 1.12%, 2.36% and 16.81%, which iIMRT better than fIMRT and CVT ($p < 0.001$) and fIMRT better than CVT ($p < 0.05$). The D_{max} for the iIMRT plan received 105.03%, which was significantly less than those from the fIMRT (106.6%, $p < 0.001$) and the conventional (110.68%, $p < 0.001$) plan. The PT V coverage ($V_{95\text{-}105\%}$) for the iIMRT, fIMRT and conventional was 96%, 91% and 87%, which iIMRT better than fIMRT and CVT ($p < 0.05$) and fIMRT better than CVT ($p < 0.05$).The PTV CI for the iIMRT technique was 0.704, which was significantly more conformity than those from the fIMRT (0.639, $p < 0.001$) and the conventional (0.539, $p < 0.001$) techniques. The PTV CI of fIMRT is significantly better than CVT ($p < 0.005$). Mean ipsilateral lung dose was 642.7 cGy, 747.6 cGy and 882.25 cGy for iIMRT, fIMRT and CVT, respectively ($p < 0.05$) The $V_{20\ Gy}$ reduced from 14.87% for conventional plan to 12.82% for the fIMRT plan, while 0.88% was obtained for the iIMRT plan ($P<0.05$). The heart $V_{30\ Gy}$ value was 3.124%, 4.65%, and 5.84% for iIMRT, fIMRT and conventional plans, respectively ($p < 0.05$). The mean dose of contralateral breast was 55.86 cGy, 60.33 cGy, 68.57 cGy for iIMRT, fIMRT and conventional plans, respectively ($p < 0.05$ both). The mean contralateral lung dose was 57.8 cGy, 43.87 cGy, and 32.28 cGy for iIMRT, fIMRT and conventional plans, respectively ($p < 0.005$ both).*

Conclusion: *The iIMRT technique provides significantly improved PTV D_{max}, PTV $V_{105\%}$, PTV $V_{110\%,}$ target volume coverage, dose homogeneity and dose conformity throughout the target volume of breast and reduced doses to all critical structures, compared to the fIMRT and conventional techniques. In view of fIMRT technique, it significantly improved the dose distribution and reduced dose to OARs compared to conventional technique, although not better than iIMRT technique.*

Keywords: *Breast conserving radiotherapy, Dosimetric study, IMRT*

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Breast cancer is a major public health problem worldwide including in Thailand. More than 1,000,000 new case diagnosis annually and is the second most common cancer of women in Thailand.

At the present, radiation therapy is an essential part of the management of localized breast cancer of all stages. For early stage breast cancer, breast conservative with lumpectomy followed by radiotherapy has become widely accepted. Adjuvant radiotherapy after breast conserving surgery (BCS) with lumpectomy in the treatment of early stage (Tis-T2) breast cancer has proved to be effective in reducing the risk of a local recurrence with limited toxicity. Results from multiple randomized clinical trials with long term follow-up have established the equivalence of breast conserving therapy with irradiation compared to mastectomy in terms of disease-free and overall survival in stage I and II invasive breast cancer[1-6].

The commonly use radiation technique is conventional tangential fields, optimized using a single central-axis isodose distribution without inhomogeneity corrections. This technique has resulted in excellent local control rates, low rate of cardiac, and pulmonary complications[7-8], and excellent cosmetic results in the vast majority of patients. However, conventional tangential fields have numerous limitations. First, dose homogeneity throughout the entire breast is difficult to produce because the breast is invariably a non-uniform structure[9-10]. A second concern is that a small amount of the ipsilateral lung is invariably irradiated; scatter dose to the contralateral breast, and in left-side patients, a portion of the heart can sometimes be irradiated to significant doses as well. Reducing unnecessary normal tissue radiation exposure is difficult to achieve with tangential fields because of the concave geometry of the breast and chest wall.

Several different techniques have been developed to optimize dose delivery for whole breast radiation therapy. New techniques such as intensity modulated radiation therapy (IMRT) delivered with multileaf collimators (MLC) theoretically should be able to provide and optimize dose distribution to the whole breast in a rapid and efficient manner[11].

In recent years, research in the investigation and clinical application of IMRT for the treatment of all stages of breast cancer has increased throughout the radiation oncology community. The main goal of IMRT is delivery of a much more homogenous and/or conformal treatment plan to the patient. IMRT has the potential to improve target volume coverage compared with that obtained from conventional treatment plans and to reduce inhomogeneities.

Several studies proposed that IMRT technique delivered highly conformal doses and reduced unnecessary dose to heart, lung, and contralateral breast of the patient. This finding has been reported in a variety of treatment sites[12,13].

Several IMRT techniques for improving dose uniformity of whole-breast treatment have been proposed, differing mostly in the methods of plans optimization and delivery[14,15].

In the present study, the authors analyzed dosimetry of inverse-planned intensity modulated, forward-planned intensity modulated, and conventional tangential technique in breast conserving radiotherapy. The aim of the present study was to compare all the potentials, at planning level, of alternative techniques of the whole breast irradiation in our center for early breast cancer treated with breast conserving therapy.

Material and Method

Between October 2004 and July 2006, 28 patients with early breast cancer treated with breast conserving therapy received whole breast radiotherapy after lumpectomy at the King Chulalongkorn Memorial Hospital (KCMH) were selected for the present study.

Patients

All patients underwent a computer tomography (CT) simulation. Patients were positioned supine on the breast board (Med tech) with arm resting in an arm rest placed above their heads. Radiopaque markers were placed at the patient's midline, midaxillaries line, 1 cm below the inframammary fold, and superior at the lower end of clavicular head. Using a helical CT scanner (light speed RT, GE, CT), continuous 5-mm CT axial images were obtained extending from the hyoid bone to the upper abdomen, including the entire both breast, the heart and bilateral lungs. The CT dataset was transferred to Eclipse Planning System Version 6 (Varian Medical system, Palo Alto, CA) for treatment planning.

Region of interest

The planning target volume (PTV), contralateral breast, ipsilateral and contralateral lung and heart were contoured on each CT slice by the investigator. The planning target volumes were defined following the recommendation of ICRU Report 62[16]. Because inter-physician variation in PTV delineation in the radiotherapy of breast cancer after conservative

surgery is rather high[17] and there is no clear definition in the literature as to what is a clinically acceptable variability in breast delineation using CT image. In the present research, the authors defined the PTV as the volume that is conventionally irradiation, i.e. the tissue within the conventional tangential fields excluding lung, heart and liver minus a 5 mm margin from the beam edges and skin surface to avoid apparent under dosage in the dose volume histograms due to build-up effect and beam penumbra[18] (Fig. 1). The superior, inferior, and median-lateral borders of breast PTV were the superior, inferior and dorsal edges of the conventional tangent beams. The skin surface and lung were delineated using an automated threshold-contouring tool of Eclipse Planning System Version 6 (Varian Medical System) while the heart was delineated manually. The heart volume included all myocardium from apex to the infundibulum of the right ventricle, the right atrium, and auricle, excluding the pulmonary trunk, root of the ascending aorta, superior venacava, and pericardium.

Treatment planning

For each patient, treatment plans for both the left and right breast were developed using conventional tangential, forward-planned intensity modulated and Inverse-planed intensity modulated techniques. All treatment plans were generated with 6 MV photon beams in order to evaluate the impact of treatment techniques with fixed photon energy. The Varian 21EX which has two rows of 40 MLCs. Each MLC is 1 cm wide at isocenter was used. All patients were prescribed a whole breast dose of 50 Gy delivered in 2 Gy fraction.

Conventional tangential technique (CVT)

The standard conventional tangential technique consisted of two tangential fields with wedges using three-dimensional planning with Eclipse Planning System Version 6 (Varian Medical system, Palo Alto, CA). Optimal beam parameters were chosen using Beams-eye-view (BEV) display. The angle between these beams is chosen in such a way that the posterior border of the lateral and medial fields are coplanar, in order to prevent extra dose to the lung due to the divergence of the beams. Beam depth, gantry angle, and collimator angle were adjusted at the computer work station as need to avoid unnecessary normal tissue irradiation (e.g., heart, lung, contra lateral breast) and to ensure full coverage of the breast and lumpectomy cavity with a "sufficient" margin. Field size and isocenter were adjusted to cover the PTV in the superior, inferior, and posterior direction, with 0.5 cm margin, and to allow at least 2 cm flash beyond the skin surface anteriorly (Fig. 2). The optimal wedge angles were chosen based on dose distribution in the central plane and calculated with inhomogenecity correction according to the authors' standard protocol. The dose distribution was normalized at the isocenter.

Forward IMRT (fIMRT)

The beam parameters for the intensity-modulated tangential fields were the same as those used for the conventional field plan. Multiple sMLC segments were used to improved dose distribution and potentially reduce acute toxicity. First step, maintaining the identical beam orientation as with standard wedges, the dose distribution was calculated for equally weighted, open tangential fields (i.e., no blocks, no wedges). The second step involved segment

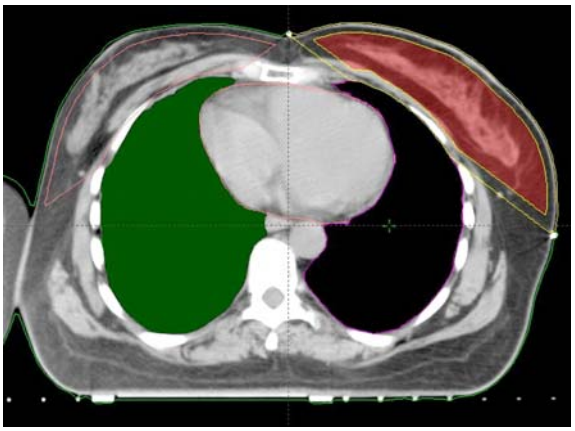

Fig. 1 An axial of central slice showing the contours of the target and OARs

Fig. 2 Tangential photon field

field planning[19]. Use the beam's eye view of the projected isodoses for the tangential fields to create multiple static fields to shield the area of higher dose (hot spot) (Fig. 3). The MLCs were moved manually to cover the hot spots by experienced physicists. The MLC shaped field was used to deliver approximately 6-10% of the total dose from each beam direction. The planner adjusted beam weighting until the most homogenous dose distribution was reached.

Inverse IMRT (iIMRT)

In the present study, the authors use techniques according to the study proposed by Hong et al[12,20]. The gantry angles for the intensity-modulated tangential fields were the same as those used for the conventional technique. The Eclipse Planning System Version 6 (Varian Medical system, Palo Alto, CA), using inverse planning two conformal tangential fields with dynamic multileaf collimators. The authors input beam configuration and dose volume constraint or biological-based constraint and then the computer will optimize. A separate sequencer (leaf motion calculator) was used to convert the optimal fluencies profiles to suitable sliding windows MLC movement, which allowed delivery on a Varian treatment unit. After final dose calculation, the radiation oncologist evaluated dose distribution slice-by-slice. The 2 cm skin flash was made to the tangential breast IMRT field to accommodate respiratory motion. The fluence in the skin flash area was the same as at 5 mm deep to the skin.

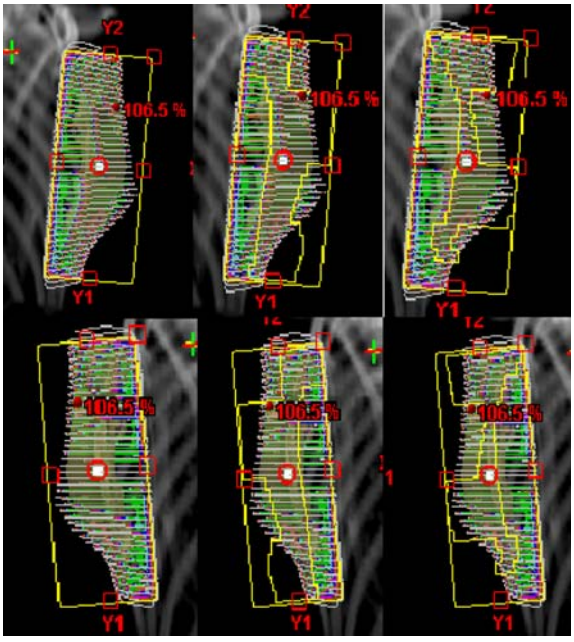

Fig. 3 The fIMRT techniques with multiple sMLC segments were used

Dose specification and dose volume constraint for iIMRT

The dose prescription was based on a dose distribution corrected for heterogeneities.

PTV (planning target volume)

- The prescription dose was 50 Gy in 25 fractions over 5 weeks.

- The prescription dose was the isodose, which encompasses at least 95% of the PTV

- No more than 5% of any PTV would receive > 105% of its prescribed dose.

- No more than 1% of any PTV would receive < 95% of its prescribed dose.

- No more than 1% or 1 cc of the tissue outside the PTV would receive > 110% of the dose prescribed to the PTV.

Critical organs

Dose constraints to normal tissues should be as follows:

1. Heart	V30Gy	< 3%
2. Ipsilateral lung	V20Gy	< 10%
3. Contralateral breast	V2Gy	< 50%
4. Contralateral lung	V20Gy	< 5%

* V30Gy: percentage of the volume receiving radiation ≥ 30 Gy
V20Gy: percentage of the volume receiving radiation ≥ 20 Gy

Dose calculation and normalization

All dose distributions were calculated using the Eclipse Planning System Version 6 (Varian Medical system, Palo Alto, CA). Furthermore, after dose calculation was completed, all treatment plans were normalized such that 95% of the prescribed dose covered the entire PTV. In order to ensure a more accurate dose calculation to the lung, inhomogeneity corrections were used by all treatment plans.

Data analysis

For comparison, all plans were normalized to the mean target dose. Dose-volume histograms (DVHs) were generated for the PTV and all organs at risk (OARs). The parameters used for comparison were planning target volume(V_{PTV}), volume enclosed by the

95% isodose ($V_{95\%}$), volume enclosed by the 105% isodose ($V_{105\%}$), volume enclosed by the 110% isodose ($V_{110\%}$), PTV maximum dose (D_{max}) or hot spot (defined in ICRU 50 as the isodose line encompassing a surface of at least 1.5 cm^2), target volume coverage ($V_{95\text{-}105\%}$), radical dose homogeneity index (rDHI), PTV conformity index (CI), heart V_{30Gy} (percentage of the volume receiving $\geq$ 30 Gy) and mean dose only the left side breast cancer, ipsilateral lung V_{20Gy} and mean dose, contralateral breast D_{max}, V_{2Gy} and mean dose and contralateral lung mean dose.

The target volume coverage ($V_{95\text{-}105\%}$) was defined as the percentage of the PTV with a dose between 95% and 105% of the prescribed dose. The radical dose homogeneity index was an index the typically describes the uniformity of dose within a brachytherapy treatment plan[21,22]. In this case, it is used to describe the uniformity of dose within the PTV of external therapy plans. The rDHI is defined as the ratio of minimum dose (D_{min}) to the PTV and the maximum dose (D_{max}) to the PTV as defined by

$$rDHI = D_{min}/D_{max}$$

The CI was calculated according to the definition proposed by Baltas et al[23] for evaluating brachytherapy implants: the fraction of the PTV that is enclosed by the Reference dose (95%) multiplied by the fraction of the total body volume included in the 95% isodose. The Baltas et al formulation used here is defined by

$$CI = PTV_{95\%}/PTV \times PTV_{95\%}/V_{95\%}$$

This definition was more sensitive to the actual coverage of the PTV by the 95% isodose than the CI definition proposed by Knoos et al[24] and recommended by ICRU Report No. 62, to evaluate the degree of conformity of external beam treatment plans ($RCI = V_{PTV}/V_{95\%}$). The Knoos et al formulation as defined by

$$RCI = V_{PTV}/V_{95\%}$$

The best plan was considered to be the one for which both the PTV HI and CI were close to unity and the dose to OARs was minimized. The results were analyzed and compared using Repeated Measurement ANOVA with a significance level of 0.05.

Results

Twenty-eight patients were entered into the present study. Fourteen (50%) had a right side breast cancer and fourteen (50%) had a left side breast cancer. The mean breast volume was 517 cc (range 156-1133 cc, SD = 229).

Planning target volume

The $V_{95\%}$ for the iIMRT, the fIMRT and the conventional technique were 95.61%, 95.77% and 97.46% of the PD, respectively (Table 1, Fig. 4, 5).

The $V_{105\%}$ for the iIMRT technique received 1.12% of the PD, which was significantly less than those from the fIMRT (2.36%, $p < 0.001$) and the conventional (16.81%, $p < 0.001$) techniques (Table 1).

The $V_{110\%}$ for the iIMRT and the fIMRT techniques rendered 0% of the PD, which was significantly less than from the conventional (1.36%, $p < 0.001$) techniques (Table 1).

The D_{max} for the iIMRT technique received 105.03% of the PD, which was significantly less than those from the fIMRT (106.6%, $p = 0.002$) and the conventional (110.68%, $p < 0.001$) techniques (Table 1). The iIMRT technique leads to a 52% and 93% reduction of the volume receiving more than 105% of the prescribed dose compared to the fIMRT technique and conventional technique (Table 1).

The target volume coverage ($V_{95\text{-}105\%}$) for the iIMRT techniques was 96%, which was significantly more improved than those from the fIMRT (91%, $p < 0.005$) and the conventional (87%, $p = 0.021$) techniques (Table 2).

The iIMRT and fIMRT techniques had significantly improved homogeneity comparison with conventional technique ($p < 0.001$) (Table 2).

The PTV CI for the iIMRT technique was 0.704, which was significantly more conformity than those from the fIMRT (0.639, $p < 0.001$) and the conventional (0.539, $p < 0.001$) techniques (Table 2).

Organ at risk

Ipsilateral lung

All parameters used to analyze lung irradiation showed that substantial benefits are obtained when iIMRT technique is introduced (Table 3). Mean lung dose reduces from 882.25 cGy for the conventional technique to 747.6 cGy for the fIMRT technique and to 642.7 cGy when iIMRT technique are used. The same trend is also observed in $V_{20\,Gy}$, which drops from 14.87% for conventional technique to 12.82% for the fIMRT technique, and to about 0.88% for iIMRT technique.

Heart

For the fourteen patients where the left breast was considered, the dose to the heart was scored in

Table 1. Comparison of D_{max}, $V_{105\%}$ and $V_{110\%}$ of PTV for the all techniques

Patient	D_{max}(%)			$V_{95\%}$(%)			$V_{105\%}$(%)			$V_{110\%}$(%)		
	iIMRT	fIMRT	CVT	iIMRT	fIMRT	CVT	iIMRT	fIMRT	CVT	iIMRT	fIMRT	CVT
1	103.40	103.40	108.10	96.62	93.34	98.23	0.00	0.00	5.71	0	0	0
2	105.20	105.20	117.20	99.95	92.03	97.87	0.00	0.16	32.02	0	0	8.79
3	102.10	102.10	108.00	89.04	90.36	93.17	0.00	0.00	12.58	0	0	0
4	103.70	103.70	108.30	97.95	97.32	99.86	0.00	0.00	11.18	0	0	0
5	103.70	103.70	109.70	95.89	98.12	99.54	0.00	0.00	15.16	0	0	0
6	104.80	104.80	111.61	95.57	97.32	99.50	0.00	2.40	24.50	0	0	3.14
7	103.80	103.80	109.10	97.67	98.12	99.65	0.00	2.53	15.90	0	0	0
8	107.50	107.50	109.00	98.79	96.99	99.74	10.53	11.67	21.02	0	0	2.34
9	104.30	104.30	110.90	92.58	97.59	99.37	0.00	0.00	8.90	0	0	0
10	107.70	107.70	117.20	97.46	98.77	99.14	2.80	6.70	27.80	0	0	0
11	102.90	102.90	112.00	95.23	95.34	92.02	0.00	0.00	15.85	0	0	1.58
12	110.00	110.00	112.70	95.19	93.16	97.52	0.99	8.23	35.97	0	0	2.37
13	104.30	104.30	113.00	88.61	93.59	99.21	0.00	2.16	42.69	0	0	15.34
14	103.40	103.40	108.10	95.98	97.54	96.00	0.00	0.00	9.07	0	0	0.16
15	107.20	107.20	109.80	97.59	98.77	99.10	0.14	2.24	20.78	0	0	2.09
16	106.40	106.40	108.10	95.54	95.90	96.16	0.07	1.32	5.68	0	0	0
17	105.70	105.70	109.10	98.22	98.56	99.82	0.01	0.46	11.21	0	0	0
18	103.90	103.90	110.10	98.77	98.77	99.33	0.00	1.22	8.51	0	0	0
19	104.40	104.40	110.40	95.87	96.78	99.77	0.00	2.10	16.50	0	0	0.07
20	106.90	106.90	109.60	95.20	93.55	99.34	3.41	3.69	11.48	0	0	0
21	106.30	106.30	107.10	98.95	93.47	86.57	0.21	0.78	2.39	0	0	0
19	102.90	104.80	112.10	95.58	93.95	97.83	0.00	0.00	6.87	0	0	0
20	107.10	110.30	117.20	92.14	94.85	98.47	1.24	4.99	23.60	0	0	0.26
21	103.40	104.10	108.10	91.60	92.97	90.02	0.00	0.00	17.30	0	0	0
22	102.50	104.80	109.60	92.58	97.59	99.38	0.00	0.00	8.98	0	0	0
23	106.40	109.80	113.70	97.33	96.25	97.58	5.30	6.97	21.80	0	0	1.31
24	106.10	108.10	110.30	94.58	95.13	96.44	6.70	8.40	23.80	0	0	0.65
25	104.80	104.70	108.90	96.66	95.35	98.24	0.00	0.00	13.50	0	0	0
26	102.90	104.80	112.10	96.62	93.34	98.23	0.00	0.00	5.71	0	0	0
27	107.10	110.30	117.20	99.95	92.03	97.87	0.00	0.16	32.02	0	0	8.79
28	103.40	104.10	108.10	89.04	90.36	93.17	0.00	0.00	12.58	0	0	0
Mean	105.03**	106.60#	110.68	95.61*	95.77#	97.46	1.12**	2.36#	16.81	0*	0#	1.36
SD	1.90	1.82	2.85	2.85	2.33	2.26	2.51	3.23	9.69	0	0	3.28

* $p < 0.05$ comparing the iIMRT technique to the conventional technique
** $p < 0.05$ comparing the iMRT technique to both the fIMRT technique and the conventional technique
# $p < 0.05$ comparing the fIMRT technique to the conventional technique

Table 2. Comparison of the PTV rHI and the PTV CI obtained from all techniques used

Dose parameters for comparison	iIMRT, mean (range)	fIMRT, mean (range)	CVT, mean (range)
$V_{95\text{-}105\%}$ [% of PTV]	96 (88.2-97.6)**	91 (85.3-93.9)#	84 (78.7-97.0)
rHI	0.908 (0.898-0.912)*	0.903 (0.895-0.91)#	0.879 (0.849-0.879)
PTV CI	0.704 (0.607-0.801)**	0.639 (0.553-0.725)#	0.539 (0.467-0.611)

* $p < 0.05$ comparing the iIMRT technique to the conventional technique
** $p < 0.05$ comparing the iMRT technique to both the fIMRT technique and the conventional technique
# $p < 0.05$ comparing the fIMRT technique to the conventional technique

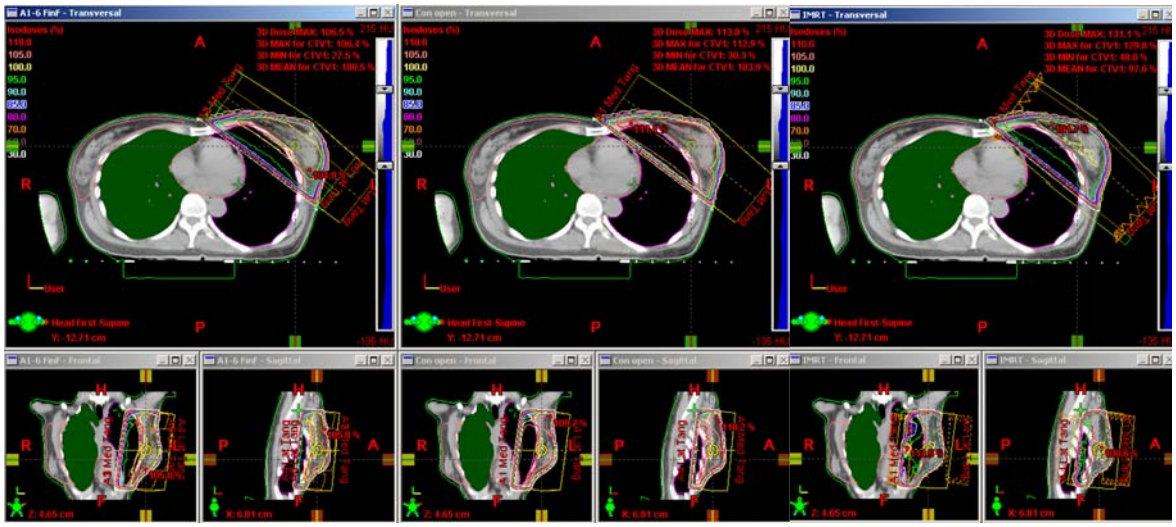

Fig. 4 Isodose distributions for all treatment planning system. Data are shown on the same CT slice for one representative patient. Distributions are similar for all other patients

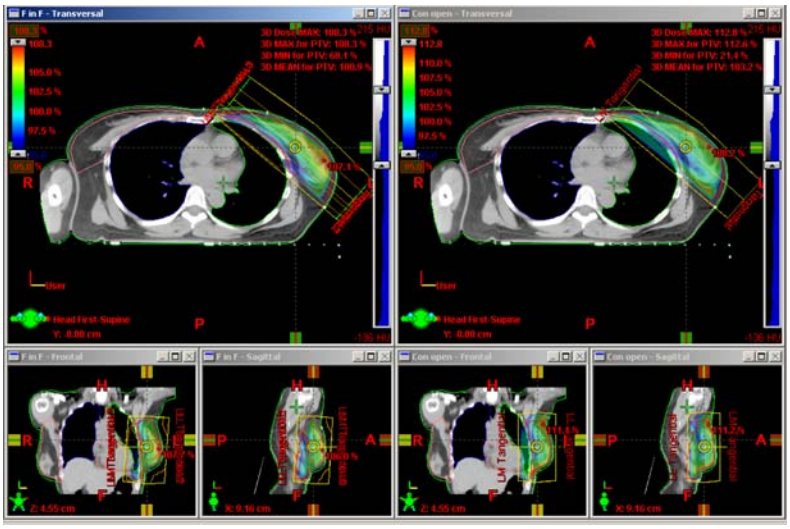

Fig. 5 Isodose distributions in color wash for conventional and fIMRT plan. Data are shown on the same CT slice for one representative patient. Distributions are similar for all other patients

terms of $V_{30\,Gy}$ and significant maximum doses (Table 3). The volume exceeding a dose of 30 Gy ($V_{30\,Gy}$) values were 3.124%, 4.65%, and 5.84% for iIMRT, fIMRT and CVT, respectively. The iIMRT techniques had significantly decreased $V_{30\,G}$ ($p < 0.001$) compared to either the fIMRT technique or conventional technique. The maximum significant dose obtained were: 102.6% (CT), 98.25% (fIMRT), 97.65% (iIMRT) with a reduction of about 4.35% ($p = 0.08$) from conventional technique to fIMRT technique and 4.95% ($p = 0.007$) with iIMRT technique.

Contralateral breast

For all patients, the dose to the contralateral breast was reduced using iIMRT technique. As shown in Table 3, the mean dose of the contralateral breast decreased from 68.57 cGy for the conventional technique to 60.33 cGy for the fIMRT technique and to

Table 3. Comparison of dose parameters of the OARs used in all techniques

Dose parameters for comparison	iIMRT, mean (range)	fIMRT, mean (range)	CT, mean (range)
Heart			
D_{max}(%)	97.65 (86.00-103.20)*	98.25 (77.90-103.90)#	102.60 (97.40-108.10)
$V_{30\ Gy}$(%)	3.124 (0.44-7.8)**	4.655 (0.17-12.5)#	5.845 (0.86-15.8)
Ipisilateral lung			
Mean dose (cGy)	642.70 (272.30-1045.40)**	747.60 (281-1246.90)#	882.25 (345.20-1471.20)
$V_{20\ Gy}$(%)	10.88 (3.57-19.87)**	12.82 (3.70-23.67)#	14.87 (4.52-26.83)
Contralateral breast			
Mean dose (cGy)	55.86 (34.80-91.45)**	60.33 (43.30-93.10)#	68.57 (43.70-113.10)
$V_{2\ Gy}$(%)	1.70 (0-6.10)**	2.47 (0.20-6.32)#	3.60 (0.01-11.86)
Contralateral lung			
Mean dose (cGy)	38.28 (25.00-53.00)**	43.87 (31.80-56.00)#	57.8 (37.80-161.30)

* $p < 0.05$ comparing the iIMRT technique to the conventional technique
** $p < 0.05$comparing the iMRT technique to both the fIMRT technique and the conventional technique
# $p < 0.05$ comparing the fIMRT technique to the conventional technique

55.86 cGy when iIMRT technique is used. The same trend is also observed in $V_{2\ Gy}$, which drops from 3.6% for conventional technique to 2.47% for fIMRT technique, and to about 1.7% for iIMRT technique.

Contralateral lung

The iIMRT techniques had a significantly lower contralateral lung mean dose compared to either the fIMRT technique or conventional technique. The mean dose was 57.8 cGy, 43.87 cGy, and 32.28 cGy for iIMRT, fIMRT and CVT, respectively.

Discussion

Recently, the IMRT has increased the important role in the period that chemotherapy is promising in excellent control of disease. The patient will have a longer life and late complications of radiotherapy might be found.

Although BCT using conventional techniques has allowed producing excellent rates of local tumor control and minimal long-term complications, many patients may be exposed to unnecessary dose inhomogeneity of up to 15-20% due to the inability to three-dimensionally optimized the dose distribution throughout the breast. High-dose cardiac and OARs irradiation are a concern when using whole-breast radiotherapy to treat patients with early breast cancer. Several techniques have been developed over the past decade with the goals of reducing dose inhomogeneity. Unfortunately, no single techniques have been shown to be practical and efficacious on a large scale in the clinic. The most comprehensive technique employs custom-designed tissue compensators to improve dose uniformity with tangential breast RT[12,14,25-29]. However, their implementation remains impractical for many institutions. While physical compensators can improve homogeneity, a significant amount of time is required to design and fabricate the compensators[26]. The resultant additional manpower and cost is often prohibitive and is one of the primary reasons for most centers employing only the standard conventional technique for breast RT. With physical compensators, there is also the concern of increased scattered dose to the contralateral breast due to the close proximity of their placement.

The advent of multileaf collimation holds promise that tissue compensation can be efficiently achieved by intensity modulation using MLC segments. Several studies have demonstrated improvements in dose uniformity with MLC segment that rival that of custom-designed physical compensators[12-15].

In the current study, the authors introduce the iIMRT and fIMRT techniques to improve the dose distribution for tangential whole-breast radiation. The present study demonstrates the iIMRT technique providing improved target volume coverage, dose homogeneity, and dose conformity and reduces doses to all critical structures, compared to the fIMRT and conventional techniques. These results agree with previous studies. For fIMRT technique, the dose distribution was significantly improved and reducing the dose to OARs compared to conventional technique, although was not better than iIMRT technique.

The $V_{110\%}$ is an important parameter because it is significantly correlated with a higher risk of developing significant skin toxicity [30]. In the present study, the $V_{110\%}$ for the iIMRT and the fIMRT techniques were significantly less than from the conventional techniques.

High dose cardiac irradiation is a concern when using conventional tangential technique to treat patients with early left breast cancer. In the study of breast cancer [31] and Hodgkin's disease [32], it was found that lower cardiac complication was obtained if the heart $V_{30\ GY}$ value was less than 10%. Several studies showed the IMRT technique reduced the heart $V_{30\ Gy}$ value less than 3%. In the present study, the heart $V_{30\ Gy}$ value compared well with the one published by Landau et al[33].

Graham[34] found that radiation pneumonitis was related with radiation dose to the lung more than 20 Gy. Yorke[35] and Kwa[36] reported the radiation pneumonitis was related with mean lung dose. In general, recommendation for the $V_{20\ Gy}$ value is less than 20% and mean lung dose is less than 20 Gy. Our series, the iIMRT techniques rendered better $V_{20\ Gy}$ and mean lung dose than the fIMRT and conventional techniques.

Some authors have reported that patients exposed to unilateral RT for breast cancer have an increased risk of contralateral breast cancer[37,38]. Boice et al[37] reported a trend toward more contralateral breast cancer, but only for patients receiving RT prior to the age 45 years. Gao et al[38] studied 5679 patients with early-stage breast cancer treated between 1973 and 1996 (before the IMRT era). Adjuvant RT was associated with a very small absolute increase in the risk of contralateral breast cancer: 0.5%, 1.3%, and 1.6% at 10, 15, and 20 years, respectively Others have found no increased risk comparing women receiving RT to those treated without RT[39]. Hall[40] estimated that switching from 3D-conformal RT to IMRT for various disease sites could increase the incidence of any second malignancy from 1% to 1.75% for patients surviving 10 years.

Clearly, the benefit of sparing the heart and bilateral lung from a high dose of radiation must be weighed against the increased overall low dose radiation.

However, the iIMRT technique requires significant resources and can be time-consuming to plan, verify, and deliver compared to the conventional technique. Therefore, this technology may be best reserved, at present, for specific cases such as bilateral breast cancer, treatment of the internal mammary nodes in addition to the breast and patients with pectus excavatum.

The present work represents a first step in applying IMRT for breast treatment. The ultimate goals using this technology are not only to reduce normal tissue toxicity but also reduce the dose application.

Conclusion

The present report examines dosimetric endpoints for three different techniques of intact breast irradiation. The results show that the iIMRT technique achieves best dose uniformity throughout the target volume of intact breast, and lowest the dose to OAEs.

However, IMRT technique is quite a complicated approach and has a high cost. Therefore it should be used in some groups of patients such as in young patients who have left side breast cancer, bilateral breast cancer at the same time, or in the case that time reduction is needed, when using simultaneous integrated boost radiation technique.

In further development work, the current IMRT technique should be compared with conventional treatments in a larger series to identify patients who maximally benefit from IMRT.

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การศึกษาการกระจายปริมาณรังสีของเทคนิคการฉายแสงแบบปรับความเข้มย้อนกลับการฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิมในผู้ป่วยมะเร็งเต้านมที่ทำการรักษาแบบสงวนเต้านม

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วัตถุประสงค์: *การศึกษานี้แสดงถึงการกระจายปริมาณรังสีของเทคนิคการฉายแสงแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม ในผู้ป่วยมะเร็งเต้านมทั้งสองด้านที่ทำการรักษาแบบสงวนเต้านม*

วัสดุและวิธีการ: *ผู้ป่วยมะเร็งเต้านมข้างซ้าย 14 ราย มะเร็งเต้านมข้างขวา 14 ราย ได้รับการกำหนดขอบเขตเต้านม หัวใจ และปอด จากภาพเอกซเรย์คอมพิวเตอร์ โดยผู้ป่วยแต่ละคนจะทำการวางแผนการฉายแสง 3 แบบ คือ การฉายแสงแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม ปริมาณรังสีที่ให้ทั้งหมด 50 Gy ใน 25 ครั้ง โดยกำหนดให้ 100% ของ PTV ได้รับปริมาณรังสีอย่างน้อย 95% ของ prescribed dose*

ผลการศึกษา: *ค่าเฉลี่ยของปริมาตรเต้านม คือ 517 ซีซี บริเวณที่ได้รับปริมาณรังสีมากกว่าร้อยละ 105 ของปริมาณรังสีที่สั่งไว้ ($V_{105\%}$) ของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม คือร้อยละ 1.12, 2.36 และ 16.81 ตามลำดับ ค่า D_{max} ของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม คือร้อยละ 105.03, 106.6 และ 110.68 ค่า $V_{95\text{-}105\%}$ ของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม คือร้อยละ 96, 91 และ 87 ค่า PTV CI ของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม คือ 0.704, 0.639 และ 0.539 ค่าเฉลี่ยของปริมาณรังสีที่ปอดด้านเดียวกับโรคได้รับของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม เท่ากับ 642.7 cGy, 747.6 cGy และ 882.25 cGy บริเวณหัวใจ ได้รับรังสีเกิน 30 Gy ของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม เท่ากับร้อยละ 3.124, 4.65, และ 5.84 ค่าเฉลี่ยของปริมาณรังสีที่เต้านมด้านตรงข้ามได้รับของการฉายรังสีแบบปรับความเข้มย้อนกลับ การฉายแสงแบบปรับความเข้มไปข้างหน้า และการฉายแสงแบบดั้งเดิม เท่ากับ 55.86 cGy, 60.33 cGy และ 68.57 cGy*

สรุป: *การฉายรังสีแบบปรับความเข้มแบบย้อนกลับ การกระจายปริมาณรังสีดีกว่า โดยลด PTV D_{max}, PTV $V_{105\%}$ และ PTV $V_{110\%}$ การกระจายปริมาณรังสีบริเวณเต้านมสม่ำเสมอมากขึ้น ช่วยลดปริมาณรังสีต่ออวัยวะสำคัญ เมื่อเทียบกับการฉายรังสีแบบปรับความเข้มไปข้างหน้า และการฉายรังสีแบบดั้งเดิมอย่างมีนัยสำคัญทางสถิติ ในส่วนของการฉายแสงแบบปรับความเข้มไปข้างหน้าเมื่อเทียบกับการฉายแสงแบบดั้งเดิมพบว่าการกระจายปริมาณรังสีบริเวณเต้านม และปริมาณรังสีต่ออวัยวะสำคัญดีกว่าอย่างมีนัยสำคัญทางสถิติ*