available at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.rpor.eu/

Original article

Comparison of dose distributions and organs at risk (OAR) doses in conventional tangential technique (CTT) and IMRT plans with different numbers of beam in left-sided breast cancer

*Hande Bas Ayata**, *Metin Güden, Cemile Ceylan, Nadir Kücük, Kayihan Engin*

Department of Radiation Oncology, Anadolu Medical Center, Gebze, Kocaeli, Turkey

ARTICLE INFO

Article history:
Received 6 December 2010
Received in revised form
31 January 2011
Accepted 21 February 2011

Keywords:
Breast cancer
IMRT
Left breast
Whole breast radiotherapy
IMRT
Conventional techniques
comparison

ABSTRACT

Aim: Our aim was to improve dose distribution to the left breast and to determine the dose received by the ipsilateral lung, heart, contralateral lung and contralateral breast during primary left-sided breast irradiation by using intensity modulated radiotherapy (IMRT) techniques compared to conventional tangential techniques (CTT). At the same time, different beams of IMRT plans were compared to each other in respect to CI, HI and organs at risk (OAR) dose.

Background: Conventional early breast cancer treatment consists of lumpectomy followed by whole breast radiation therapy. CTT is a traditional method used for whole breast radiotherapy and includes standard wedged tangents (two opposed wedged tangential photon beams). The IMRT technique has been widely used for many treatment sites, allowing both improved sparing of normal tissues and more conformal dose distributions. IMRT is a new technique for whole breast radiotherapy. IMRT is used to improve conformity and homogeneity and used to reduce OAR doses.

Materials and methods: Thirty patients with left-sided breast carcinoma were treated between 2005 and 2008 using 6, 18 or mixed 6/18 MV photons for primary breast irradiation following breast conserving surgery (BCS). The clinical target volume [CTV] was contoured as a target volume and the contralateral breast, ipsilateral lung, contralateral lung and heart tissues as organs at risk (OAR). IMRT with seven beams (IMRT7), nine beams (IMRT9) and 11 beams (IMRT11) plans were developed and compared with CTT and among each other. The conformity index (CI), homogeneity index (HI), and doses to OAR were compared to each other.

Results: All of IMRT plans significantly improved CI (CTT: 0.76; IMRT7: 0.84; IMRT9: 0.84; IMRT11: 0.85), HI (CTT: 1.16; IMRT7: 1.12; IMRT9: 1.11; IMRT11: 1.11), volume of the ipsilateral lung receiving more than 20 Gy (>$V_{20\,Gy}$) (CTT: 14.6; IMRT7: 9.08; IMRT9: 8.10; IMRT11: 8.60), and volume of the heart receiving more than 30 Gy (>$V_{30\,Gy}$) (CTT: 6.7; IMRT7: 4.04; IMRT9: 2.80; IMRT11: 2.98) compared to CTT. All IMRT plans were found to significantly decrease >$V_{20\,Gy}$ and >$V_{30\,Gy}$ volumes compared to conformal plans. But IMRT plans increased the volume of OAR receiving low dose radiotherapy: volume of contralateral lung receiving 5 and 10 Gy (CTT: 0.0–0.0; IMRT7: 19.0–0.7; IMRT9: 17.2–0.66; IMRT11: 18.7–0.58, respectively)

* *Corresponding author*. Tel.: +90 262 678 55 17; fax: +90 262 654 05 68.
E-mail address: Hande.bas@anadolusaglik.org (H.B. Ayata).

doi:10.1016/j.rpor.2011.02.001

and volume of contralateral breast receiving 10 Gy (CTT: 0.03; IMRT7: 0.38; IMRT9: 0.60; IMRT11: 0.68). The differences among IMRT plans with increased number of beams were not statistically significant. IMRT significantly improved conformity and homogeneity index for plans. Heart and lung volumes receiving high doses were decreased, but OAR receiving low doses was increased.

1. Introduction

Breast conserving surgery (BCS) followed by radiotherapy is highly effective for local control of early-stage breast cancer. Whole breast radiotherapy (WBR) after tumor excision generally includes 5 (23–25 fractions) weeks of external beam radiotherapy for the whole breast (46–50 Gy) followed by a boost to the tumor bed with an additional 7–10 fractions of external beam radiotherapy. Several different techniques have been developed in order to achieve optimal dose delivery for WBR (conventional techniques, segmental forward IMRT, inverse IMRT). Most centers use conventional tangential techniques (CTT) known as two opposite wedged photon fields for WBR. Conventionally, WBR is planned to a crude planning target volume consisting of the whole breast and treated by two tangential wedged beams. Although the usage of wedge increases the dose homogeneity, the use of wedged fields can result in a heterogeneous distribution, particularly in cranial and caudal parts of the breast, where low and high dose areas can occur. An overdosage may result in worse cosmetic results after irradiation and underdosage may result in a lower tumor control probability. There can be a significant variability in the total dose delivered to the lumpectomy site, particularly in women with large breasts. Recently, inverse IMRT techniques have been started to be used frequently in whole breast radiotherapy and studies, the use of intensity modulated radiotherapy (IMRT) to treat the whole breast after breast-conserving surgery has been shown to improve both dose homogeneity and target coverage, as well as to reduce the dose to normal tissues compared to a conventional tangential technique CTT.[1–9] Another advantage of using the IMRT technique may be expected especially in cases where large parts of the lung and the heart are covered with high dose using conventional treatment. Doses to the lung and the heart must be kept as low as possible to avoid long-term complications, since most patients have long life expectancy. With the usage of IMRT, this can lead to reduced toxicity and late effects as compared to conventional tangential technique.[10–13] Studies demonstrate increased mortality rate from myocardial infarction and ischemic heart diseases among irradiated patients with left-sided breast cancer as compared to similar patients with right sided breast cancer.[14–18] A possible disadvantage of using IMRT is the increased scatter dose to the organs at risk (OAR) such as the contralateral breast.[3]

The purpose of this study was to improve dose distribution to the left breast in order to determine the dose received by the ipsilateral lung, the heart, the contralateral lung and the contralateral breast during primary left-sided breast irradiation by using IMRT techniques compared to CTT. We have used several different numbers of IMRT beams and CTT for this comparison.

There are some studies showing that target volume coverage is increased while the dose to organs at risk (such as heart and lungs) reduced with increased number of beams in IMRT.[1,3] In our study, we researched the effect of increased numbers of beams on heterogeneity index (HI), conformity index (CI) and OAR dose in IMRT and the effects of HI, CI and OAR dose. Positive and negative effects of increased number of the beams are discussed. In addition, HI, CI and OAR dose impact was researched according to breast volume.

2. Materials and methods

2.1. *Patients*

Thirty patients with early stage, left-sided breast cancer that had been previously treated with radiation therapy by using CTT after a breast conserving surgery were selected to compare different treatment planning techniques. All patients had American Joint Committee on Cancer (AJCC) pathologic Stages I–IIA (T1–T2 N0) infiltrating ductal carcinoma of the breast. The patients' mean age was 49 years old. Patients with radiotherapy to the axillary or supraclavicular lymph nodes were not included in this study.

All patients underwent a computer tomography (CT) scan at 5-mm intervals using Siemens Biograph Duo LSO combined PET-CT scanner. Patients were positioned supine on a breast board with the left arm elevated above the head and the head turned to the right equivalent to the treatment position. CT axial images were obtained of the area extending from the underside of the chin to the upper abdomen, including the entire bilateral lungs and heart.

2.2. *Target volume and organs at risk (OAR) definition*

The CT axial images were transferred to our contouring workstation (Focalsim) for the target volumes and the OAR to be delineated by the radiation oncologist. The breast tissue (clinical target volume [CTV]) was defined as a target volume and the contralateral breast, ipsilateral lung, contralateral lung and heart tissues as OAR (Fig. 1). The heart was defined as all the visible myocardium and pericardium, from the apex to the right auricle, atrium and infundibulum of the ventricle. The lungs were contoured automatically on CT scans. CTV is defined medially at the lateral edge of the sternum, inferi-

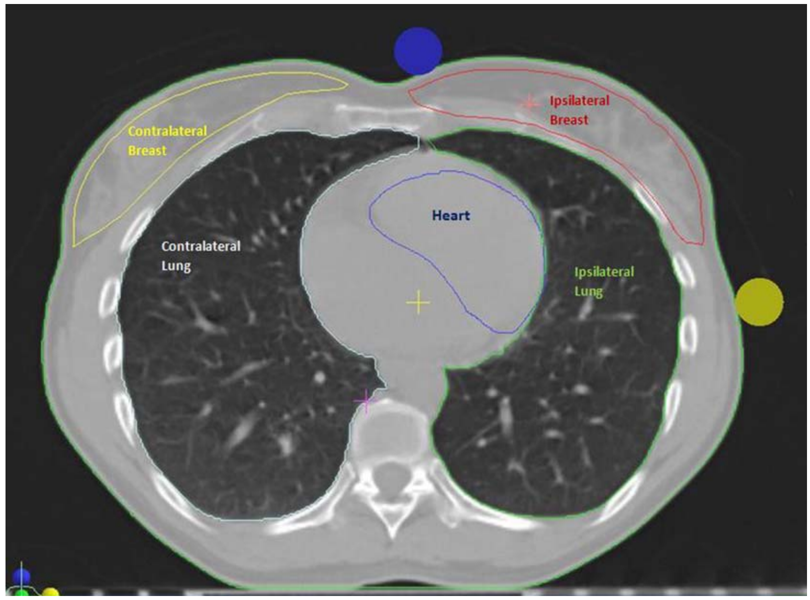

Fig. 1 – Targets and OAR determined by the radiation oncologist on CT slices.

orly at the inframammary fold, superiorly at the inferior edge of the medial head of the clavicula, and laterally to include all apparent breast tissue. Breast volumes ranged from 312 to 2390 cc. For the evaluation, breast volume median value is calculated (853 cc) and evaluated in two groups (<853 cc and >853 cc) according to CI, HI and OAR dose.

2.3. *Planning techniques*

We used the XiO Treatment Planning System (TPS) (Version 4.33.02) (Computed Medical System (CMS), Elekta Software, St. Louis) for all the CTT and IMRT planning. All planning methods used beam parameters of Linear Accelerator (Siemens Medical Solution, Conrad) with 82 leaves. Clarkson-based calculation algorithm was used for CTT plans and superposition-based algorithm used for IMRT plans. The dose for the CTT and IMRT plan was 46 Gy (2 Gy/fraction), prescribed to the isocenter, which was placed near the center of the breast. We determined the same isocenter to deliver dose to the prescribed point in all techniques for the same patient. Each plan was reviewed and approved by the radiation oncologist.

2.4. *Conventional tangential technique (CTT)*

A standard conventional tangential technique consists of two opposed tangential fields with/without wedges using three-dimensional planning with TPS. Treatment fields were individually shaped by means of a multileaf collimator in order to minimize normal tissue dose. A multileaf collimator (MLC) shape was designed to shield as much of the heart and lung as possible without compromising coverage of the CTV. The field borders of the rectangular beam were designed to encompass the whole breast. Wedges were used to improve the dose homogeneity. The dose distribution of a conventional plan usually shows three high dose areas in the central plane, at the medial and lateral side of the lung and near the apex of the breast. The wedge angles and weights of the two tangential beams were optimized to obtain a homogeneous dose distribution in the central plane. The collimator was angled to accommodate the shape of the chest wall.

2.5. *IMRT technique*

Different beam numbers were investigated in order to perform the best plan. Number of beams were increased from 7 (IMRT7) to 9 (IMRT9) to 11 (IMRT11). Initially IMRT beams were equally spaced through the 210 sector angle in the axial plane. We used different beginning gantry angles in some patients because of the different breast anatomies. The goal of inverse treatment planning was to optimize the dose homogeneity with the target and minimize the integral dose to the normal tissue at the same time. Inhomogeneity corrections were used to ensure more accurate dose calculation in the lung. A possible disadvantage of using IMRT techniques in primary breast irradiation is an increased scatter dose to the whole body. The main goal is to reduce heart V_{30} (percentage of the heart receiving more than 30 Gy) and ipsilateral lung V_{20} (percentage of the lung receiving more than 20 Gy). After the final dose calculation, dose distributions were evaluated slice by slice by the radiation oncologist. A 1.5 cm skin margin was given to the IMRT field to accommodate respiratory motion. The dose constraints were as follows:

The clinical tumor volume (CTV) to receive 46 Gy in 23 fractions.

Ipsilateral lung	$V_{20\,Gy} < 20\%$ (no more than 20% of ipsilateral lung receiving 20 Gy or more)
Heart	$V_{30\,Gy} < 10\%$ (no more than 10% of heart receiving 30 Gy or more)
Contralateral lung	$V_{5\,Gy}$ and $V_{10\,Gy}$
Contralateral breast	$V_{10\,Gy}$

2.6. *Comparison of plans*

Different numbers of IMRT beams were created for each patient who had been previously treated with CTT plans. Same initial constraints and numbers of optimization iterations were applied for all IMRT plans with increased numbers of beams. The plans had the best possible homogeneity and conformity indices while dose deliveries to OAR were minimized for all techniques. Dose-volume histograms (DVHs) were generated for CTV and all OAR. The parameters used for comparisons were homogeneity (HI) and conformity index (CI),[23] ipsilateral lung $V_{20\,Gy}$, heart $V_{30\,Gy}$, contralateral lung $V_{10\,Gy}$–$V_{5\,Gy}$ and contralateral breast $V_{10\,Gy}$.

We defined conformity and homogeneity index equations as follows:

$$CI = \frac{V_{RI}}{TV} \quad (1)$$

$$HI = \frac{I_{max}}{RI} \quad (2)$$

where V_{RI} is the volume of prescribed dose for PTV, *TV* is the total volume of PTV, I_{max} is the maximum dose and *RI* is the prescribed dose of PTV.

2.7. *Statistical analysis*

Individual patient results of the IMRT plans were compared with 3D-CRT for each of the parameters. Statistical analyses in order to compare the results with different techniques were carried out with SPSS for Windows version 17.0 statistical package (SPSS Inc., Chicago, IL, USA). Continuous variables were presented as mean and standard deviations. Differences between the treatments and interactions between treatment and breast volume were evaluated with repeated measures (ANOVA). Pairwise comparisons were performed by the Bonferroni adjustment. A *p* value less than 0.05 were considered significant.

3. Results

3.1. *Target volume comparison analyses*

The best CTT plans were compared to the best IMRT plans generated with different numbers of beams using DVH analysis. Additionally, IMRT with different numbers of beams were compared among one another with regards to conformity, homogeneity and dose delivered to the OAR. There was a difference in terms of CI ($p < 0.0001$) among the four treatment plans as shown in Table 1. CTT plans had less CI, but IMRT treatment plans were almost the same (Fig. 2). Increasing the number of IMRT beam from 7 to 11 did not improve conformity. Raising the number of beams increased the number of monitor units (MUs) required for the delivery of treatment.

Breast volume was divided into two groups (<853 cc and ≥853 cc) when the analyses were repeated. There was a difference in CI between treatment techniques ($p < 0.001$). The conformity index of the treatment plans also differed from the volume of the breast. The breast volume has no effect on the CI in between the IMRT treatment plans ($p = 0.126$) as shown in Table 2. But there was a significant difference in CTT plans compared to IMRT plans. When the breast volume was higher than 853 cc, the conformity index decreased as shown in Fig. 3.

There was a difference in terms of homogeneity index ($p < 0.001$) among the four treatment plans as shown in Table 3.

Table 1 – Conformity index of 3DCRT plans and IMRT plans with different numbers of beams.

Treatment techniques	Conformity index (mean ± std.deviation)
CTT	0.76 ± 0.12
IMRT7	0.84 ± 0.05[A]
IMRT9	0.84 ± 0.04[A]
IMRT11	0.85 ± 0.04[A]

[A] $p < 0.05$ significantly higher than CTT.

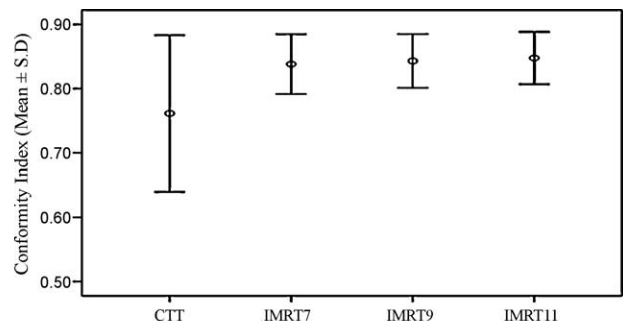

Fig. 2 – Conformity index distribution of 3DCRT plans and IMRT plans with a different number of beams.

Table 2 – Conformity index of 3DCRT plans and IMRT plans with different numbers of beams according to breast volume.

Treatment techniques	Conformity index (mean ± std.deviation)	
	Breast volume < 853 cc	Breast volume ≥ 853 cc
CTT	0.81 ± 0.11	0.71 ± 0.12
IMRT7	0.84 ± 0.06	0.83 ± 0.03
IMRT9	0.85 ± 0.05	0.84 ± 0.02
IMRT11	0.85 ± 0.05	0.85 ± 0.02

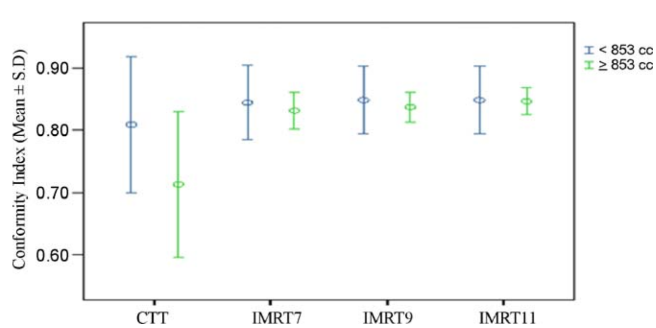

Fig. 3 – Conformity index distribution of 3DCRT plans and IMRT plans with different numbers of beams according to breast volume.

Table 3 – Homogeneity index of 3DCRT plans and IMRT plans with different numbers of beams.

Treatment techniques	Homogeneity index (mean ± std.deviation)
CTT	1.16 ± 0.02
IMRT7	1.12 ± 0.01[A]
IMRT9	1.11 ± 0.01[A]
IMRT11	1.11 ± 0.01[A]

[A] $p < 0.05$ significantly higher than CTT.

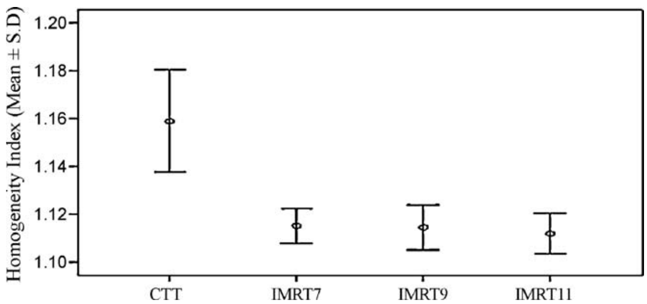

Fig. 4 – Homogeneity index distribution of 3DCRT plans and IMRT plans with different numbers of beams.

CTT plans had greater homogeneity indices than other plans, but IMRT treatment plans were not statistically different from one another (Fig. 4).

Breast volumes were separated into two groups (<853 cc and ≥853 cc) when analyses were repeated. There was a difference in terms of homogeneity index among the treatment plans ($p < 0.001$) but breast volume had no effect on differences between the treatment plans ($p = 0.514$) as shown in Table 4. There was also no statistically significant difference in the interactions with the treatment plan of breast volume ($p = 0.065$). It shows that the homogeneity index of treatment plans does not vary according to breast size (Fig. 5).

3.2. Organs at risk (OAR) comparison analyses

3.2.1. Ipsilateral lung (V_{20}): percentage of ipsilateral lung that received 20 Gy

The difference among four treatment plans was statistically significant in terms of percentage of ipsilateral lung that received 20 Gy ($p < 0.001$) as shown in Table 5. CTT plans had higher percentages of ipsilateral lungs that received 20 Gy than other plans as shown in Fig. 6. In addition, IMRT plans with 9 fields had lower percentages of ipsilateral lungs that received 20 Gy.

Table 4 – Homogeneity index of 3DCRT plans and IMRT plans with different numbers of beams and according to breast volume.

Treatment techniques	Homogeneity index (mean ± std.deviation)	
	Breast volume < 853 cc	Breast volume ≥ 853 cc
CTT	1.15 ± 0.02	1.17 ± 0.02
IMRT7	1.12 ± 0.01	1.11 ± 0.01
IMRT9	1.11 ± 0.01	1.12 ± 0.01
IMRT11	1.11 ± 0.01	1.11 ± 0.01

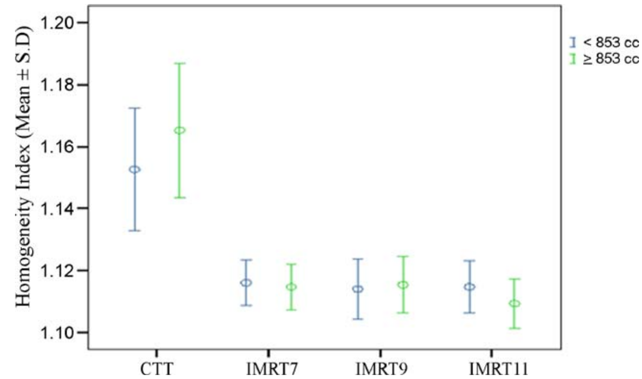

Fig. 5 – Homogeneity index distribution of 3DCRT plans and IMRT plans with different numbers of beams according to breast volume.

Table 5 – Percentage of ipsilateral lung that received 20 Gy of 3DCRT plans and IMRT plans with different numbers of beams.

Treatment techniques	Percentage of ipsilateral lung that received 20 Gy (V_{20}) (mean ± std.deviation)
CTT	14.62 ± 6.93
IMRT7	9.08 ± 3.89[A,B]
IMRT9	8.12 ± 3.46[A]
IMRT11	8.57 ± 3.57[A,B]

[A] $p < 0.05$ significantly higher than CTT.
[B] $p < 0.05$ significantly higher than IMRT9.

3.2.2. Heart (V_{30}): percentage of heart that received 30 Gy

The difference among four treatment plans was statistically significant in terms of percentage of heart that received 30 Gy (see Table 6, $p = 0.008$). CTT plans had higher percentages of heart that received 30 Gy compared to IMRT plans with 9 fields (IMRT plans with 11 fields as shown in Fig. 7). This difference was statistically significant. The differences between plans of CTT and IMRT with 7 fields were not statistically significant

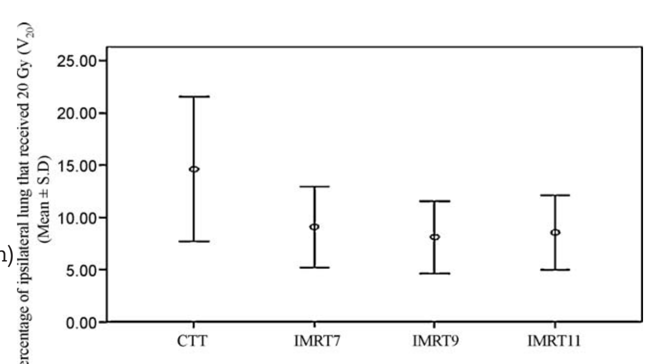

Fig. 6 – Percentage of ipsilateral lung distribution that received 20 Gy of 3DCRT plans and IMRT plans with different numbers of beams.

Table 6 – Percentage of heart that received 30 Gy of 3DCRT plans and IMRT plans with different numbers of beams.

Treatment techniques	Percentage of heart that received 30 Gy (V_{30}) (mean ± std.deviation)
CTT	6.66 ± 8.35
IMRT7	4.04 ± 4.57
IMRT9	2.82 ± 3.39[A]
IMRT11	2.98 ± 3.13[A]

[A] $p < 0.05$ significantly higher than CTT.

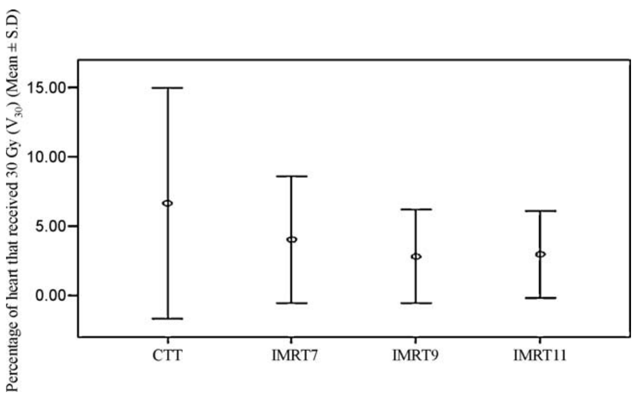

Fig. 7 – Percentage of heart distribution that received 30 Gy of 3DCRT plans and IMRT plans with different numbers of beams.

and there was no statistically significant difference among IMRT plans.

3.2.3. Contralateral breast (V_{10}): percentage of contralateral breast that received 10 Gy

The difference among four treatment plans was statistically significant in terms of percentage of contralateral breast that received 10 Gy ($p = 0.001$) as shown in Table 7. CTT plans had lower percentages of contralateral breast that received 10 Gy compared to IMRT plans with 9 fields and IMRT plans with 11 fields. There was no statistically significant difference among IMRT plans in terms of percentage of contralateral breast that received 10 Gy.

Table 7 – Percentage of contralateral breast that received 10 Gy of 3DCRT plans and IMRT plans with different numbers of beams.

Treatment techniques	Percentage of contralateral breast that received 10 Gy (V_{10}) (mean ± std.deviation)
CTT	0.03 ± 0.18
IMRT7	0.38 ± 0.82
IMRT9	0.60 ± 1.11[A]
IMRT11	0.68 ± 1.19[A]

[A] $p < 0.05$ significantly higher than CTT.

Table 8 – Percentage of contralateral lung that received 10 Gy of 3DCRT plans and IMRT plans with a different number of beams.

Treatment techniques	Percentage of contralateral lung that received 10 Gy (V_{10}) (mean ± std.deviation)
CTT	0.00 ± 0.00
IMRT7	0.70 ± 1.58[A]
IMRT9	0.66 ± 1.39[A]
IMRT11	0.58 ± 1.38[A]

[A] $p < 0.05$ significantly higher than CTT.

3.2.4. Contralateral lung (V_{10}): percentage of contralateral lung that received 10 Gy

The difference among four treatment plans was statistically significant in terms of percentage of contralateral lung that received 10 Gy (see Table 8, $p = 0.017$). As shown in Fig. 11, CTT plans had lower percentages of contralateral lung that received 10 Gy compared to IMRT plans, but there was no statistically significant difference among IMRT plans.

3.2.5. Contralateral lung (V_5): percentage of contralateral lung that received 5 Gy

The difference among four treatment plans was statistically significant in terms of percentages of contralateral lung that received 5 Gy (see Table 9, $p < 0.001$). CTT plans had lower percentages of contralateral lung that received 5 Gy compared to IMRT plans, but there was no statistically significant difference among IMRT plans.

4. Discussion

The use of IMRT to treat the whole breast after breast-conserving surgery proved to improve both dose homogeneity and target coverage as well as to reduce the dose to normal tissue compared to CTT. The IMRT technique tends to spare normal tissue better than conventional tangential technique.[1,26] In our study, we evaluated the conformity index, homogeneity index and OAR dose in plans for CTT, IMRT7, IMRT9 and IMRT11 using DVH analysis. The primary goals of breast IMRT were to reduce ipsilateral lung $V_{20\,Gy}$, heart $V_{30\,Gy}$ and also to improve homogeneity and conformity for patients with left-sided breast cancer.

Table 9 – Percentage of contralateral lung that received 5 Gy of 3DCRT plans and IMRT plans with a different number of beams.

Treatment techniques	Percentage of contralateral lung that received 5 Gy (V_5) (mean ± std.deviation)
CTT	0.00 ± 0.00
IMRT7	19.18 ± 14.86[A]
IMRT9	17.18 ± 13.09[A]
IMRT11	18.71 ± 14.57[A]

[A] $p < 0.05$ significantly higher than CTT.

Popescu et al. reported that IMRT plans which have 7, 9, and 11 beams had been created and compared with PTV dose homogeneity, PTV conformity and dose in OAR according to the increase in the number of beams. The increased numbers of beams from 7 to 11, increased PTV homogeneity and conformity without increasing dosage of healthy tissues. It was found that IMRT plans with 11 and 9 beams had similar homogeneity and conformity.[3] However, increasing the number of beams did not improve homogeneity and conformity in our study. 11 beams IMRT plan was found to have lower heart V_{30} and left lung V_{20} compared to 7 and 9 beams IMRT plans. In addition, with increasing numbers of beams, low and middle dose to left lung and heart volume decreased. The increasing number of beam (up to 11 beams) decreased ipsilateral lung dose in this study.

We showed that CTT plans had lower conformity and homogeneity indices compared to IMRT plans, but IMRT treatment plans were almost the same. Increasing the number of IMRT beam from 7 to 11 did not improve conformity. Increasing the number of beams increased the number of monitor units (MUs) required for treatment delivery. The time needed to deliver the maximum number of MUs for 11 beam plans was increased compared to 7 beam plans. Ipsilateral lung dose in CTT plans were found to be higher compared to IMRT. Among IMRT plans, IMRT9 had a lower percentage of ipsilateral lung volume that received 20 Gy.

Studies demonstrated increased mortality from myocardial infarction and ischemic heart disease among irradiated patients with left-sided breast cancer as compared to similar patients with right sided breast cancer.[14–18] The study which compared 4-field IMRT and conformal technique found that heart and lungs dose decreased in IMRT technique but contralateral breast dose significantly increased.[17] In our study, CTT plans had a higher percentage of heart volume that received 30 Gy compared to IMRT plans with 9 and 11 fields. The difference was statistically significant but differences between plans of CTT and IMRT with 7 fields were not. There was also no statistically significant difference among IMRT plans.

Although some studies previously demonstrated that contralateral breast dose was reduced with IMRT,[19–22] in our study contralateral breast dose was found higher. This could be important especially for younger patients who have a statistically significant risk of contralateral breast cancer associated with breast cancer. Contralateral breast and lung dose were found to be higher in IMRT plans compared to CTT plans because more beams exited through these structures, but there was no statistically significant difference among IMRT plans.

Previous studies demonstrated that most of the toxicities can be significantly reduced with IMRT.[10–13] Patients with large breasts tend to have greater dose heterogeneity in the breast volume and also the toxicities effect which occurs after breast radiotherapy depends on the volume of the breast as shown in some studies.[24,25] The usage of IMRT technique significantly decreased grade 2 or skin toxicities, breast edema and hyperpigmantation compared to CTT plans. Patients who had breast volume $\geq$1600 cm^3 had more acute grade 2, dermatitis ($p = 0.1$), chronic grade 2, or hyperpigmantation ($p = 0.07$) compared to patients who had breast volume < 1000 cm^3.[11] In our study, patients were separated into two groups according to median value of breast volume and studied for CI, HI, OAR dose. We found that there was a difference in the conformity index among treatment techniques ($p < 0.001$). The conformity index of the treatment plans also differed with the volume of breast. Breast volume had no effect on the conformity index in between the IMRT treatment plans. But there was a significant difference in CTT plans compared to IMRT plans. When the breast volume was higher than 853 cc, the conformity index decreased. There was a difference in terms of the homogeneity index between treatment plans ($p < 0.001$) but breast volume had no effect on those differences ($p = 0.514$). There was also no statistically significant difference in the interactions between the treatment plan and breast volume ($p = 0.065$). It shows that the homogeneity index of treatment plans does not vary according to breast size.

As a consequence, 7 beam IMRT techniques may be sufficient for many breast patients. If there is a need to reduce the dose to the ipsilateral lung and heart, 9 or 11 beam IMRT techniques can be used.

5. Conclusion

IMRT plans for breast radiotherapy prepared in our clinic are generally slightly better than CTT plans in terms of the conformity index (CI) and the homogeneity index (HI). It is also clear that IMRT plans significantly reduce the absorbed dose to the ipsilateral lung and heart compared to CTT plans. IMRT is a feasible technique of delivering a homogenous dose to the whole breast. However, dose delivered to contralateral organs with IMRT plans have been found to be higher compared to CTT plans.

Conflict of interest

The authors have not had any actual or potential conflict of interest.

REFERENCES

1. Beckham W, Popescu CC, Patenaude VV, et al. Is multibeam IMRT better than standard treatment for patients with left-sided breast cancer? *Int J Radiat Oncol Biol Phys* 2007;**69**:918–24.
2. Rongsriyam K, Rojpornpradit P, Lertbutsayanukul C, et al. Dosimetric study of inverse-planned intensity modulated, forward-planned intensity modulated and conventional tangential techniques in breast conserving radiotherapy. *J Med Assoc Thai* 2008;**91**:1571–82.
3. Popescu CC, Olivotto I, Patenaude VV, et al. Inverse-planned, dynamic, multi-beam, intensity-modulated radiation therapy (IMRT): a promising technique when target volume is the left breast and internal mammary lymph nodes. *Med Dosim* 2006;**31**:283–91.
4. Oliver M, Chen J, Wong E, et al. A treatment planning study comparing whole breast radiation therapy against conformal, IMRT and tomotherapy for accelerated partial breast irradiation. *Radiother Oncol* 2007;**82**:317–23.
5. Mayo CS, Urie MM, Fitzgerald TJ. Hybrid IMRT plans-concurrently treating conventional and IMRT beams

for improved breast irradiation and reduced planning time. *Int J Radiat Oncol Biol Phys* 2005;**61**:922–32.
6. Van Asselen B, Schwarz M, et al. Intensity-modulated radiotherapy of breast cancer using direct aperture optimization. *Radiother Oncol* 2006;**79**:162–9.
7. Van Asselen B, Raaijmakers CPJ, Hofman P, et al. An improved breast irradiation technique using three-dimensional geometrical information and intensity modulation. *Radiother Oncol* 2001;**58**:341–7.
8. Ahunbay EE, Chen GP, Thatcher S, et al. Direct aperture optimization-based intensity-modulated radiotherapy for whole breast irradiation. *Int J Radiat Oncol Biol Phys* 2007;**67**:1248–58.
9. Fogliata A, Nicolini G, Alber M, et al. IMRT for breast. A planning study. *Radiother Oncol* 2005;**76**:300–10.
10. Pignol JP, Olivotto I, Rakovitch E, et al. A multicenter radomized trial of breast intensity-modulated radiation therapy to reduce acute radiation dermatitis. *J Clin Oncol* 2008;**26**:2085–92.
11. Harsolia A, Kestin L, Grills I, et al. Intensity-modulated radiotherapy results in significant decrease in clinical toxicities compared with conventional wedge-based breast radiotherapy. *Int J Radiat Oncol Biol Phys* 2007;**68**:1375–80.
12. Kestin L, Sharpe BM, Frazier CR, et al. Intensity modulation to improve dose uniformity with tangential breast radiotherapy: initial clinical experience. *Int J Radiat Oncol Biol Phys* 2000;**48**:1559–68.
13. Vicini FA, Sharpe M, Kestin L, et al. Optimizing breast cancer treatment efficacy with intensity-modulated radiotherapy. *Int J Radiat Oncol Biol Phys* 2002;**54**:1336–44.
14. Paszat LF, Mackillop WJ, Groome PA, et al. Mortality from myocardial infarction following postlumpectomy radiotherapy for breast cancer; a population-based study in Ontario, Canada. *Int J Radiat Oncol Biol Phys* 2007;**69**: 918–24.
15. Gyenes G, Rutqvist LE, Liedberg A, et al. Long-term cardiac morbidity and mortality in a randomized trial of pre- and post operative radiation therapy versus surgery alone in primary breast cancer. *Radiother Oncol* 1998;**48**:185–90.
16. Cho BC, Schwarz M, Mijnheer BJ, Bartelink H. Simplified intensity-modulated radiotherapy using pre-defined segments to reduce cardiac complications in left-sided breast cancer. *Radiother Oncol* 2004;**70**:231–41.
17. Landau D, Adams EJ, Webb S, Ross G. Cardiac avoidance in breast radiotherapy: a comparison of simple shielding techniques with intensity-modulated radiotherapy. *Radiother Oncol* 2001;**60**:247–55.
18. Correa CR, Das IJ, Lıtt HI, et al. Association between tangential beam treatment parameters and cardiac abnormalities after definitive radiation treatment for left-sided breast cancer. *Int J Radiat Oncol Biol Phys* 2008;**72**:508–16.
19. Woo TC, Pignol JP, Rakovitch E, et al. Body radiation exposure in breast cancer radiotherapy: impact of breast IMRT and virtual wedge compensation techniques. *Int J Radiat Oncol Biol Phys* 2006;**65**:52–8.
20. Bhatnagar AK, Brandner E, Sonnik D, et al. Intensity modulated radiation therapy (IMRT) reduces the dose to the contralateral breast when compared to conventional tangential fields for primary breast irradiation. *Cancer J* 2004;**10**:381–5.
21. Burmeister J, Alvarado N, Way S, et al. Assessment and minimization of contralateral breast dose for conventional and intensity modulated breast radiotherapy. *Med Dosim* 2008;**33**:6–13.
22. Fong A, Bromley R, Beat M, et al. Dosimetric comparison of intensity modulated radiotherapy techniques and standard wedged tangents for whole breast radiotherapy. *J Med Imaging Radiat Oncol* 2009;**53**:92–9.
23. Feuvret L, Noel G, Mazeron J-J, Bey P. Conformity index: a review. *Int J Radiat Oncol Biol Phys* 2006;**64**(2):333–42.
24. Gray JR, McCormick B, Cox L, et al. Primary brest irradiation in large-breasted or heavy women: analysis of cosmetic out-come. *Int J Radiat Oncol Biol Phys* 1991;**21**:347–54.
25. Neal AJ, Torr M, Helyer S, et al. Correlation of breast dose heterogeneity with breast size using 3D CT planning and dose-volume histograms. *Radiother Oncol* 1995;**34**:210–8.
26. Korczyńska BS, Śladowska A, et al. Comparison between intensity modulated radiotherapy (IMRT) and 3D tangential beams technique used in patients with early-stage breast cancer who received breast-conserving therapy. *Rep Pract Oncol Radiother* 2010;**15**(4):79–86.