Radiation doses to heart and contralateral breast: A comparison of different left chest wall irradiation techniques

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Abstract

Introduction: Reduction of heart and contra-lateral breast (CB) doses is considered an important factor when selecting radiotherapy technique in left sided breast cancer patients.
Aim: To compare radiation doses received by heart and CB using three different left chest wall irradiation techniques aiming to achieve optimum technique with good target coverage and sparing of heart and CB among patients with left breast cancer treated by modified radical mastectomy according to size of CB & PTV.
Methods: CT simulation was performed for ten left sided breast cancer patients. Three techniques using different shielding (multileaf collimator (MLCs), asymmetric half-beam technique (HBB) and lead custom block).of the lungs, heart and CB were generated for tangential fields. The dose volume parameters (DVPs) of the three plans were analyzed statistically. A correlation was tested between the differences in DVPs of the plans and the volume of PTV and CB to find out which technique shows the best DVPs according to size of CB & PTV.
Results: Lead custom block shows the best heart & CB sparing. The significant correlation between the differences of the DVPs of the plans and volume of PTV and CB shows that the volume of PTV and CB help in the selection of optimum technique.
Conclusion: Volume of PTV and CB are the predictors for selection of the optimum technique. Lead custom block is the best shielding method specially in patients with small PTV and CB while MLCs could be used in patient with large CB.
I declare that there is no conflict of interest with any financial organization regarding the material in this manuscript

Introduction

Breast cancer is one of the most common malignancies in women and is the most common cause of death among women aged between 40 and 50 years.[1,2] The most common treatment modalities are either breast conserving surgery followed by adjuvant breast irradiation or mastectomy followed by adjuvant radiotherapy of the chest wall for the patients with locally advanced disease at diagnosis.[2,3,4]

Adjuvant radiotherapy of the chest wall is commonly achieved with tangential beams[5,6] , although adjuvant radiotherapy of the chest wall improves local control and survival in breast cancer patients after mastectomy, it is associated with a significantly increased risk of developing ipsilateral second lung cancer and cardiac morbidity and mortality in patients treated on the left side.[4-7] This is because tangential beams include part of the anterior thoracic cavity, so they are affecting the organs at risk (OARs) in particular lung and heart.[3] In addition, CB dose is an issue of concern in radiotherapy field. As it is exposed to leakage and scattered radiation which is influenced by wedges, blocks and the use of half beam.[4,8,9] This might lead to significant doses of radiation to CB with an increase in CB cancer rate in patients who had radical mastectomy under the age of 45 and received a total dose of 46–54 Gy.[1,7,9,10]

Different radiotherapy techniques such as electrons and external photon beams using half-beam with asymmetric collimator jaw, cerrebond, lead custom block, or MLCs for shaping the target volume deliver different levels of scatter doses to heart, lungs and CB. [8,11]Hence they may induce different risks of secondary cancers, pulmonary complications or cardiomyopathy, therefore, a reduction of the dose to CB, lungs and heart is considered an important factor when selecting a treatment technique.[4,6,8]

So every effort should be made to apply recent technical advances in the delivery of radiation therapy and to minimize the dose to heart, lungs and CB. In practice, minimizing the dose to the ipsilateral lung and heart has higher priority than minimizing the dose to the CB. Then if minimizing the dose to CB is prioritized, other treatment techniques may be considered.[6,12]

Aim

To compare radiation doses received by heart and CB using three different left chest wall irradiation techniques aiming to achieve optimum technique with good target coverage and sparing of heart and CB among patients with left breast cancer treated by modified radical mastectomy according to size of CB & PTV.

Methods

Ten left sided breast cancer patients who had modified radical mastectomy aged 40-63 years treated from January 2011 to March 2012 in the Clinical Oncology and Nuclear Medicine department, Alexandria University Hospital were included in this study.

CT simulation was performed in the supine position on breast board with the arms positioned above the head. The CT data were transferred to treatment planning system (Precise Elekta) where all required structures were contoured. The planning target volume (PTV) definition for the chest wall was done according to the breast cancer atlas for radiation therapy planning consensus definitions of the Radiation Therapy Oncology Group (RTOG). Supraclavicular nodes and axilla Level I-III nodes were also contoured. CB, heart and both lungs were also contoured.

All CT scans were planned, calculated with a 6 MV photon beam on a Precise Elekta linear accelerator. Optimized plans were carried out using medial & lateral wedged tangential photon fields and anterior supraclavicular field (SC). To optimize coverage of the PTV, and to reduce the dose to the lungs, heart and to avoid CB irradiation beam angles, wedge angles, and beam weighting were chosen. Gantry angles ranged from 300° to 319° for the medial fields and ranged from 120° to 146° for the lateral fields. Collimator and couch rotation of 8^0-30^0 & 6^0-28^0 were done. Wedge angles of 10°, 15° & 35° were used in tangential fields. For SC field, gantry angle of 341^0-353^0 with 1^0-2^0 collimation rotation and 90^0 couch rotation was used. A bolus of 1-1.5cm thickness was used in tangential and SC fields to improve the target coverage in build up region.

Then for the tangential photon fields for each patient three isocentric radiation techniques were generated using different methods for shaping the PTV and shielding of the lungs, heart and CB; a) multileaf collimator (MLCs) (Figure 1 a). b) asymmetric half-beam technique using asymmetric collimator jaw (HBB); the centre of the field is not at the centre of PTV but at the periphery of the PTV at the lung side and one jaw is used to create the field size; the other jaw is closed (Figure 1 b), and c) lead custom block. (Figure 1. c).

SC field extended superiorly to thyroid cartilage, inferiorly to clavicular head, medially to trachea, posterolaterally to anterior scalene muscle and posteromedialy to carotid artery. The matching between tangential and SC field was adjusted using the couch and collimator rotation of the tangential fields and gantry rotation of SC field.

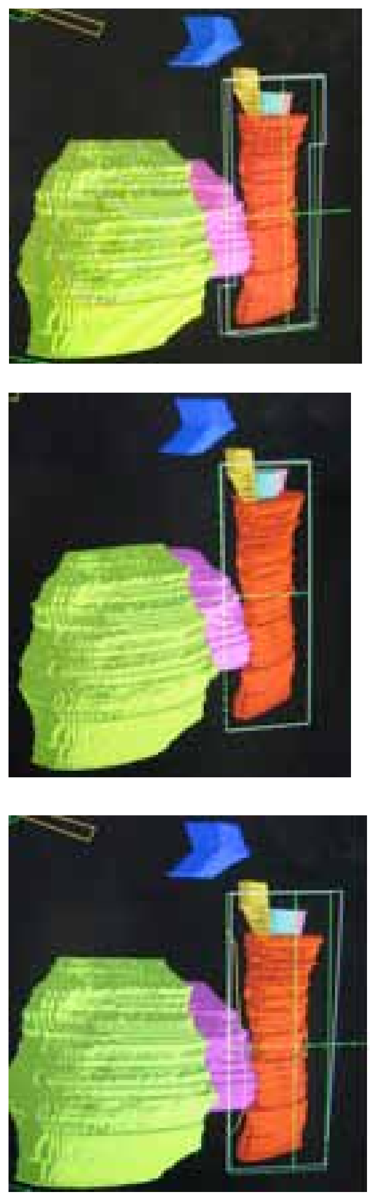
The dose of 50 Gy in 25 fractions was prescribed to the isocenter which is placed at the center of the PTV for tangential field and at 3-5cm depth for SC field. For each plan the added dose plan function was used to check the dose coverage of the tangential and SC fields.

Isodose distributions and DVHs for these techniques were generated and compared. The plans evaluation depends on the coverage of different target volumes and the sparing of the heart and CB. The coverage of target volumes was evaluated using the dose to 95% of the PTV, supraclavicular area, axilla Level I-III nodes ($D_{95\%}$). The sparing of the heart was assessed using the volume of the heart that receives 2.5 Gy, 5 Gy, 10 Gy, 20 Gy and 30 Gy ($V_{2.5\,Gy}$, $V_{5\,Gy}$, $V_{10\,Gy}$, $V_{20\,Gy,}$ & $V_{30\,Gy}$), and the dose to 5% & 30% of heart volume ($D_{5\%}$ & $D_{30\%}$). The dose to CB was assessed using maximum point dose to breast tissues.

This study had approval of Institutional Review Board as a retrospective one in which confidentially of records was considered.

Statistical Analysis

The DVPs for the three plans for each patient were compared and analyzed statistically using excel sheet and Wilcoxon signed Rank test of SPSS (version18). A *P* value of less than 0.05 was taken as statistically significant. Then the differences and the percentage of the reduction in the most important DVPs between the plans were calculated. Then a correlation was tested between these differences and the volume of PTV and CB to find out if any of them affect the DVPs differences. Also to find out which technique show the best DVPs among patients according to size of CB & PTV.



a

b

c

Fig 1: Beam eye view for medial tangential field comparing shielding of heart (pink) & CB (green) from radiation using MLCs (A), (B) asymmetric collimator jaw and (c) a block.

Results

A. Dose distribution

By reviewing the DVPs of the three treatment plans of all patients, the followings were the results as regards the dose distribution of the target volumes and OARs including heart and CB (table 1 & figure 2 & 3).

As regard radiation dose to target volumes

For all patients the coverage of different target volumes was adequate and comparable for all plans (p values >0.05).

As regard radiation dose to organs at risk (OARs)

Table 1 shows the min and max average of DVPs among the three plans, & Table 2 summarises the differences in heart and CB DVPs among the plans that were statistically significant.

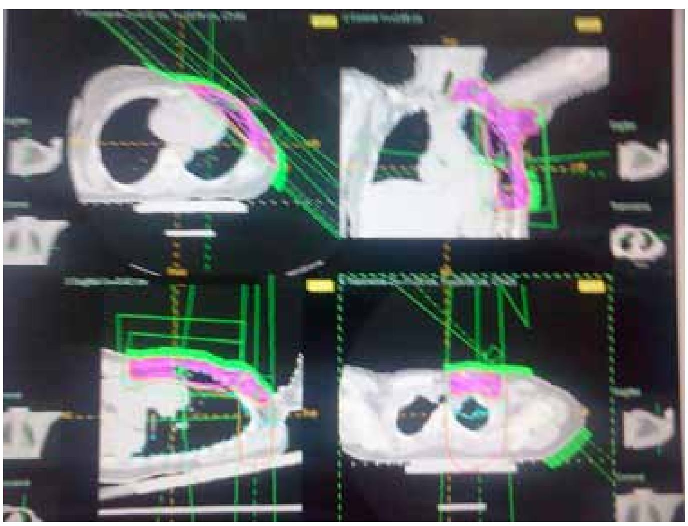


Fig 2: Isodose distributions of adding tangential and SC fields for chest wall irradiation in axial, coronal & sagittal plane. It also shows that chest wall and supraclavicular area are well covered by 95% of the dose (pink shadow)

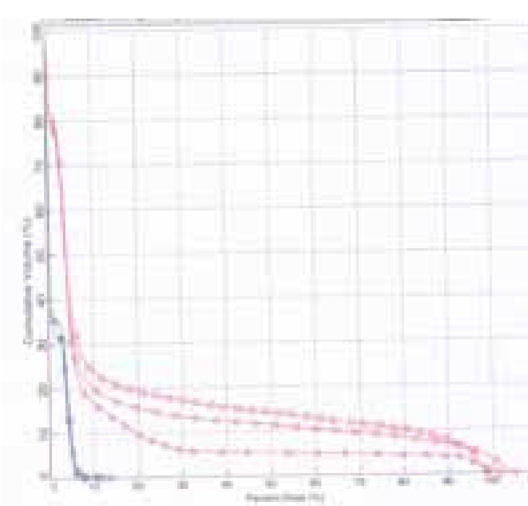


Fig 3: Dose volume histogram parameters in % for heart in pink, & CB in blue comparing shielding using MLCs, asymmetric jaw and custom lead block (triangle curve).

Table 1: Comparison of the average of DVPs for target volumes, heart and CB for different plans. The dose is in % and the volume is in cc

DVPs	Plan 1	Plan 2	Plan 3
Heart			
$D_{5\%}$	94	94.5	87
$D_{30\%}$	11	15.5	8
$V_{2.5Gy}$	54	52	53
V_{5Gy}	28	27.5	21
V_{10Gy}	23	23	16
V_{20Gy}	19	19	13.5
V_{30Gy}	16	17	12
CB Max dose	14	26	16
PTV $D_{95\%}$	95	95	93
SC $D_{95\%}$	98	97	97
AXL I $D_{95\%}$	93	92	93
AXL II $D_{95\%}$	94	94	94
AXL. III $D_{95\%}$	95	93	95

Table 2: The differences in DVPs between the plans for heart and CB that were statistically significant.

	Heart DVPs					CB
	$D_{30\%}$	V_{5Gy}	V_{10Gy}	V_{20Gy}	V_{30Gy}	Max dose
Differences 1 & 3 P value	0.045	0.005	0.007	0.014	0.019	
Differences 2 & 3 P value		0.007	0.005	0.008	0.012	0.027

B. Correlation results

Table 3 summarises the correlation between the differences in heart & CB DVPs of the three plans from one side and the volume of the CB (ranges from 425-1156 cc (average 805cc) and volume of PTV (ranges from 257 to 1288cc (average 646cc) from other side. Table 4 shows how heart & CB DVPs differe among the plans according to the volume of CB and PTV. (+) sign indicates that the corresponding plan shows the best DVPs among the plans for the patients according to the volume of PTV and CB.

From both table we concluded that:

Comparing sparing of heart using MLCs and HBB, we found that; with smaller volume of CB, there is no difference to use MLCs (plan 1) or asymmetric HBB (plan 2) for shaping the tangential fields and sparing heart and CB (as the differences in DVPs decrease with the decrease in CB volume). On the other hand for large CB, MLCs is prefferd for shaping the PTV and to spare heart and CB (this is because plan 1 shows better results than plan 2 (table 1) and as the differences in DVPs between the plans increase with the increase in the size of CB). Regading volume of PTV, MLCs shows best heart sparing for small PTV (the differences between two plans increase with the decrease in the size of PTV)

Comparing sparing of heart using lead block (plan 3) with using either HBB (plan 2) or MLCs (plan 1); we found that; lead block (plan 3) shows the best heart sparing when the volume of CB and PTV is small (as the differences between the plans increase with the decrease in the volume of CB & PTV). So block is the best method for shaping the tangential fields for small CB and PTV.

So for small PTV and CB lead custom block should be used to reduce heart DVPs.

For CB the differences in the max dose to the CB between plan 2 & 3 increase with the decrease in the volume of PTV so it is better to use lead block to shape the PTV specially if it is small as it provide more sparing of CB.

So lead custom block is the best shielding method for patients with small PTV and CB as it shows the best heart and CB sparing.

Table 3: The correlation between the differences in heart and CB DVPs of the plans and the volumes of PTV and CB.

	Heart DVPs							CB
Differences 1 & 2	$D_{5\%}$	$D_{30\%}$	$V_{2.5Gy}$	V_{5Gy}	V_{10Gy}	V_{20Gy}	V_{30Gy}	Max dose
CB (r)	-0.59	0.71		0.77	0.55	0.59	0.55	
P value	0.07	**0.022**		**0.009**	0.1	0.069	0.1	
PTV (r)	-0.49		-0.42					
P value	0.149		0.228					
Differences 1 & 3								
CB (r)		-0.68					-0.3	
P value		**0.029**					0.39	
PTV (r)			0.62	-0.41	-0.41			
P value			**0.05**	0.237	0.233			
Differences 2 & 3								
CB (r)		-0.71		-0.64	-0.74	-0.69	-0.59	
P value		**0.02**		**0.04**	**0.014**	**0.026**	0.07	
PTV (r)			0.68	-0.64	-0.5	-0.3	-0.32	-0.38
P value			**0.03**	**0.04**	0.137	0.392	0.366	0.285

Table 4: Summary table showing the differences in heart DVPs between the plans and the volume of CB and PTV. (+) indicates that the corresponding plan shows the best DVPs among the plans.

Plans	**CB**		**PTV**	
	small	large	small	large
MLCs	=	+(heart)	+(heart)	=
1/2 BB	=			=
MLCs		=		=
blocks	+(heart)	=	+(heart)	=
1/2 BB		=		=
blocks	+(heart)	=	+(heart) & CB	=

Discussion

Breast is one of the difficult sites in treatment planning, where inhomogeneity could be higher because of the shape and size of the breast.[5]

The choice of technique for chest wall irradiation in post-mastectomy breast cancer patients depends on patient geometry (chest wall (CW) thickness, curvature, separation, length of mastectomy scar, and breast volume), adequate target coverage and normal tissue tolerance. [6,13]

Current study compared radiation doses received by heart and CB using three different left chest wall irradiation techniques.

Using MLCs or lead custom block for shaping the tangential fields showed the lowest dose to CB. On the other hand using asymmetric HBB showed the highest dose to CB. These results are against the results done by Tercilla et al[8] & Charmayne et al[11] & Kelly et al[14] who found that the asymmetric HBB technique gives significantly lower dose than the cerrobend HBB. They attributed this to the difference between the cerrobend block transmission and the collimator transmission. Kelly also found that the use of physical wedges, cerrobend blocks or compensators increases the scatter dose to the opposite breast; therefore, protection to the CB is necessary when 3DCRT plus cerrobend is used. Our results are against their work because in the current study, a piece of block was only used to cover part of lung, heart and CB present in the field, on the other hand they use the block to shield the whole length of the field (HBB) not only a part of the field as we did so the scatter was more than in our work.

On the other hand, the results of current study are in accordance with those reported by Edgardo et al [1] who found that the dose to CB was reduced by 60% when a 2.5 cm lead shield was used. Because they use it as in the current study to shield part of the tangential field. They concluded that as the use of lead shield reduced the dose to OARs and therefore the risk of radiation-induced cancer, thus a 3DCRT plan with lead blocks should be used. Our results also agree with Muller-Runkel et al [15] work that used lead shield for covering and protecting CB.

This study also showed that using lead custom block for shaping the tangential fields is considered the best technique for sparing heart. These results agree with the work done by Tercilla et al[8] who recommended non use of HBB as it increases the dose to the OARs.

Also our results are in accordance with David et al[16] who achieved lower doses to lung, heart and CB by using conformal lead blocks to shield both tangential beams compared with standard tangents.

The current study also correlated the differences in heart and CB DVPs between the plans with the volumes of the PTV and CB to find if any of both volumes affect these differences and the results of the plans and so the selection of a suitable chest wall irradiation technique (table 4). Both the volumes of PTV and CB are considered as the predictors for the selection of the optimum technique for chest wall irradiation; for patients with large CB, MLCs is preferred for shaping the target volume to spare the heart. For patients with small PTV and CB lead custom block is the best shielding method as it shows the best heart and CB sparing.

Some authors correlated the choice of technique with patient geometry (chest wall (CW) thickness, CW curvature, length of mastectomy scar, chest wall separation and breast volume), adequate target coverage and normal tissue tolerance. [6,13]

Bhatnagar et al[17] have studied the effect of breast size on scatter dose to CB. They found that the contribution to CB dose is strongly dependent on primary breast size of the patient.

Prabhakar et al[12] correlate the breast dose heterogeneity with different breast parameters such as chest wall separation and breast volume. They found that the increase in dose inhomogeneity was correlated with increasing the target volume. Neal et al[18] also correlated large-breasted women with heterogeneous dose distributions. Das et al.[19] correlated larger chest wall separation with the hot spot presence and he solved this by using energy higher than 6 MV.

Moody et al[13] found a correlation between breast size and dose inhomogeneity which may account for the marked changes in breast appearance reported in women with large breasts.

Based on the results of this study, we recommend that lead custom block should be used in 3DCRT of the chest wall as a shielding method for heart and CB, as it provides the best sparing. We also determined that the volume of PTV and CB are the predictors for the selection of the optimum technique for chest wall irradiation. Lead custom block should be used instead of asymmetric half beam techniques and MLCs in patients with small PTV & CB volume for the best heart and CB sparing. However the limited number of the patients included in our study does not allow for determining the cutoff value for the volume of PTV & CB that could be used for optimal technique selection. So this work should be continuing in future on large patient group.

Conclusion

The volume of PTV and CB are the predictors for the selection of the optimum technique for left side chest wall irradiation. Lead custom block is the best shielding method for 3DCRT of the chest wall as it provides the best heart and CB sparing specially in patients with small PTV and CB and MLCs could be used in patient with large CB.

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