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The Effect of the Number of Fields on Radiotherapy Plans of Breast Cancer Patients in Three-Dimensionally Conformal Radiotherapy Plans: Dosimetric Studies

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Abstract

Background: The objective of this study was to compare the dosimetric outcome of plans with more fields to those with fewer ones for breast cancer patients.

Method: 23 breast cancer patients were examined in this experimental study. Two groups of these patients were planned by treatment planning system. The number of beams was changed for each group, and the dosimetric parameters were calculated. The dose volume histogram (DVH) and the statistical analyses were performed for the two plans of all patients.

Results: The DVH for the planning target volume (PTV) of the two techniques was estimated. Optimized plans were carried out to ensure that 95 % of the target volume takes 95 % of the dose. Based on the statistical analysis, the best coverage of dose had no relationship with the number of beams because the *P*-value of $V_{105\ \%}$, $V_{95\%}$,$V_{110\%}$, D_{mean}, D_{max}, conformity index, homogeneity index, and D5% were 0.9537, 0.9152, 0.3446, 0.8156, 0.9516, 0.7888, 0.2127, and 0.7282, respectively. The Mean ± standard error of mean for all PTV parameters was nearly the same. Also, the organ at risk had no significant difference after changing the number of beams, which means that the complication to normal tissue was nearly the same for both plans.

Conclusion: The number of beams has no effect on PTV and normal tissue. Therefore, it is important for medical physicists to conduct the optimized plan without exceeding the number of beams to reduce the scattered radiation.

Keywords: Breast neoplasms, 3D, Conformal, Radiotherapy, DVH

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Introduction

Breast cancer is the most prevalent cancer type in females. Its annual occurrence increases with the increase in age. It comprises nearly 30% of the malign diseases that commonly occur in women and 16 % of cancer-related deaths in females. Because of the progress in mammography in early diagnosis and the advances in chemotherapy and radiotherapy, the treatment of breast cancer varies frequently and includes many treatment combinations.[1]

Random clinical trials of breast cancer have shown that radiotherapy of whole breast (RT) after breast conserving surgery improves local control rates, as well as disease-free survival.[2] However, this treatment entails toxicity, especially cardio-toxicity, increases the risk of mortality, and prevents the observation of the actual survival benefit.[3] Randomized and population-based studies have also indicated that the radiotherapy of the chest wall is associated with a significantly increased risk of ipsilateral secondary lung cancer.[4-11]

In the radiotherapy of whole breast and chest wall, a two-field tangentially-opposed photon beam arrangement is preferred. For nodal dosing, it is recommended that an anterior field be used with a posterior field used to encompass clinical target volume (CTV), when required. Isocentric techniques are further suggested in this regard.[12]

For the conventional tangential wedged beams (TWB) technique for whole breast irradiation, it is difficult to achieve homogenous dose distribution because of breast contour irregularities. Many studies have also reported the large dose inhomogeneity within the target volume.[13, 14]

This study aimed to evaluate the homogenous dose distribution to the tumor with different numbers of beams, compare dosimetric parameters with different numbers of beams of conformal radiotherapy, and study the effect of the number of beams on dose distribution. The dose coverage of the planning target volume (PTV) and the radiation taken by the organs at risk (OARs) were further assessed. Many parameters, such as dose homogeneity index (DHI) and conformity index (CI), were used in the dose estimation of the PTV and OARs volume such as ipsilateral lung, heart, and the other breast.[15]

Methods

Patients

In this experimental study, 23 unselected left and right side breast cancer patients aged 39-73 years (mean 56 years) were investigated on the prowess planning system. All the patients underwent breast-conservative surgery or modified radical mastectomy. The patients underwent computed tomography (CT) scan in a supine position. To maintain the position of treatment, a breast board was settled in both the CT and table of treatment. The CT data were acquired with a close axial slice of 5 mm, including the entire chest with normal free breathing. The data obtained from CT were transferred to the treatment planning system (TPS) "prowess TPS version 7.6c, Philips Healthcare Best and The Netherlands".[16, 17] The prescription dose was 40 Gy in 15 fractions (266.6 Gy per fraction). Patients delivered the three-dimensionally conformal radiotherapy (3D-CRT) with the linear accelerator unit by 6 MV or 15 MV of the ELEKTA and a precise 6 MV of the SL 75/5 photon beams. The radiotherapy available only on our department is 3D-CRT.

Target volumes and OARs

Body and lung contours were created via an automatic contouring feature of TPS. The planning PTV, CTV, and OAR "heart and contralateral breast" were delineated by the same radiation oncologist. The CTV of the whole breast, including all visible breast parenchyma, was delineated on each CT slice. The target volumes were determined and the dose was prescribed according to the International Commission on Radiation Units and Measurement (ICRU) Reports 50 and 62 recommendations. Accordingly, the target volume should be covered with 95 % of isodose line. The PTV for the chest wall was defined according to the breast cancer atlas for radiation therapy planning consensus definitions of the Radiation Therapy Oncology Group (RTOG). The PTV included the chest wall with

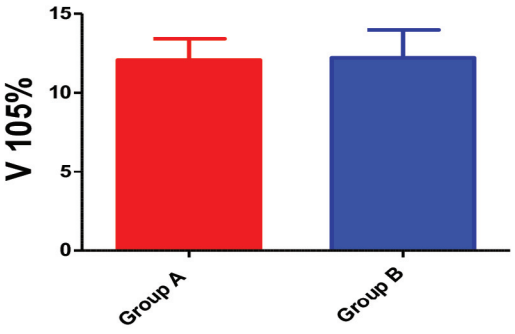
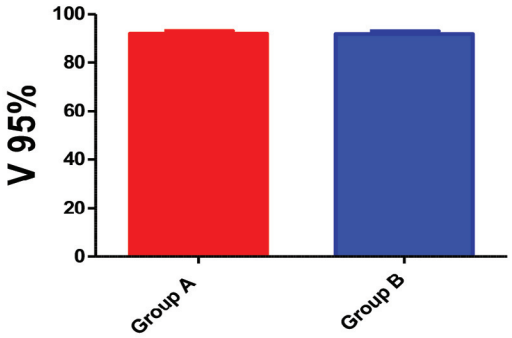


Figure (a)



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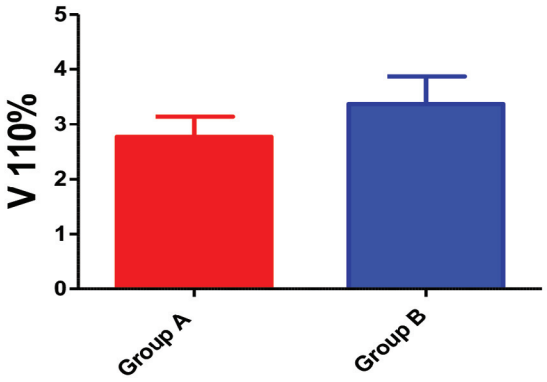

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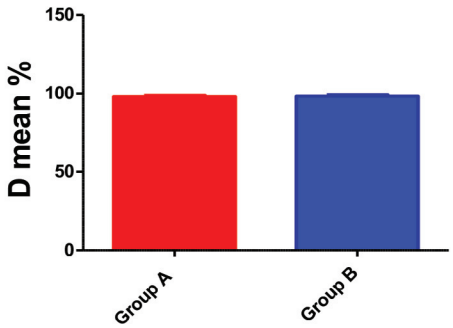

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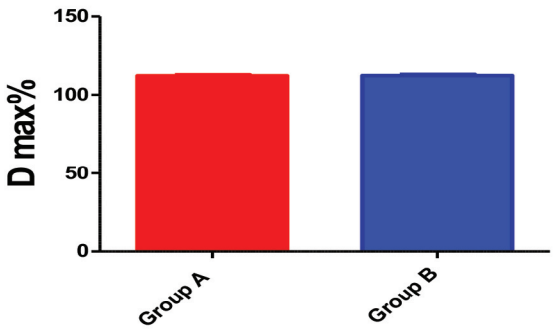

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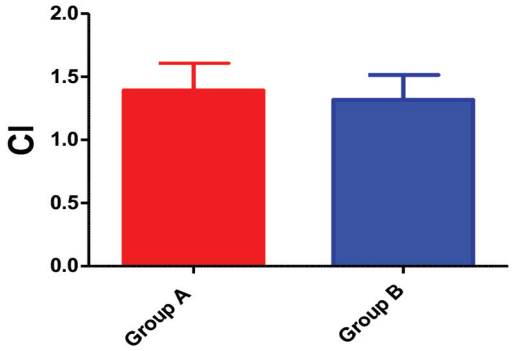

Figure (f)

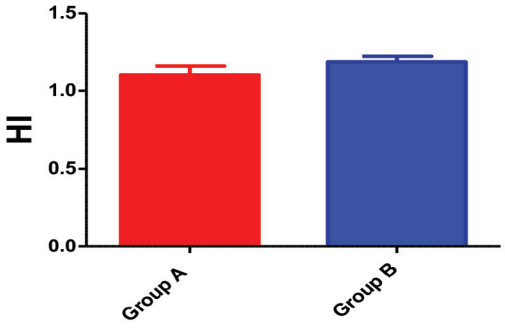

Figure (g)

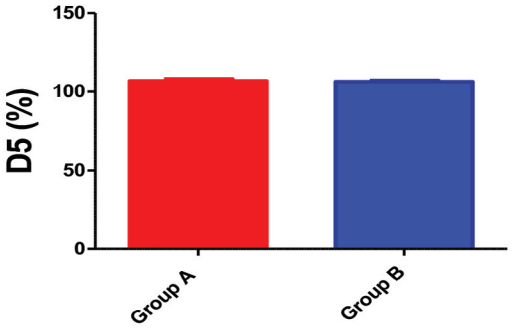

Figure (h)

Figure 1. (a, b, c, d, e, f, g and h). This figure shows the diagram of statistical analysis of PTV dosimetric parameters for all patients.
D_{max}: Maximum dose; D_{mean}: Mean dose; CI: Conformity index; HI: Homogeneity index; PTV: Planning target volume; Group A: More number of beams; Group B: Less number of beams

Table 1. PTV data obtained from the dosimetric parameters of group (a) for each DVH

Patients Group A	$V_{95\%}$	$V_{105\%}$	$V_{110\%}$	$D_{mean\%}$	$D_{max\%}$	CI	HI	D5 (%)
1	88	20	3	102.40	113.80	2.6	1.22	110
2	92	15	5	100	116	4.5	1.23	111
3	90	7	4	91.10	114.6	1.13	1.1	109
4	89	12	3	98.70	111.60	4.00	1.23	110
5	93	20	5	96.50	111.30	0.95	1.12	106
6	96	14	4	100.10	112.7	0.96	1.18	112
7	93	12	2	99.20	109.80	0.93	1.03	112
8	98	5	3	96.6	108.10	0.99	1.12	106
9	93.5	28	2	99.90	109.2	0.9	1	99
10	89	20	2	98.50	109.30	0.89	1.09	107
11	89	9	5	94.70	104.40	0.89	1.72	104
12	87	7	0	91.3	109.90	0.85	0.06	105
13	94	13	6.5	101.3	114.1	0.94	1.16	111
14	80	20	2.5	95.6	114.2	0.8	0.96	84
15	91	7	3	101.30	115.3	2.6	1.17	110
16	98	6	0	98.4	109.5	0.99	1.11	105
17	99	5	5	104.10	116.7	0.99	1.2	114
18	85	12	2	94.5	112.3	0.87	1.14	107
19	98	12	1.5	100.2	112.3	0.95	1.09	107
20	95.5	18	3	100.7	117.5	1	1.07	110
21	96	3	0.5	97.2	111.5	0.96	1.12	104.5
22	97	5	0.3	99.5	111	1.45	1.13	109.5
23	84	8	1.5	94.4	112.3	0.92	1.15	106

D_{max}: Maximum dose; D_{mean}: Mean dose; CI: Conformity index; HI: Homogeneity index; PTV: Planning target volume; DVH: Dose volume histogram; Group A: More number of beams

the pectoralis muscle, chest wall muscles, and ribs and excluded the outermost 3 mm from the superficial skin surface. The heart was defined as all visible myocardium, from the apex to the right auricle, atrium, and infundibulum of the ventricle. The pulmonary trunk, root of the ascending aorta, and superior vena cava were excluded.[18]

Plan analysis

All the patients underwent two treatment plans, each differing from the other regarding the number of beams. The two plans included group (a), which represented more number of beams, and group (b), representing fewer beams. In each plan, the dosimetric parameters were calculated.

The plans were assessed via analysis of dose volume histogram (DVH). In PTV, the average doses and values of $V_{105\%}$, $V_{110\%}$, and $V_{95\%}$ (the percentage of the PTV received several times at minimum 105, 110, and 95% of the target dose), maximum dose (D_{max}), and mean dose (D_{mean}) were reported. The D5% (minimum dose to 5% of the PTV) was also registered. CI can be estimated from the value of BV95 %. HI can be measured based on the estimated value of D5% besides D95%.[12] The definitions below were used to estimate the CI and HI values. When these values are close to 1, the conformal coverage is better:

CI=(BV95%/PTV volume) (1)

BV 95%=(volume of the body with95% isodose of the target dose):HI=$D_{5\%}/D_{95\%}$ (2)

($D_{5\%}$=minimum dose to 5% of the PTV, $D_{95\%}$=minimum dose to 95 percent of the volume).

The irradiated dose to OARs can be evaluated through measuring the mean dose and V YGy (volume of OAR receiving Y Gy), which depend on each organ. The constraints for the lung are V20 less than 30%-35% or V5 less than 60% in conventional fractionated radiotherapy.[18-20] The V25 Gy, D_{mean} for the heart, and minimum and maximum dose were also compared. Differences were reported to be statistically significant at $P < 0.05$.

Table 2. PTV data obtained from the dosimetric parameters of group (b)

Patients Group B	$V_{95\%}$	$V_{105\%}$	$V_{110\%}$	$D_{mean\%}$	$D_{max\%}$	CI	HI	D5 (%)
1	88.5	20	4	102.90%	114.20%	2.62	1.16	105
2	93	16	6	105.5	118.9	4.6	1.22	110
3	81.85	6	5	102.9	114.2	1.23	1.07	102.5
4	81.35	7	5	96.40	109.90	3.5	1.33	105
5	94	30	7	96.00	111.5	0.96	1.11	106
6	94	12	6	95.10	105.90	0.94	1.24	105
7	98	18	3	99.2	109	0.98	1.24	112
8	97	4	1.5	96.60	108.1	0.98	1.72	106
9	93	28	2.5	100.7	114	0.85	0.99	97
10	94	12	2	99.90	109.2	0.94	1.13	107
11	88	14	4	94	104	0.88	1.16	104
12	88	6	1	90.60	110.30	0.88	1.17	105.5
13	96	16	8	102	116	0.96	1.01	99
14	84	9	2	95.10	113.40	0.84	1.14	107
15	92	31	5	100.80	116.4	0.95	1	110
16	96	5	0	98.5	109.3	0.97	1.09	104
17	97	6	6	105	120	0.97	1.18	112
18	89	14	5	98.6	118.4	0.91	1.54	110
19	97	7	2.7	99.30	108.5	0.97	1.1	105.5
20	95	9	0.8	94	113.3	0.96	1.16	111.5
21	94.5	2	0	97.3	112.2	0.95	1.17	111
22	98	7	0	97.6	109.3	1.52	1.09	107
23	82	2	1	93.9	112.9	0.89	1.29	105

D_{max}: Maximum dose; D_{mean}: Mean dose; CI: Conformity index; HI: Homogeneity index; Group B: Less number of beams; PTV: Planning target volume

Results

DVH of PTV

The estimation of histogram between dose and PTV with the two techniques was carried out.

Optimized plans were done for all patients in order to ensure that 95% of the target volume "PTV" was covered with 95% of the dose. The obtained data of dosimetric parameters are shown in tables 1 and 2, where table 1 depicts more numbers of beams and table 2 illustrates fewer ones. The student t-test was used for comparing the values of PTV and OAR for both two techniques. Differences were reported to be statistically significant at $P< 0.05$.

All the results representing the following parameters $V_{105\%}$, $V_{95\%}$,$V_{110\%}$, D_{mean}, D_{max}, CI, HI and D5% are shown in figures 1 (a, b, c, d, e, f, g, and h), respectively. These figures illustrated that the dose coverage related to all PTV dosimetric parameters was nearly the same after changing the number of beams. Table 3 also emphasizes that there was almost no difference between higher and lower number of beams regarding all the previous parameters. It further summarizes the compared coverage or distribution of PTV for both the increased and decreased number of beams for the DVH of each patient. The dose distribution is also shown in figure 2 (a, b), where (a) shows the dose coverage for patients with three fields and (b) indicates the same patients with two fields.

For OARs

Concerning statistical analysis, the means of normal tissue, lung, and heart were also almost the same, which is shown in tables 4 and 5. The statistical analyses of heart were done for only 11 left-sided patients. The complication of normal tissue in group (b) of heart is lower than in group (a) because Mean ± standard error of mean (SEM) = 14.07 ± 1.416 and 9.773 ± 1.685 in groups (a) and (b), respectively, with a *P* value of mean dose for heart = 0.0649 and for lung = 0.6561, meaning there is no significance here either. These results are indicated in table 6 and in figure 3 (a-d).

Table 3. The compared coverage of PTV parameters for plans (a) and (b)

	Plan (a) increased number of beams	Plan (b) reduced number of beams	*P* value
PTV parameters	**Mean ± SEM**	**Mean ± SEM**	
$V_{95\%}$	91.96 ± 1.056	91.79 ± 1.125	0.9152
$V_{105\%}$	12.09 ± 1.353	12.22 ± 1.775	0.9537
$V_{110\%}$	2.774 ± 0.3702	3.370 ± 0.5016	0.3446
D_{mean}	98.10 ± 0.6974	98.34 ± 0.7935	0.8156
D_{max}	112.1 ± 0.6360	112.1 ± 0.8590	0.9516
CI	1.394 ± 0.2139	1.315 ± 0.1988	0.7888
HI	1.104 ± 0.05589	1.187 ± 0.03461	0.2127
D5%	106.9 ± 1.254	106.4 ± 0.8069	0.7282

PTV: Planning target volume; SEM: Standard error of mean; D5 (%): Minimum dose to 5% of the PTV volume; Plan A: More number of beams; Plan B: Less number of beams; CI: Conformity index; HI: Homogeneity index; D_{max}: Maximum dose; D_{mean}: Mean dose

Discussion

Based on the statistical analysis of all patients, the dose coverage is not dependent on the number of beams because the *P* values of all PTV parameters were > 0.05, which indicates no significant difference. Also, the Mean ± SEM for all PTV parameters was nearly the same.

The mean of $V_{95\%}$ was higher, though not significantly, after increasing the number of beams and the target was more covered (*P*=0.9152). Our results are similar to those of Safae Mansouri et al. who used two tangential fields in 3D conformal radiation therapy (3DCRT) and five to seven fields in intensity-modulated radiation therapy (IMRT) technique. In their study, the difference of $V_{95\%}$ was not significant (*P*=1) although the IMRT was more advanced.[21]

In the study of Rongsriyam et al, the mean of V_{110} from the conventional tangential technique was 3.28%, which is in line with our results (3.370 ± 0.5016).[23] This enables medical physicists to reduce the number of beams.[22]

According to the guidelines of RTOG, the ranges of the CI values have determined the conformation quality because obtaining a value of 1 is barely achievable.[23] If the CI is positioned between 1 and 2, it complies with the treatment plan. As observed in tables 1 and 2, all the values approached 1, where the mean values were 1.394 ± 0.2139 and 1.315 ± 0.1988 for both groups after increasing and decreasing the number of beams, respectively.

The study of Zhou et al. reported that the CIs of both IMRT (more number of fields) and 3D-CRT (less number of fields) had significant values (*P* < 0.05) due to the more advances in IMRT compared with 3D-CRT; the present study had no significant CI value, but it is more conformal

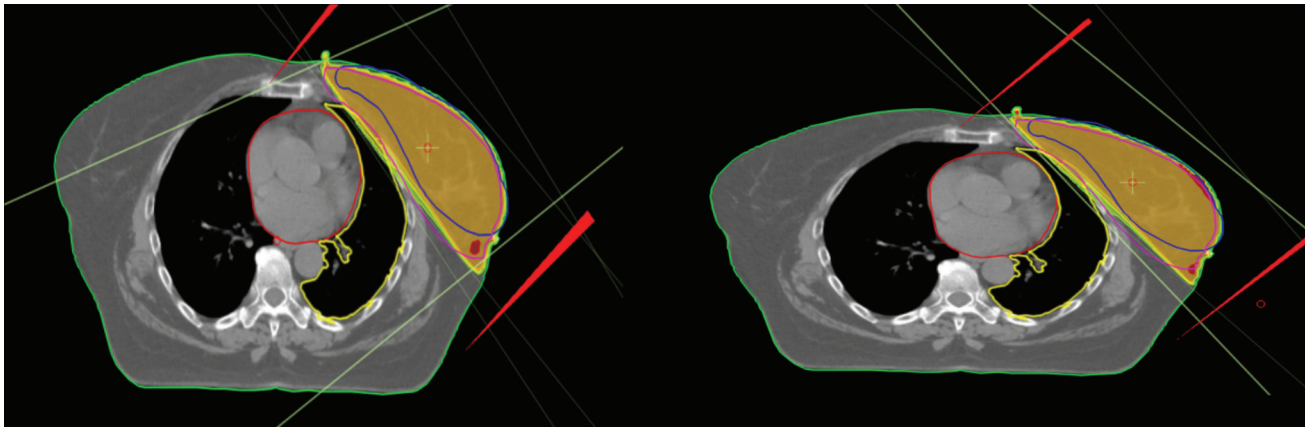

Figure 2. (a) This figure represents the patient planned with three fields. The orange color represents the color wash of 95% of isodose and red color is 110 % of isodose; (b) is the same patient planned with two fields, the orange color is the color wash of 95 % of isodose and the red color is 110 % of isodose.

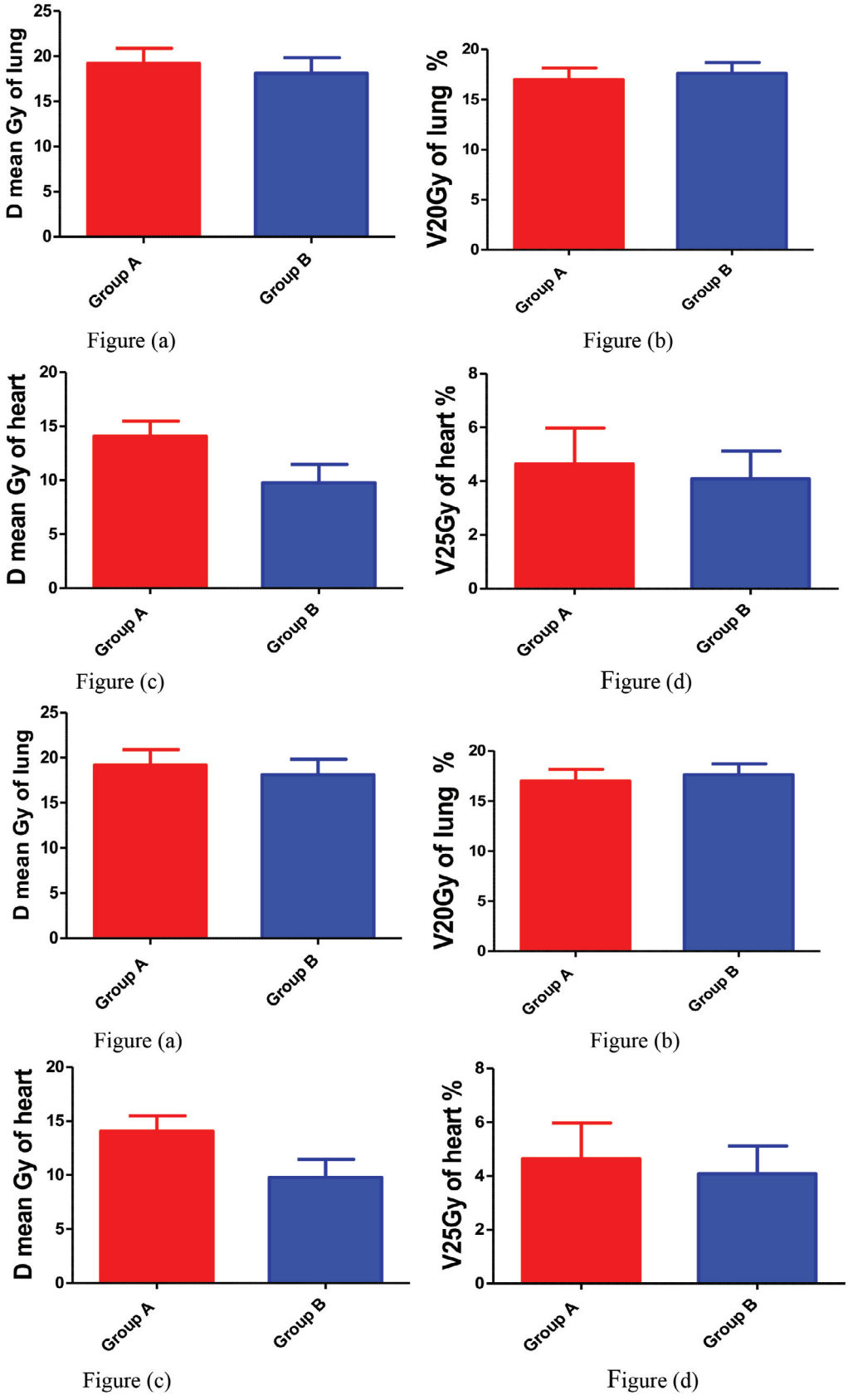

Figure 3. (a, b, c, and d). The results obtained from the DVH of normal tissues and their statistical analysis. The red bars represent the plans related to more number of beams and the blue bars indicate fewer beams. D_{mean} Gy is the mean dose that heart and lung receive.
DVH: Dose volume histogram; D_{mean}: Mean dose

Table 4. Group (a): OAR dosimetric parameters for each DVH group for the normal tissue

Patients group (a)	D_{mean} Gy of lung	V20 Gy of lung %	D_{mean} Gy of heart	V25 Gy of heart %
1	8.201	19	Right side breast	
2	27.90	19	14.6	10
3	23	19	Right side breast	
4	13.7	20	Right side breast	
5	8.201	23	Right side breast	
6	4	6	Right side breast	
7	5.5	6	5.5	3
8	22	21	Right side breast	
9	17.5	17	10	8
10	24.3	21	12	7.5
11	21	21	Right side breast	
12	22.2	21	Right side breast	
13	34	23	Right side breast	
14	18.60	20	Right side breast	
15	26.80	21	14.90	0.4
16	26.80	17	Right side breast	
17	19.30	5	15.9	0
18	17.40	12	14.80	0.2
19	25.5	18	19.10	3
20	29.70	19	8.6	0
21	11.7	13	18.5	7
22	11.5	10	20.90	12
23	22.7	20	Right side breast	

V25Gy: Volume of heart received 25Gy; V 20 Gy: Volume of lung received 20Gy; D_{mean}: Mean dose; Plan A: More number of beams; Plan B: Less number of beams; OAR: Organs at risk; DVH: Dose volume histogram

than that of Zhou et al.

The HI of their study was 1.14 ± 0.02 and 1.17 ±0.04, respectively, which is consistent with the present study; however, there were significant differences ($P < 0.05$) in their study due to the differences in both techniques.[24]

For OAR such as lung, the Mean ± SEM was 19.20 ± 1.690 and 18.11 ± 1.722 for both higher and lower number of beams, respectively. This indicates that the complication was nearly the same in both groups and the P= 0.6561 had no statistical significance. This also occurred in the rest of the constrains, such as V5Gy (%), V20Gy (%) of lung, and V25Gy (%) of heart.

The study of Imjai Chitapanarux et al. is in line with the present study regarding the mean value of lung with fewer beams (16.4±2.8), which is close to the current study (18.11 ± 1.722) and slightly beyond the value of the more number of fields.[25]

Yorke et al. (2002) and Kwa et al. (1998) also showed that radiation pneumonitis was related to a high mean lung dose, so the mean dose to the lung should be as low as possible.[26] In our study, the lower number of fields showed lower mean lung doses.

Narudom Supakalin et al. (2018) reported that the mean V20Gy to ipsilateral lung from radiotherapy plan of breast cancer was 17.09%, which is in accordance with this study concerning both increased and decreased number of fields.[26]

Based on our results, the reduction in the number of beams decreased, though not significantly, the mean heart doses from 14.07 ± 1.416 to 9.773 ± 1.685(P = 0.0649).

In the present study, the difference in the number of beams was only 2 in each patient. This confirms that there was no effect when the differences between each plan were small, such as 1 to 3; thus, medical physicists must opt for the lower number to avoid any error during the treatment sessions.

Fewer beams means lower scattered radiation, thereby saving more time for patients and treatment centers as well as increasing the chances of treatment for patients.[27] The values of normal

Table 5. Group (b) OAR of the obtained dosimetric parameters

Patients group (B)	D_{mean} Gy of lung	V20 Gy of lung %	D_{mean} Gy of heart	V25 Gy of heart %
1	8.209	20		Right side breast
2	28	20	13	9.5
3	23	20		Right side breast
4	11.5	20		Right side breast
5	8.209	21		Right side breast
6	3.8	7		Right side breast
7	6	6	5.5	3.5
8	21.7	23		Right side breast
9	18	17	10	8
10	24.5	22	13	7.3
11	23	20		Right side breast
12	22	22		Right side breast
13	34.5	21.5		Right side breast
14	18.90	20		Right side breast
15	19.9	21	6.10	0.2
16	27.5	18		Right side breast
17	8.80	9	4.7	0
18	12.70	9	6.20	1.5
19	24.80	19	18.60	3.5
20	26.10	21.5	0.5	0
21	10.90	11.5	13.60	6.5
22	12	17	16.30	5
23	22.6	20		Right side breast

V25Gy: Volume of heart received 25Gy; V 20 Gy: Volume of lung received 20Gy; D_{mean}: Mean dose; Plan A: More number of beams; Plan B: Less number of beams; OAR: Organs at risk

tissue in both plans indicated that the complication was almost the same after increasing the number of beams, meaning toxicity was the same in both cases.

Our study was done only in breast cancer patients, so future research is to focus on other types of cancer with a larger number of patients. We studied the dosimetric effect only; hence it is recommended that the biological effect be studied as well.

Conclusion

In our study, the number of beams had no significant effect on the dose coverage, HI, CI, and the normal tissue; therefore, it is extremely important for medical physicists to carry out an optimized plan, so as to achieve 95 % of dose to the target without exceeding the tolerance of normal tissue regardless of the number of beams. This can be time-saving for medical physicists trying to increase the number of beams to obtain the optimum coverage.

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Table 6. Compared doses of organs at risk using dosimetric parameters

	Plan (a) increased number of beams	Plan (b) reduced number of beams	*P* value
Whole Lung	**Mean ± SEM**	**Mean ± SEM**	
D_{mean} Gy	19.20 ± 1.690	18.11 ± 1.722	0.6561
V5Gy (%)	106.9 ± 1.254	106.4 ± 0.8069	0.7282
V20Gy (%)	17.00 ± 1.152	17.63 ± 1.086	0.6924
Heart			
D_{mean}	14.07 ± 1.416	9.773 ± 1.685	0.0649
V25Gy (%)	4.645 ± 1.328	4.091 ± 1.033	0.7452

Plan A: More number of beams; Plan B: Less number of beams; SEM: Standard error of mean; D_{mean}: Mean dose

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Conflict of Interest

None declared.

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