



Dosimetric Study of Hybrid Intensity Modulated Radiation Therapy Treatment Plan with Flattened Filter Free Photon Beam for Carcinoma of Breast: Treatment Planning Study

Subhas HALDAR,^{1,2} Archana DIXIT,³ Biplab SARKAR⁴

¹Department of Physics, GLA University, Institute of Applied Science and Humanities, Mathura-India

²Department of Radiotherapy, Saroj Gupta Cancer Centre and Research Institute, Kolkata-India

³Department of Mathematics, GLA University, Institute of Applied Science and Humanities, Mathura-India

⁴Department of Radiation Oncology, Apollo Multispeciality Hospital, Kolkata-India

OBJECTIVE

This study assesses the use of the flattening filter free (FFF) photon beam in hybrid treatment planning for breast carcinoma and the various dosimetric indices of planning target volume (PTV) and organs at risk (OARs).

METHODS

We selected 15 female breast cancer patients treated with Field-in-Field technique to a dose of 40 Gy/15 fractions. Retrospectively, hybrid intensity-modulated radiation therapy (IMRT) plans with FF, and FFF photon beams were created. To make the hybrid IMRT plan, a planning weightage of 60% (3DCRT): 40% (IMRT) was applied. The dose-volume histograms (DVH) were assessed for various dosimetric indicators for PTV and OARs.

RESULTS

A UDI scoring of 1.090 ± 0.023 and 1.078 ± 0.024 was observed between 6FF_Hybrid and 6FFF_Hybrid treatment plans with $p < 0.05$. ID for I/L lung was 6387 ± 1658.51 (Gy-L) and 6347.056 ± 1643.41 (Gy-L) in 6FF_Hybrid and 6FFF_Hybrid IMRT plan ($p = 0.05$), respectively. ID value to heart was 2272.52 ± 1086.63 (Gy-L) and 2212.40 ± 1059.49 (Gy-L) in 6FF_Hybrid and 6FFF_Hybrid IMRT plans ($p > 0.05$), respectively. The beam on time (BOT) values of 0.882 ± 0.08 (6FF_Hybrid) and 0.5436 ± 0.07 (6FFF_Hybrid) were reported.

CONCLUSION

Hybrid IMRT planning with an FFF photon beam offers comparable target coverage, conformality, and homogeneity with greater OAR sparing and faster treatment time.

Keywords: Ca-breast; flattened filter free; hybrid plan; intensity-modulated radiation therapy; radiotherapy.

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INTRODUCTION

The most common cancer in women and the main cause of cancer death in women is breast cancer.[1] In several randomized clinical trials, it has been shown

that adding chest wall and regional lymph node irradiation after modified radical mastectomy improves disease-free survival (DFS) and overall survival (OS) in breast cancer patients with positive axillary lymph nodes.[2-4] Since 1990, the death rate from breast

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Subhas HALDAR

Department of Physics,

GLA University, Institute of Applied Science and Humanities,
Mathura-India

Department of Radiotherapy,

Saroj Gupta Cancer Centre and Research Institute,

Kolkata-India

E-mail: subhasdmp@gmail.com

cancer has decreased in industrialized nations due to better detection methods and a combination of radiation, chemotherapy, and surgery.[5,6] Radiotherapy (RT) is a crucial adjuvant therapy for patients undergoing breast-conserving surgery or with a high risk of recurrence after a modified radical mastectomy. Numerous radiation theories and mechanisms have evolved throughout time. Tangential opposing fields with hard wedge filters are used in static three-dimensional radiotherapy in conventional radiation therapy (3D-CRT). To give more uniform and conformal dose distributions for the target volume (PTV), two modern dynamic irradiation techniques, volumetric modulated arc therapy (VMAT) and intensity-modulated radiation therapy (IMRT) have been developed.[7–9] IMRT has outperformed three-dimensional conformal radiation therapy in several locations, including the head and neck, central nervous system, lung, and prostate (3DCRT). Using multileaf collimators, IMRT regulates fluence and breaks a beam into tiny beamlets to provide the best radiation to the target while preserving vital organs. In the event of chest wall radiation, the lungs and heart remain the two most important vital organs.

With high accuracy, IMRT concentrates radiation on the breast tumor and modifies the radiation beams' intensities, sparing the surrounding healthy tissue. With IMRT, each radiation dosage may be precisely adapted to the breast tumor's geometrical form.[10] On the other hand, because of increased low-dose exposure and more monitor units (MU), dynamic radiation techniques may promote the development of secondary tumors.[11] To maximize the advantages of static and dynamic radiation treatments, Mayo et al.[12] suggested a composite technique combining 3DCRT and IMRT, dubbed hybrid IMRT (H-IMRT). Traditional open fields and IMRT fields computed through inverse treatment planning optimization are combined in a hybrid IMRT. Our previous research demonstrated that the hybrid IMRT plan provided equivalent target coverage and minimal dosage to neighboring OARs.[13] The enhanced dosimetric potential of flattening filter free (FFF) beams has been the subject of several articles.[14,15] Reports on the impact of the FFF beam on breast radiation may be found in many articles.[16–18] Published results [13,19–21] show that 3DCRT is a good base-dose plan for breast RT ideas that use a flat beam of photons.

The current research uses the 3DCRT with the FF photon beam as the base plan and incorporates the FFF photon beam into the hybrid IMRT treatment plan. This research aims to evaluate the hybrid IMRT treatment plan using FF and FFF photon beams. In addition,

a novel idea known as the Unified Dosimetry Index (UDI) was put forth by Akpati et al.[22]. The UDI, used to rank the designs, was used to assess the plans using different dosimetric indices. Full uniform dose coverage, flawless target fit, and a gradual fall-off dosage beyond the target are all characteristics of a great plan.[23–25] The four dosimetric indicators, coverage index (C), conformity index (CI), homogeneity index (HI), and gradient index (GI), as well as the UDI rating, are all taken into account. It was recommended to have the lowest possible UDI score.

MATERIALS AND METHODS

Patient Simulation and Target Delineation

Fifteen female patients with infiltrating ductal carcinoma of the left breast were chosen for this study. Their primary diagnosis was left breast cancer with lymph nodes in the supraclavicular and axillary regions (SCL). All patients were treated for 15 fractions with a Field-in-Field (FiF) treatment plan with a daily dose of 2.67 Gy.

All patients were immobilized in the head first supine position and scanned in a Siemens CT Scanner with a 3 mm slice thickness. A Carbon Fiber breast board was used to immobilize the patients, and their left arms were lifted above their heads to keep them out of the treatment field. After the planning CT was finished, digital imaging and communication in medicine (DICOM) pictures were uploaded to the Eclipse treatment planning system (version 16.1, Varian Medical Systems, USA). The body outlines the ipsilateral lung (IL), contralateral lung, contralateral breast, heart, spinal cord, and planning target volume (PTV), as well as the gross tumor volume (GTV), clinical tumor volume (CTV), and PTV, were developed. The GTV, or GTV, is the total lumpectomy cavity that can be detected using surgical clips implanted after surgery. The CTV, PTV, and organs at risk (OARs) were created using the RTOG protocol. The CTV was defined by a three-dimensional uniform 1.5 cm margin expanded in all directions surrounding the GTV. However, it had to fit within 5 mm of the external contour and up against the main muscle.

Treatment Planning

Eclipse treatment planning system (TPS) V16.1 (Varian Medical Systems, USA) was used to generate the hybrid plan for vital beam linear accelerator (LINAC) equipped with 120 micro leaf controllers (MLC). For each patient, hybrid IMRT plan with 6MV FF photon beam (hybrid-FF) and FFF photon beam (hybrid-FFF) were created. Both the Hybrid plans are optimized by

Table 1 Treatment planning objective and dose constraints

Organ	Volume	Dose (Gy)
PTV chest wall	$V_{95\%} \geq 95\%$. Max point dose 107%	
C\L breast	Max point dose ≤ 3.86 Gy, $D5\% \leq 1.86$ Gy	
Spinal Cord	Max dose	35Gy
Heart (For left breast)	V_{20Gy}	$\leq 25\%$
	V_{10Gy}	$\leq 30-35\%$
	Mean	≤ 5 Gy
I\L Lung	V_{20Gy}	$\leq 25-30\%$
	V_{10Gy}	$\leq 35-40\%$
	V_{5Gy}	$\leq 50-55\%$
C\L Lung	V_{5Gy}	$\leq 10\%$

PTV: Planning target volume; C\L: Contralateral; I\L: Ipsilateral; Gy: Gray; Vxx: Volume received by xx dose in Gy

keeping the 3DCRT treatment plan as a base. Please put the photograph of all the plans described in this paper. The 3DCRT plan had two coplanar open tangential fields that passed via an isocenters axially at the lung-PTV interface and craniocaudally at the center of the PTV (photograph, please). With collimator angles of 0° , the gantry angles were calculated based on the PTV curvature, heart, and IL involvement. These tangential fields were extended 2.5 cm outside the body to account for the breast setup mistake. The analytical anisotropic algorithm (AAA) was used for volume dose calculation using a 2.5 mm dose grid matrix. All 3DCRT plans were normalized to deliver prescription doses to PTV mean. Two 3D-CRT and 2 IMRT beams are combined in hybrid IMRT planning. Plans for hybrid IMRT were created in two steps. Two tangent open beams of 6 MV photon beam is used to conform the breast PTV make up step one. With a 60% beam weightage, doses were computed for the tangent fields. The 3DCRT plan was used as the base plan while optimizing an IMRT treatment plan with 6 MV Photon beam with a similar beam angle. The fluence was computed for the IMRT field. Step 2 involved copying the 3DCRT beam to the IMRT plan and calculating the final dose along with 2 open tangent field calculated in step 1. A hybrid plan consists of 3DCRT and IMRT plan in a 60:40 ratio. All plans were normalized to achieve mean PTV doses equal to prescribed dose. Similar methodology was involved in the development of hybrid IMRT plan with FFF photon beam. Hybrid-6FF and hybrid 6FFF treatment plan is developed with 6 MV FF and 6MV FFF photon beam, respectively. Hybrid 6FFF treatment plan consists of 3DCRT plan with 6MV FF photon beam and IMRT plan with 6MV FFF photon beam. Photon optimizer (PO) was used

for inverse treatment plan optimization. A leaf motion calculator was used to convert the fluences into dynamic MLC sequences, and final dose computation was performed with the AAA algorithm. During Inverse optimization, dose constraints listed in Table 1 were utilized. Both hybrid IMRT plan uses the same optimization parameter and dose penalty.

Planning Evaluation Indices

The treatment plans can be evaluated qualitatively by performing a visual slice-by-slice examination using isodose line distribution. A qualitative assessment is required for treatment plans containing hot and cold areas. Dose volume histograms (DVH) were all included in the quantitative analysis. To assess the dose to various structures in various schemes, DVH was developed. The dose-volume parameters D98% (minimum dose received by 98% of PTV volume) and D2% (maximum dose received by 2% of PTV volume) were analyzed for PTV as per the International Commission on Radiation Units and Measurements (ICRU) report 83.[26] DVHs were used to calculate various dosimetric indices doses for PTV and OARs and to compute the integral doses for the OARs.

Statistical Tools and Analysis

The statistical analysis was conducted using IBM Corporation's Statistical Software Package for the Social Sciences (SPSS) version 17.0. To find the mean and median, descriptive analysis was used. To compare the Hybrid FF plan to the Hybrid FFF plan IMRT, a paired t-test was used. For statistical significance, $p=0.05$ was used. 100% of the PTV receiving the prescribed dose is referred to as dose coverage. It is a metric that indicates how effectively the prescribed dose covers the PTV. It is acceptable to have a plan that covers 92% of the required dose.[27]

Table 2 Patient demographic, tumour staging, PTV and OARs Volume characteristics

Patients	Tumour staging	Age (years)	PTV volume (cc)	Left lung volume (cc)	Right lung volume (cc)	Heart volume (cc)	C/L breast volume (cc)
1.	III	65	294.4	830.1	900	640.2	506.7
2.	III	45	109.1	1114.1	1100.3	352.5	1500
3.	IVB	31	252.5	1107.4	1104.8	406.8	927.8
4.	IV	58	380.5	689	904.5	480.1	352.8
5.	IV	61	263.4	1054.4	1290.8	635.7	628.1
6.	IIIB	37	399.2	701.23	770.5	535.4	1021.1
7.	IIIC	47	213.2	654.5	770.9	358	308.7
8.	IVB	59	300.29	758.9	842.8	430.1	985.4
9.	IIIC	37	264.7	929.5	970.2	362.2	1161
10.	IIB	52	530.9	790.69	850	523	841.2
11.	IIB	53	468.1	768.2	1069.5	768.5	560.3
12.	IIIC	65	391.8	716.3	925.8	437	780.3
13.	IV	48	279.5	839.1	925	730.6	698
14.	III	45	310	716.4	811.6	440.1	840.6
15.	IIIB	59	239.6	738	951.9	439.9	739.1
Average		50.8	313.15	827.19	945.91	502.67	790.07
SD		10.56	105.81	153.50	143.39	133.91	310.68
Range		31–65	109.1–530.9	654.5–1114.1	770.5–1290.8	352.5–768.5	308.7–1500

PTV: Planning target volume; OARs: Organs at risk; CL: Contralateral; cc: Cubic centimetres SD: Standard deviation

Coverage index (C) = PTV_{PI} / PTV

Where PTVPI is the PTV getting the prescribed isodose (PI), as stated in ICRU Report No. 62,[28] RTOG recommended the CI in 1993. The relationship between the volumes of the reference dosage and the target dose is displayed.

Conformity index (CI) = V_{IR} / TV

Where V_{IR} is the reference dose volume, and TV is the total target volume.

To assess the level of conformity, CI value ranges have been defined. The ideal CI value is 1, according to the theory. The treatment is deemed to comply with the treatment plan if the CI is between 1 and 2. RTOG proposed guidelines for routinely evaluating plans on several factors and HI in 1993. The dosimetric analysis of the treatment plan served as the foundation for developing the HI concept.[29]

Homogeneity Index (HI) = I_{max} / RI

I_{max} is the target's maximal isodose, and RI is the reference isodose.

If HI value is $0 < HI \leq 2$: No Violation,

$2 < HI \leq 2.5$: A minor violation,

$HI \geq 2.5$: Major violation.

The dose GI can compare plans that are similar in conformance but have distinct dose gradients. GI evaluates the quality of this dose gradient. The dose GI can compare plans that are similar in conformance but have

distinct dose gradients. The ratio of the volume receiving the PI line to the volume receiving half of the recommended isodose line is known as the dose GI.[25]

Dose gradient index (GI) = $D_{50\%} / D_{100\%}$

Where $D_{100\%}$: Volume of the prescribed dose.

$D_{50\%}$: Volume of half the prescribed dose.

All four parameters stated above are included in the UDI. It is an effective tool for determining the best treatment plan strategy. The CI, HI, GI, and C are the ideal parameter to evaluate treatment plan quality. Changes can influence UDI's value in any of the four components. A UDI value near 1 is preferable, while a greater UDI value is not considered.

$UDI = CN \times CI \times HI \times GI$

RESULTS

Table 2 summarizes the patient's characteristics. The patient's age ranged from 31 to 65 years, with a mean of 50 ± 10.56 years. The average PTV volume was 313.15 cc with a standard deviation of 105.81 cc. The PTV volume ranged from 109.1 cc to 530.9 cc. Right, and left lung volumes were 827.19 ± 153.50 cc and 945.91 ± 143.39 cc, respectively. The heart and contralateral (C/L) breast volumes were 502.67 ± 133.91 cc and 790.07 ± 310.68 cc, respectively.

Table 3 Illustrates the dosimetric parameter for the planning target volume (PTV) in the intensity modulated radiation therapy (IMRT) plan for 6X_FF (Flattened Filter) & 6X_FFF (Flattened Filter Free)

Variables	Treatment plans		p
	6FF_Hybrid (Mean±SD)	6FFF_Hybrid (Mean±SD)	
Coverage index (C)	0.950±0.007	0.945±0.013	0.166
Conformity index (CI)	0.970±0.010	0.963±0.021	0.24
Homogeneity index (HI)	1.125±0.026	1.134±0.025	0.22
Gradient index (GI)	0.566±0.034	0.540±0.037	0.022
Unique dosimetric index (UDI)	0.586±0.033	0.557±0.041	0.022

Table 4 Illustrate the dosimetric indices for the Organs at Risk (OARs)

Variables	Treatment plans		p
	6FF_Hybrid (Mean±SD)	6FFF_Hybrid (Mean±SD)	
Lungs V _{5Gy} (%)	27.51±5.02	27.39±5.21	0.31
Lungs V _{10Gy} (%)	21.51±4.59	21.32±4.27	0.3
Lungs V _{20Gy} (%)	17.23±3.54	17.09±3.51	0.31
Lungs mean (Gy)	7.72±1.31	7.67±1.35	0.14
Heart V _{20Gy} (%)	8.06±3.69	7.89±3.59	0.22
Heart V _{10Gy} (%)	10.24±4.10	10.05±4.08	0.18
Heart mean (Gy)	4.29±1.40	4.18±1.41	0.04
C\L breast (Max)	5.81±6.8	4.81±5.46	0.04
C\L (D5%)	0.64±0.33	0.63±0.35	0.99

FF: Flattened Filter; FFF: Flattened Filter Free; SD: Standard deviation; Vxx: Volume received by xx dose in Gy; C\L: Contralateral

Table 5 Show the Comparison of ID, MU and BOT between 6FF_Hybrid and 6FFF_Hybrid IMRT Plan.

Variables	Treatment plans		p
	6FF_Hybrid (Mean±SD)	6FFF_Hybrid (Mean±SD)	
ID (Gy-L)			
Heart	2272.52± 1086.63	2212.40 ± 1059.49	0.1
I/L Lung	6387 ± 1658.51	6347.056 ± 1643.41	0.0028
C/L Lung	101.61 ± 27.07	117.27 ± 30.81	0.0068
Number of MUs	529.14 ± 50.46	761.07± 102.51	0.001
BOT (min)	0.882 ± 0.08	0.5436 ± 0.07	0.001

ID: Integral dose; MU: Monitor unit; BOT: Beam on time; FF: Flattened Filter; FFF: Flattened Filter Free; IMRT: Intensity-modulated radiation therapy; I\L: Ipsilateral; C\L: Contralateral; min: minute

Table 3 shows the different treatment plan quality index comparisons for 6FF_Hybrid and 6FFF_Hybrid treatment plans. The coverage index for the 6FF_Hybrid plan was 0.945±0.013, and for the 6FF_Hybrid treatment was 0.950±0.007 with p>0.05. PTV in the 6FF hybrid plan had a conformity index of 0.970±0.010, whereas the 6FFF Hybrid had a conformity index of 0.963±0.021 with p>0.05. The hybrid IMRT treatment with 6FF and 6FFF photon beams had HI

values of 1.125±0.026 and 1.134±0.025, respectively. In the 6FF_Hybrid and 6FFF_Hybrid treatment plans, an insignificant GI value of 1.050±0.020 and 1.042±0.017 was found (p>0.05). A UDI scoring of 1.090±0.023 and 1.078±0.024 was observed between 6FF_Hybrid and 6FFF_Hybrid treatment plans with p>0.05.

Table 4 illustrates the different volumetric doses to the OARs for the 6FF-Hybrid and 6FFF_Hybrid IMRT plans. V_{5Gy} and V_{10Gy} of the IL were smaller in the 6FF_Hybrid

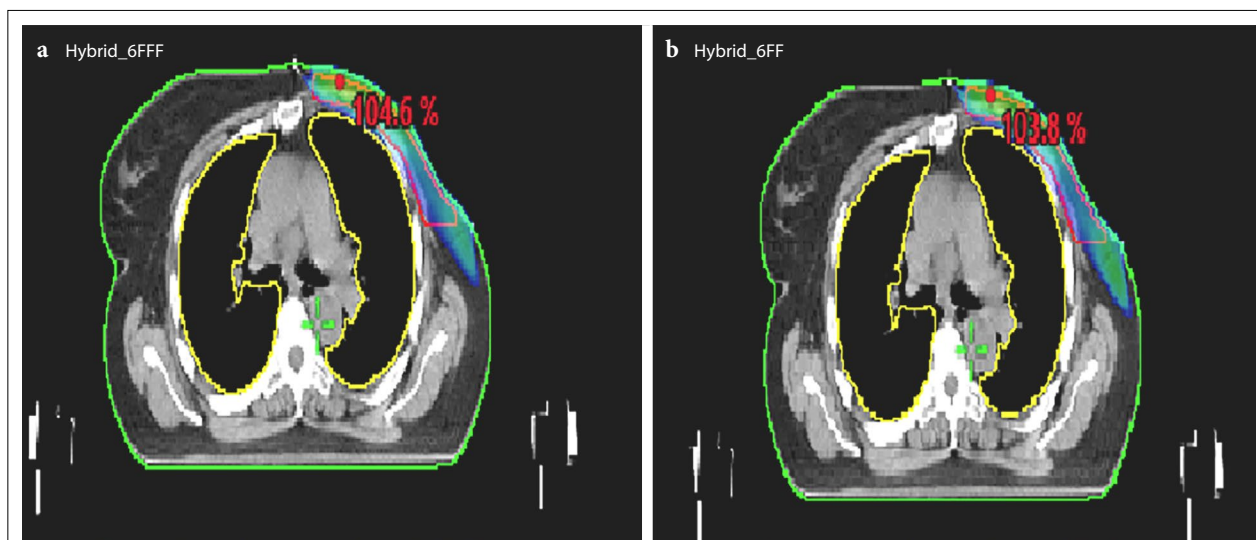


Fig. 1. The color dose wash of 95% of dose distribution of prescribed dose for 6FFF and 6FF Hybrid IMRT plan.
FF: Flattened Filter; FFF: Flattened Filter Free; IMRT: Intensity-modulated radiation therapy.

IMRT plan compared to the 6FF_Hybrid IMRT plan ($p > 0.05$). V_{20Gy} of IL received a lesser dose in 6FF_Hybrid than 6FFF_hybrid IMRT plan ($p > 0.05$). The mean dose of the IL was less in the 6FF_Hybrid IMRT plan than in the 6FFF_Hybrid plan ($p > 0.05$). V_{20Gy} and V_{10Gy} of the heart were reported with smaller radiation doses in the 6FF_Hybrid IMRT plan compared to the 6FFF_Hybrid IMRT treatment plan ($p > 0.05$). Significantly, the 6FFF_Hybrid IMRT plan delivers lower doses of radiation in comparison to the 6FF_Hybrid IMRT plan. The D_{max} of the contralateral breast significantly received reduced doses of radiation on the 6FFF_hybrid plan concerning the 6FF_Hybrid plan. $D5\%$ of contralateral breasts receives an insignificantly lesser dose in 6FFF_Hybrid IMRT compared to 6FF_Hybrid plan.

Integral Doses

Table 5 shows the comparison of integral dose (ID), monitor unit (MU), and beam on time (BOT) between the 6FF_Hybrid IMRT and 6FFF_Hybrid IMRT. ID for I/L lung was 6387 ± 1658.51 (Gy-L) and 6347.056 ± 1643.41 (Gy-L) in 6FF_Hybrid and 6FFF_Hybrid IMRT plan ($p < 0.05$), respectively. I/p breast was reported with ID of 117.27 ± 30.819 (Gy-L) and 101.61 ± 27.07 (Gy-L) in 6FF_Hybrid and 6FFF_Hybrid IMRT plan ($p < 0.05$). ID value to heart was 2272.52 ± 1086.63 (Gy-L) and 2212.40 ± 1059.49 (Gy-L) in 6FF_Hybrid and 6FFF_Hybrid IMRT plans ($p > 0.05$), respectively. The number of MUs for the 6FF_Hybrid and 6FFF_Hybrid IMRT plans was 529.14, 50.46 and 761.07 102.51, respectively, with a significant difference of $p < 0.05$.

The BOT in the 6FF_Hybrid IMRT plan was much lower than in the 6FFF_Hybrid IMRT plan. 6FF_Hybrid and 6FFF_Hybrid IMRT plans have BOT values of 0.882 ± 0.08 and 0.5436 ± 0.07 , respectively ($p < 0.05$).

DISCUSSION

A limited study is available for a Hybrid treatment plan compared with IMRT, 3DCRT and VMAT. [30,31] Numerous studies have compared the IMRT treatment with the FFF photon beam and FF photon beam for the different treatment sites. They have concluded that no significant dose difference was observed between the IMRT treatment plan with FF and FFF photon beam. Figure 1 shows the color dose wash of 95% isodose of prescribed dose for 6FFF and 6FF Hybrid IMRT treatment plan.

Figure 2a shows the CI, C, and HI comparison between the FF and FFF Hybrid treatment plans. Similar results were also observed in our study of Hybrid treatment plans with and without the flattening filter. No significant dose difference was found for PTV target coverage (C, CI, and HI between 6FF_Hybrid IMRT and 6FFF_Hybrid IMRT treatment plan. Figure 2b compares GI and UDI between the FF and FFF Hybrid plans. Higher dose fall is one of the main characteristics of the FFF photon beam, but here in our study, the GI value for a hybrid plan using the FFF photon beam does show how significant the dif-

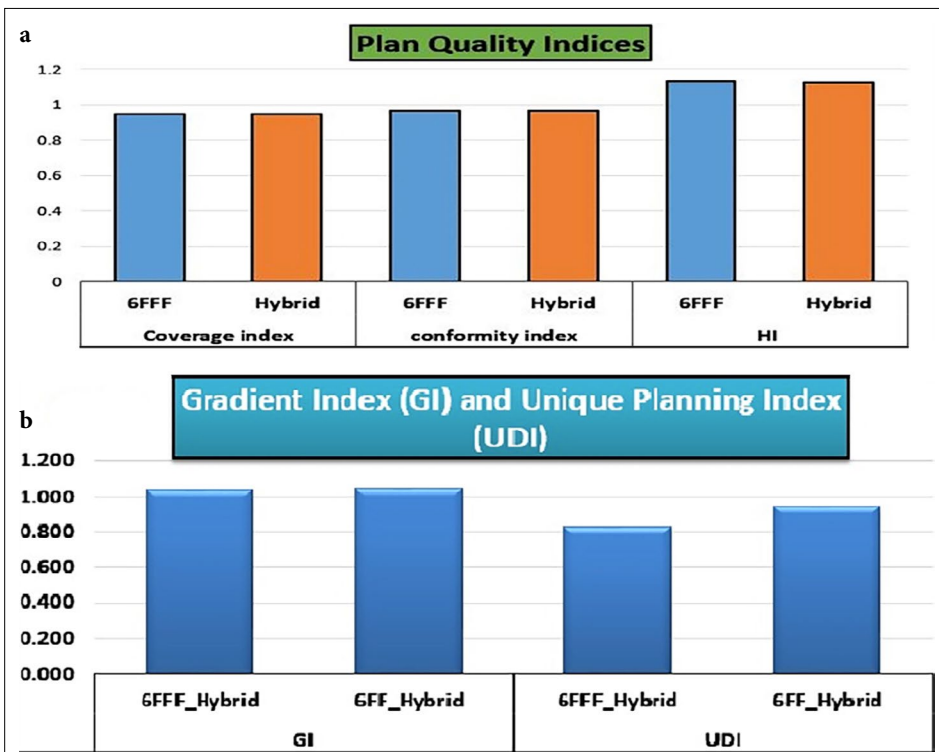


Fig. 2. (a) The comparison of various treatment plan quality Indices and (b) comparison of gradient index and unique dosimetric index between the 6FF_Hybrid and 6FFF_Hybrid treatment plans.
FF: Flattened Filter; FFF: Flattened Filter Free; HI: Homogeneity index.

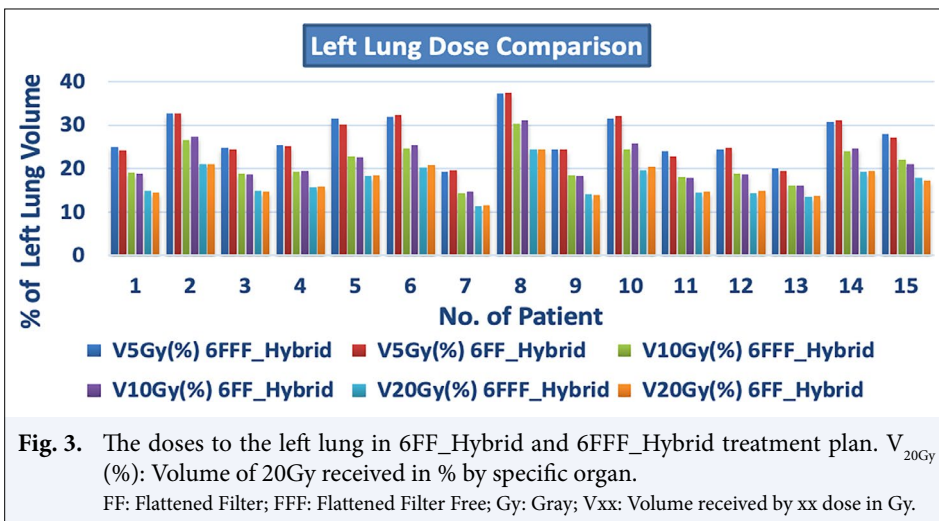


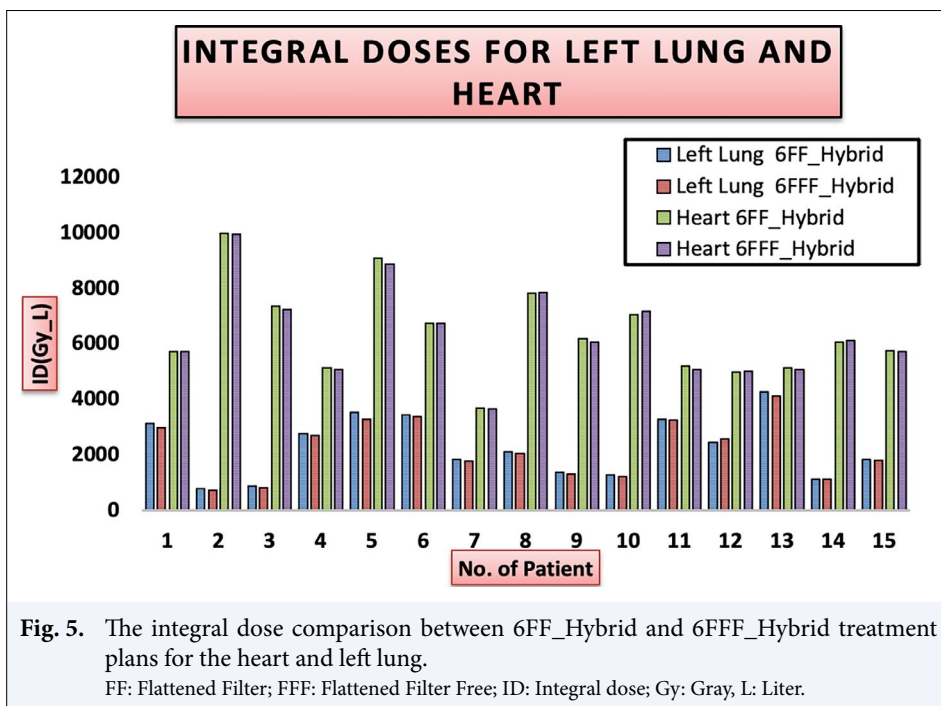
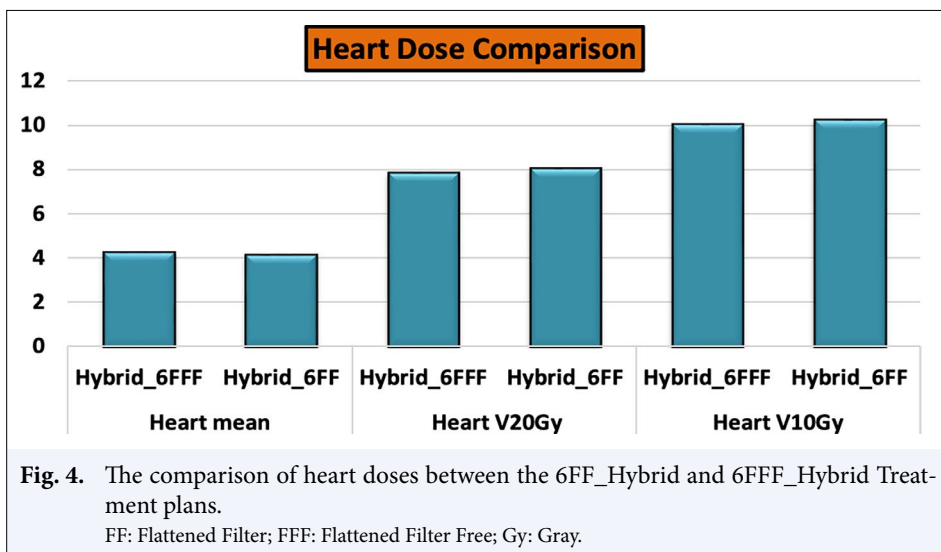
Fig. 3. The doses to the left lung in 6FF_Hybrid and 6FFF_Hybrid treatment plan. V_{20Gy} (%): Volume of 20Gy received in % by specific organ.
FF: Flattened Filter; FFF: Flattened Filter Free; Gy: Gray; Vxx: Volume received by xx dose in Gy.

ference is from that of the FF hybrid plan. Comparing the UDI score, the FFF hybrid plan has a lesser score than the FF hybrid plan. One of the dominating factors in calculating UDI was the GI value.

The fundamental goal of the hybrid technique is to preserve the heart, I/L, C/L lung, and C/L breast

to avoid radiation-induced secondary cancers and long-term consequences (such as heart failure and lung pneumonia).

Figure 3 illustrates the volume of the left lung receiving various doses in the 6FF_hybrid and 6FFF_Hybrid treatment plan. Radiation pneumonitis, which



subsequently develops into irradiated lung fibrosis, can affect patient’s right after irradiation. Clinically severe pneumonitis should be uncommon in breast cancer patients if the V_{20Gy} of the IL is <30%. V_{20Gy} was the lowest in both types of Hybrid plans and achieved the lowest value in the FFF hybrid plan. V_{5Gy} and V_{10Gy} were well below their threshold value, and FFF hybrid attains the lowest volume compared to the FF Hybrid plan.

Another important OARs while treating the ca-breast with radiation therapy is the heart. The Figure 4 shows the comparison of mean dose, V_{20Gy} and V_{10Gy}

received by heart between 6FF_hybrid and 6FFF_Hybrid treatment plan. Evidence from various research indicates that for every additional 1 Gy given to the heart’s normal exposure, the incidence of major coronary accidents rises by 7.4%. [32] The average Dmean to heart was 2.6% lower in the FFF Hybrid plan than in the FF hybrid. Our study achieved the mean dose to heart well below the planning threshold in both planning schemes.

ID is the absorbed dose within the specific organ. The distribution of the ID doses for the heart and

lungs for the 6FF_ and 6FFF_ Hybrid IMRT Treatment Plans is shown in Figure 5. It is typically reported that the ID of IMRT increases as the number of small aperture and monitor units increases. 6FFF_Hybrid plan has more MU than the 6FF_Hybrid plan, but the ID for the heart and left lung was less in the 6FFF_Hybrid plan than the 6FF_Hybrid plan. This could be because of the less scattered dose in the FFF photon beam. Saroj et al.[15] reported similar results. 70% reduction in scattered dose for IMRT planning with FFF photon beam is reported by Cashmore et al.[33]. Another advantageous aspect of the FFF photon beam is the availability of a higher dose rate. IMRT plan with FFF photon beam has more MU than FF IMRT plan. Our finding is consistent with the literature. We have seen a 44% increase in the number of MUs with the 6FFF_Hybrid IMRT plan as opposed to the 6FF_Hybrid IMRT plan. FFF photon beam with a high dose rate will help deliver the higher MU in a shorter time. A 62% reduction is observed in BOT for the 6FFF_Hybrid plan compared to 6FF_hybrid Plan. Lower BOT will help reduce patients' couch time during treatment.

CONCLUSION

The scope of the hybrid treatment plan was expanded with additional benefits by including the FFF photon beam. The FFF photon beam hybrid technique still provides a desirable and acceptable treatment plan. A hybrid IMRT treatment plan with FFF photon beam characteristics spares the OARs better than a hybrid IMRT plan with an FF photon beam, giving patients a higher standard of living. Finally, our study concludes that using an FFF photon beam in a Hybrid IMRT plan for the ca-breast patient will be beneficial due to better OARs sparing, less scattered dose, and faster treatment delivery.

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