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Comparison of Hybrid IMRT Plans for Breast Cancer Utilizing the Variable Ratio of 3DCRT and IMRT Components to Establish an Optimal Plan for Target Coverage with Sparing Lung and Heart

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ABSTRACT

Introduction: Intensity Modulated radiation therapy (IMRT) and Volumetric modulated arc therapy VMAT enhance PTV coverage, compliance, and homogeneity while minimizing heart and ipsilateral (IL) lung exposure. However, they may increase organ at risks (OARs) dosage and require additional MUs, raising cancer recurrence risk. Hybrid treatment planning is ideal for ca-breast treatments without complex treatment planning technique.
Study aims to achieve the optimal ratio of 3DCRT and IMRT treatment plans in the Hybrid IMRT Plan.

Material and Methods: The study involved 15 left-side breast cancer patients selected from our hospital's medical records. Three different planning strategies were created namely 3DCRT, IMRT and Hybrid IMRT plans. Different ratios of 3DCRT and IMRT treatment plans were kept while creating the Hybrid IMRT treatment plans. All treatment plans were made in the treatment Planning system (TPS) Eclipse (Version 16.1, Varian Medical Systems, Palo Alto, CA, USA), with a prescription dose 40.05Gy in 15 fractions.

Results: Hybrid IMRT 80%, 60%, 40%, and 20% had Unique Dosimetric Index (UDI) scores of 0.989 ±0.022, 0.997±0.256, 0.0999±0.026, and 0.9958±0.0291. The hybrid $IMRT_{80\%}$ treatment plan had the lowest Total MU of 497.33±45.36, and V20Gy of Ipsilateral lung was 16.93±3.50%, compared to 17.14±3.39%, 17.51±3.14%, and 17.73±3.0% in $IMRT_{60\%}$, $IMRT_{40\%}$, and $IMRT_{20\%}$. Heart mean dose was lowest in $IMRT_{80\%}$ (4.13±1.47Gy) and increased insignificantly from 4.426±1.344Gy to 4.51±1.344Gy in 3DCRT and $IMRT_{100\%}$.

Conclusion: The present dosimetry analysis recommends that hybrid IMRT should be 80% 3DCRT open field and 20% IMRT plan to spare lungs and heart and cover the planning target volume.

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Introduction

The rising prevalence of breast cancer in emerging nations is a serious public health concern worldwide [1]. While death rates from breast cancer are falling in many industrialized nations, they are expected to rise in many developing countries in the coming years. Consequently, the detection and treatment of breast cancer are of significant concern to doctors worldwide, and it is now imperative that concerted efforts be made to lessen the burden of this illness in the developing world. Radiotherapy after radical mastectomy improves survival rates and reduces cancer recurrence risks for patients with advanced breast cancer [2-4]. Loco-regional radiation (RT) after a mastectomy improves overall survival by 6%, and the incidence of chest wall recurrence is reduced by a factor of 3-4 [5].

Breast RT planning is complicated because breathing may alter the target's size and shape. Because the target volume is shallow at the lung interface, chest wall (CW) and lymph node irradiation are challenging [6]. Cardiac toxicity, pulmonary complications, and the potential of secondary malignancy in the opposite breast are all significant issues with chest wall RT [7-9].

Modern treatment techniques, including intensity-modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT), increase PTV coverage, conformity, and homogeneity while minimizing the dose to the heart and Ipsilateral (IL) lung. Nonetheless, these strategies may increase the proportion of OARs that get a low dose and need additional MUs, raising the risk of recurrent malignancies [10]. Therefore, we need

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more efficient plans for reducing chest wall (CW) irradiation and OAR dose. Towards this goal, Mayo et al. [11] proposed the hybrid IMRT, which combines conventional and IMRT fields for entire breast RT. According to the literature, hybrid techniques are superior for total breast RT [11-14]. However, there has been little published research on using a hybrid approach to CW irradiation, whereas most have shown that VMAT is preferable to IMRT [15,16]. There has yet to be a lot of study into using hybrid IMRT for CW irradiation. By optimizing the combination ratio between 3DCRT and IMRT and simultaneously reducing planning time, this study aims to achieve the optimal dose constraints for ipsilateral lung and heart with fixed coverage to PTV. This approach is a class solution for relatively common treatments because it reliably achieves desirable outcomes while requiring less sophisticated abilities on the part of the treatment planner. We also compared the hybrid plan with the optimum ratio of the hybrid IMRT plan with 3DCRT and IMRT to evaluate the plan quality indices [17] for PTV and compare the doses to the OARs.

Materials and Methods

Fifteen breast cancer patients treated in sequence participated in this dosimetric study. The average age of the patients was 50±13.5 years. These patients were seen at our facility between December 2018 and November 2020. Our multidisciplinary tumour board recommended Adjuvant radiation therapy for all of these patients, as is standard practice for treating breast cancer. Patients lie supine on the CT simulator with an angled all-in-one (AIO) breast set. The patient's arms were abducted to keep the rod near their head. All treatment plans were created in Eclipse (Version 16.1, Varian Medical Systems, Palo Alto, CA, USA). 6 MV photon treatments were delivered using a Varian Vital beam linear accelerator (Version 16.1, Varian Medical Systems, Palo Alto, CA, USA).

Simulation and contouring

Using laser guidance, we correctly positioned the Patient within the CT simulator. The anterior and lateral locations of the patient's head were marked with three fiducials (2 mm diameter balls made of lead) using a laser (approximately in the plane passing through the craniocaudal center of the chest wall or breast). To facilitate the contouring procedure, appropriate wires/markers were placed above the scars resulting from breast surgery or mastectomy. A 3 mm axial CT scan was obtained from the hyoid bone to a point 8 cm below the ipsilateral infra-mammary fold (in the case of conservation) or contralateral infra-mammary fold (in the case of mastectomy). An experienced radiation oncologist delineated the chest wall of each patient and designated it as the planned target volume (PTV). All contours were created in the treatment Planning system (TPS) Eclipse (Version 16.1, Varian Medical Systems, Palo Alto, CA, USA) and then transferred to a regular Eclipse workstation for treatment planning.

Treatment Planning

The Eclipse TPS was used to create treatment plans with a single isocenter located at the CW and supraclavicular lymph node (SCL) intersection. The PTVs (PTVcw + PTV_{SCL}) were given 50 Gy in 25 fractions. The IMRT optimization was carried out using the advanced resolution optimizer (PRO version - III). The final dose was calculated using the Analytical Anisotropic Algorithm (AAA) and a dosage grid matrix of 2.5 mm. The average dosage for the PTVs was adjusted in all plans to meet the target. The dosage goals for both PTVs and OARs are shown in Table 1.

3DCRT Planning

We employed field-in-field planning techniques to develop a 3DCRT treatment plan. The 3DCRT plan was created with the help of 2 tangential 6 Mega voltage (6 MV) Photon beams. To maximize coverage of the PTV and reduce exposure to the ipsilateral lung, heart, and contralateral breast, beam angles and beam weighting were chosen. The Beam angle was optimized for each patient to cover the entire PTV. The Gantry angle ranges from 310° to 315° for the medial field and from135° to 125° for the lateral field. We have added a subfield to achieve the PTV coverage and reduce the region of a hot spot. A single anterior field with a gantry angle ranging from 355° covers the SCF.

Table 1. Dose constraints for planning target volume (PTV) and organs at risk (OARs) used for treatment plans

Organ	Volume	Dose (Gy)
PTV chest wall	$V_{95\%}$ ≥95%. Max point dose less than 110%	
C\L breast	Max point dose≤3.86 Gy , D5%≤1.86Gy	
Oesophagus	Max dose	47Gy
Heart (For left breast)	V_{20}	≤5%
	V_{10}	≤30-35%
	Mean	≤5 Gy
I\L Lung	V_{20}	≤25-30%
	V_{10}	≤35-40%
	V_5	≤50-55%
C\L Lung	V_5	≤10%

I\L=Ipsilateral lung; C\L=Contralateral lung; C\L =Contralateral breast; Gy=Gray; Vxx= Volume received by xx doses in Gy.

IMRT planning

The IMRT treatment plans were created with four Gantry angles spanning from 305° to 130°. The IMRT treatment plan was developed using a 6 MV Photon beam. An IMRT treatment plan was generated using a Photon optimizer (PO). The dosage estimate was calculated using the Analytical Anisotropic Algorithm (AAA) with a dose grid size of 2.5mm. The optimal combination of dosage volume was used to achieve the necessary coverage of the PTV and sparing of the OAR.

Hybrid planning

We made four hybrid IMRT ($IMRT_{Hybrid}$) plans with variable weightage, each with one static conformal and two intensity-modulated beams with the same gantry angle combination. A two-stage process was used to create the hybrid IMRT plans. First, the breast PTV conformed to two tangent open beams with a variable percentage of beam weightage, such as 20%, 40%, 60%, and 80%. Following this, two IMRT beams were optimized, each with the same beam angle. The flow rate was computed. The final dosage was determined, and the IMRT plan was duplicated from the 3DCRT beam in step two. In the hybrid plan, different 3DCRT: IMRT combinations were used, like 80:20 ($3DCRT_{80\%}$: $IMRT_{20\%,}$), 60:40($3DCRT_{60\%}$: $IMRT_{40\%,}$), 40:60 ($3DCRT_{40\%}$: $IMRT_{60\%,}$), and 20:80($3DCRT_{20\%}$: $IMRT_{80\ \%,}$). The mean dose to be delivered was adjusted across all plans to meet the prescribed dose. All four plans included a 0.5cm bolus to provide sufficient dosage coverage at or near the skin's surface. IMRT and Hybrid plans were optimized to achieve the following dose constraints listed in Table 1.

Treatment plan evaluation

Retrospective, IMRT, and Hybrid IMRT treatment plans with different combinations of 3DCRT and IMRT Treatment plans were created and compared with each other. The Cumulative Dose Volume histogram (cDVH) was computed for all the volumes in each of the various planning techniques, and the isodose distribution was used to evaluate each plan. When evaluating plans for PTV, the parameters D98%, D50%, and D2% were considered, where D98% and D2% values represent the dose received by 98% and 2% of the PTV volume, respectively. The "minimum dose" in the PTV is represented by D98%, the minimum dose to 98% of the PTV volume. The "maximum dose" in the PTV is represented by D2%, and the minimum dose to 2% of the PTV volume. D50% is the dose received by 50% of the volume of the target. The mean dose and maximum dose for the heart, ipsilateral lung, and contralateral lung were utilized to evaluate the treatment plan for OARs.

An analysis of the PTV's mean dosage, maximum dose, and lowest dose was conducted using a DVH. Consequently, the Conformity Index and Homogeneity Index were calculated using V95%, Target Volume, D2%, D98%, and D50%. The conformance index, initially introduced by the Radiation Therapy Oncology Group (RTOG) in 1993, is described in Report 62 [17] of the International Commission on Radiation Units and Measurements. The correlation between the target volume (TV) and the volume of the reference dose (VRI) is illustrated.

$$\text{Conformity index RTOG} = \frac{(The\ volume\ of\ the\ reference\ dose)}{The\ target\ volume\ (TV)} \quad (1)$$

C.I. = 1(one) is the ideal value.

Ranges of conformity index values have been developed to assess conformation quality by the RTOG recommendations. If the conformance index is between 2 and 3, the therapy is by the treatment plan; between 2 and 2.5 or between 0.9 and 1, the violation is deemed to be moderate; and when the index value is less than 0.9 or exceeds 2.5, the protocol breach is regarded to be serious. That being said, it's still possible that it's okay.

The International Commission on Radiation Units and Measurements Report 83 [18]. Defines the Homogeneity Index (HI) as

$$\text{Homogeneity Index HI} = \frac{D2\%-D98\%}{D50\%} \quad (2)$$

Doses received by 98%, 2%, and 50% of the PTV volume are denoted by D98%, D2%, and D50%, respectively.

HI= 0 is the ideal value.

For the evaluation of target conformation [3]. The Conformation number (CN) [19] is defined as

$$CN= [TV_{RI}/ TV] * [TV_{RI} /V_{RI}] \quad (3)$$

The abbreviations TV, TVRI, and VRI represent the treatment volume, the treatment volume at reference isodose (RI) of the recommended dose, and the total volume at RI of the prescribed dosage, respectively. The RI was defined as being equivalent to 95% of the PTV dosage. The maximum number for CN is 1, which indicates PTV's comprehensive and absolute coverage.

Complete uniformity of dose coverage, perfect conformity to the target, and a gradual decrease in dose outside the target are the hallmarks of an optimal plan [8, 11].

The unique dosimetric Index (UDI) helps you choose the best course of action. For the planning to go smoothly, all the values of CI, HI, GI, and C must be spot on. The worth of UDI can shift if any of its four parts changes. A lower UDI number is preferable to a greater one, and vice versa. A UDI of one indicates perfect planning. Since all four factors are equally important in planning, UDI [20] can be defined as:

$$UDI=CI\times CN\times HI\times GI \quad (4)$$

Statistical analysis

Kruskal-Walli’s test for multiple samples examined the dosimetric outcomes of four $IMRT_{Hybrid}$ Treatment plans with a different sum of 3DCRT and IMRT Treatment plans. The Mann-Whitney U test was used to compare Field in Field (FIF), optimal weighted $IMRT_{Hybrid}$, and IMRT alone plans across two groups. “All statistical tests were two-tailed, with a threshold for statistical significance of $p < 0.05$”.

Results

PTV Dosimetric analysis

Table 2 shows the dosimetric parameter and plan quality for PTV for various combinations of 3DCRT and IMRT in a hybrid IMRT treatment technique. D98% of PTV was insignificantly highest for IMRT$_{80\%}$ with 37.67±0.34 Gy and lowest for IMRT$_{20\%}$ with 37.47±0.41 Gy (p=0.56). D95% of PTV was insignificantly higher for IMRT$_{80\%}$ with 38.332 ± 0.28Gy and lowest for IMRT$_{20\%}$ with 38.27±0.30 Gy (p=0.99). IMRT$_{20\%}$ records the maximum point dose (D$_{Max}$.) inside the PTV with a dose of 43.20±0.77Gy and the lowest D$_{Max}$ was 42.96± 0.75 Gy observed in IMRT$_{80\%}$.of all the hybrid IMRT plans, IMRT$_{20\%}$ received the lowest dose to PTV (D$_{Min}$) Was observed in the IMRT$_{20\%}$ treatment plan with a dose value of 28.80±4.29Gy.

The highest CI value was 0.965 ± 0.013 for IMRT$_{80\%}$, and the lowest was 0.961 ± 0.014 for IMRT$_{20\%}$ (p=0.91). CN was lowest and highest for IMRT$_{20\%}$ and IMRT$_{80\%}$, with the corresponding value of 0.918 ±0.02 and 0.924 ±0. 019. HI was lowest in IMRT$_{80\%}$ with a value of 0.1037±0.0163, and its highest value of 0.1134±0.0163 was observed in the IMRT$_{20\%}$ treatment plan (p=0.28). UDI score for Hybrid IMRT$_{80\%}$, IMRT$_{60\%}$, IMRT$_{40\%}$ and IMRT$_{20\%}$ are 0.989 ±0.022, 0.997±0.256, 0.0999±0.026and 0.9958±0.0291 respectively. The hybrid IMRT$_{80\%}$ treatment plan received the lowest Total MU of 497.33±45.36. The hybrid IMRT$_{20\%}$ treatment plan holds the maximum value of total MU as 615.6±76.59 (p=0). Beam on Time (BOT) values of 0.828±0.075 and 1.026 ± 0.128 was the lowest and highest value observed in Hybrid IMRT$_{80\%}$ and IMRT$_{20\%}$, respectively.

The doses received by OARs in various Hybrid IMRT treatment schemes are compared in Table 3. Average heart dosage was lowest with IMRT40% (4.12 ±1.4Gy) and increased only somewhat with IMRT20% (4.13± 1.47Gy),

IMRT$_{60\%}$ (4.19± 1.24Gy), and IMRT$_{80\%}$ (4.21± 1.34Gy). V$_{20\%}$ of heart was insignificantly lowest for IMRT$_{20\%}$ (7.90 ± 3.68Gy) in comparison to IMRT$_{80\%}$ (7.95 ± 3.86Gy), IMRT$_{40\%}$ (8.05±3.50Gy) and IMRT$_{40\%}$ (8.09 ± 3.39Gy). V$_{10\%}$ of heart was 10.45±3.93Gy (maximum) in IMRT$_{20\%}$ and it significantly reduces to 9.87± 4.30Gy (minimum) in IMRT$_{80\%}$.

Table 2. The various dosimetric parameter and their comparison between the different hybrid plans combinations for PTV

Parameter	IMRT $_{20\%}$	IMRT $_{40\%}$	IMRT $_{60\%}$	IMRT $_{80\%}$	P- value
PTV D98%(Gy)	37.67±0.34	37.62 ±0.33	37.55±0.38	37.47±0.41	0.56
PTV D95% (Gy)	38.332±0.28	38.32±0.26	38.31±0.29	38.27±0.30	0.99
DMax.	42.96± 0.75	43.15±0.79	43.14±0.73	43.20±0.77	0.84
DMin.	30.31±2.90	29.68±3.14	28.84±3.70	28.80±4.29	0.38
CI	0.965±0.013	0.964±0.012	0.963±0.013	0.961±0.014	0.91
CN	0.924 ±0.019	0.922± 0.018	0.921± 0.189	0.918 ±0.02	0.88
HI	0.1037±0.0163	0.1088±0.0170	0.1100±0.0161	0.1134±0.0163	0.28
UDI	0.989 ±0.022	0.997±0.256	0.999±0.026	0.996±0.0291	0.58
Total MU	497.33±45.36	531.8±54.91	565.2±76.44	615.6±76.59	<0.0001
BOT (min.)	0.828+0.075	0.886±0.091	0.942±0.127	1.026±0.128	<0.0001

DMax: maximum Point Dose; DMin. : Minimum Point dose; DMean: average dose Dxx%: Dose to XX % of Volume; CI: conformity Index ; CN; Conformation Number; HI: Homogeneity index;
UDI: Unique Dosimetric Index Total MU: Total Monitor Unit; BOT: Beam on Time; min: minutes; IMRT$_{20\%}$: Ratio of 20$_{\%}$ (IMRT) and 80%(3DCRT); IMRT$_{40\%}$: Ratio of 40$_{\%}$ (IMRT) and 60%(3DCRT); IMRT$_{60\%}$: Ratio of 60$_{\%}$ (IMRT) and 40%(3DCRT); IMRT$_{80\%}$: Ratio of 80$_{\%}$ (IMRT) and 20%(3DCRT).

Table 3. The comparison of doses to the OARs for various hybrid IMRT treatment plans

Parameter	IMRT $_{20\%}$	IMRT $_{40\%}$	IMRT $_{60\%}$	IMRT $_{80\%}$	P- value
Heart Mean (Gy)	4.13±1.47	4.12±1.4	4.19±1.24	4.21±1.34	0.97
V20Gy (%)	7.945±3.86	7.90±3.68	8.05±3.50	8.09±3.39	0.98
V10Gy (%)	9.87±4.30	9.99±3.68	10.34±3.98	10.45±3.93	0.92
Ipsilateral Lung Mean	7.59±1.31	7.66±1.29	7.80±1.29	7.83±1.18	0.77
V5Gy (%)	27.01±4.90	27.38±4.94	27.88±4.92	28.13±4.85	0.61
V10Gy (%)	21.03±4.22	21.47±4.38	22.03±4.33	22.16±4.31	0.53
V20Gy (%)	16.93±3.50	17.14±3.39	17.51±3.14	17.73±3.0	0.63

Mean: mean dose; V$_{xxGy}$: volume covered by xx Gy dose

Table 4. The comparison of the 3DCRT plan with $IMRT_{100\%}$ and Hybrid $IMRT_{20\%}$ treatment plan for OARs dose

Various Treatment Planning Technique				p- Value		
Parameter	3DCRT	$IMRT_{100\%}$	$IMRT_{20\%}$	FiF Vs. Hybrid	IMRT Vs. Hybrid	FiFvs. IMRT
Dmax.	42.84±0.61	42.66±0.85	42.96± 0.75	0.38	0.32	0.58
Dmin.	31.86±5.00	27.21±4.02	30.31±2.90	0.056	0.02	<0.0001
PTV D98%(Gy)	37.359±0.52	37.352±1.01	37.67±0.34	0.08	0.47	0.61
PTV D95%	38.057±0.32	38.172±0.59	38.332±0.28	0.051	0.61	0.24
CI	0.956±0.022	0.960±0.027	0.965±0.013	0.21	0.83	0.4
HI	0.11681±0.175	0.1071±0.355	0.1037±0.016	0.056	0.61	0.06
UDI	1.129±0.025	1.067±0.030	0.989±0.022	0.38	0.36	0.21
CN	0.910±0.024	0.915±0.034	0.924 ±0.019	0.25	0.12	0.63
Total MU	320.8±10.50	755.33±117.42	497.33±45.36	0	0	<0.0001
BOT	0.535±0.0175	1.258±0.195	0.828+0.075	0	0	<0.0001

Table 5. The comparison of the 3DCRT plan with IMRT100% and Hybrid $IMRT_{20\%}$ treatment plan for OARs dose

Various Treatment Planning Technique				p- Value		
Parameter	3DCRT%	$IMRT_{100\%}$	$IMRT_{20\%}$	FiF Vs. Hybrid	IMRT Vs. Hybrid	FiFvs. IMRT
Heart mean	4.426±1.344	4.51±1.344	4.13±1.47	0.5	0.58	0.93
V20Gy (%)	8.36±3.32	8.354±3.314	7.945±3.86	0.66	0.77	0.95
V10Gy (%)	9.473±3.33	11.516±4.033	9.87±4.30	0.56	0.56	0.35
Lung mean	8.421±1.602	8.42±1.398	7.59±1.31	0.1	0.48	0.77
V5Gy (%)	28.61±5.27	30.97±7.11	27.01±4.90	0.39	0.12	0.4
V10Gy (%)	22.51±4.78	24.44±6.73	21.03±4.22	0.32	0.16	0.46
V20Gy (%)	18.99±4.29	17.14±2.98	16.93±3.50	0.09	0.57	0.29

V_{5Gy} of Ipsilateral lung was lowest in Hybrid $IMRT_{80\%}$ with 27.01±4.90Gy, which in significantly raises to 27.38±4.94Gy, 27.88±4.92Gyand 28.13±4.85Gy in $IMRT_{60\%}$, $IMRT_{40\%}$, and $IMRT_{20\%}$ respectively. V_{10Gy} of ipsilateral lung irradiated with the lowest dose of21.03±4.22Gy in Hybrid $IMRT_{80\%}$and found to be increased insignificantly for the rest of the Hybrid IMRT treatment plans. The 21.47±4.38Gy, 22.03±4.33Gy and 22.16±4.31Gy for ipsilateral lung were recorded for $IMRT_{60\%}$, $IMRT_{40\%}$, and $IMRT_{20\%}$ accordingly. V_{20Gy} of Ipsilateral lung achieved the lower value of 16.93±3.50 % in the $IMRT_{80\%}$ treatment plan and comparatively increased to 17.14±3.39%, 17.51±3.14% and 17.73±3.0% in $IMRT_{60\%}$, $IMRT_{40\%}$, and $IMRT_{20\%}$ treatment plans respectively.

The maximum dose for the PTV was comparatively low at 42.66±0.85Gy for $IMRT_{100\%}$ than 42.84±0.61Gy and 42.96± 0.75Gy for 3DCRT and Hybrid $IMRT_{80\%}$, respectively. The minimum dose for the PTV was successively increased in the order of $IMRT_{100\%}$ < $IMRT_{80\%}$ <3DCRT with doses of 27.21±4.02Gy, 30.31±2.90Gy and 31.86±5.00Gy, respectively. $D_{98\%}$ for PTV was better in $IMRT_{80\%}$ (37.67±0.34Gy) and got lowered in $IMRT_{100\%}$ and 3DCRT treatment plan. The CI value improved when comparing its values of0.956±0.022, 0.960±0.027, and 0.965±0.013 for 3DCRT, IMRT100%, and $IMRT_{80\%}$, respectively. HI value for 3DCRT (0.11681±0.175) was high on comparing it with $IMRT_{100\%}$ (0.1071±0.355) and $IMRT_{80\%}$ (0.1037±0.016). Total MU for IMRT100% plan (497.33±45.36) was higher when comparing it with IMRT80% (497.33±45.36) and 3DCRT (320.8±10.50). Beam on Time(BOT) for the 3DCRT was least 3DCRT (0.535±0.0175) and raises for the $IMRT_{100\%}$ (1.258±0.195) and $IMRT_{80\%}$ (828±0.075).

OARs Dose Analysis

The summary of various doses of the OARs among the different planning strategies is shown in Table 4 and Table 5. Heart mean dose was lowest in $IMRT_{80\%}$ (4.13±1.47Gy) and increased significantly from 4.426±1.344Gy to 4.51±1.344Gy in 3DCRT and $IMRT_{100\%}$. V20Gy for the heart received the lowest volume irradiation in $IMRT_{80\%}$ (7.945±3.86 %) on comparing it to 8.36±3.32 % and 8.354±3.314% in 3DCRT and $IMRT_{100\%}$, respectively. 9.473±3.33%, 11.516±4.033% and 9.87±4.30% were the relative volumes of 10Gy dose of heart. The mean dose to the ipsilateral lung was 8.421±1.602Gy, 8.42±1.398Gy, and 7.59±1.31Gy in 3DCRT, IMRT100%, and $IMRT_{80\%}$, respectively. V5Gy of ipsilateral lung were on higher side for $IMRT_{100\%}$ (30.97±7.11%) and 3DCRT (28.61±5.27%), and was on lower side for IMRT80% (27.01±4.90 5%). V10Gy for ipsilateral lung insignificantly received the higher (24.44±6.73%) percentage of volume in $IMRT_{100\%}$ than 22.51±4.78% and 21.03±4.22% in 3DCRT and $IMRT_{80\%}$ respectively (p=046). $IMRT_{80\%}$ recorded insignificantly the lowest 16.93±3.50% of volume of V20Gy for ipsilateral lung in comparison to 3DCRT (18.99±4.29%) and $IMRT_{100\%}$ (17.14±2.98 %).

Discussion

High-precision radiation dosimetry studies comparing CW and nodal volumes are a few [6]. The most common treatment techniques for ca-breasts in the radiotherapy setup are tangential and SCL fields. Compared to IMRT and 3DCRT in planning comparative studies, VMAT is superior as a treatment choice for post-mastectomy breast cancer patients because of its excellent PTV coverage, CI, and HI and lower dosages of OARs [12, 15, 16]. Most planning studies [11–14] using IMRT or VMAT have used open tangential 3DCRT fields. Lin et al. [16] devised a countermeasure by basing their H-VMAT dosage technique on T-IMRT. T-IMRT differs from 3DCRT because it incorporates two tangential fields into IMRT rather than just one. However, there was no statistically significant difference between T-IMRT and open 3DCRT technology in OAR dosages, as observed by Viren et al. [21]. IMRT could not be used as a reference dosage or a hybrid modality in the research. The hybrid's VMAT component mitigates some of the dangers of 3DCRT. As a result, not even the least successful treatment plan requires FiF. The FiF approach may sometimes simplify the VMAT part of the treatment. However, there is a penalty for MU and planning time associated with the ongoing requirement to alter subfield settings and recalculate dosage.

Our present study has compared the various combinations of IMRT and 3DCRT treatment plans into the Hybrid IMRT treatment plan. Figure 1 Shows the Isodose Line comparison for Planning Target Volume and Dose volume Histogram for PTV and OARS between 1(a) 3DCRT, 1 (b) $IMRT_{100\%}$ and $IMRT_{20\%}$ Treatment Plan. Again, the best hybrid plan is compared with pure 3DCRT and IMRT treatment plans. Figure 2. (A) Shows the comparison of CI and HI for the different ratios of 3DCRT and IMRT in a Hybrid IMRT treatment plan. D98% and D95% of PTV have better dose distribution for $IMRT_{80\%}$ than other combinations of Hybrid IMRT treatment plans. We have found that $IMRT_{80\%}$ had better CI and HI values than other Hybrid IMRT plans.

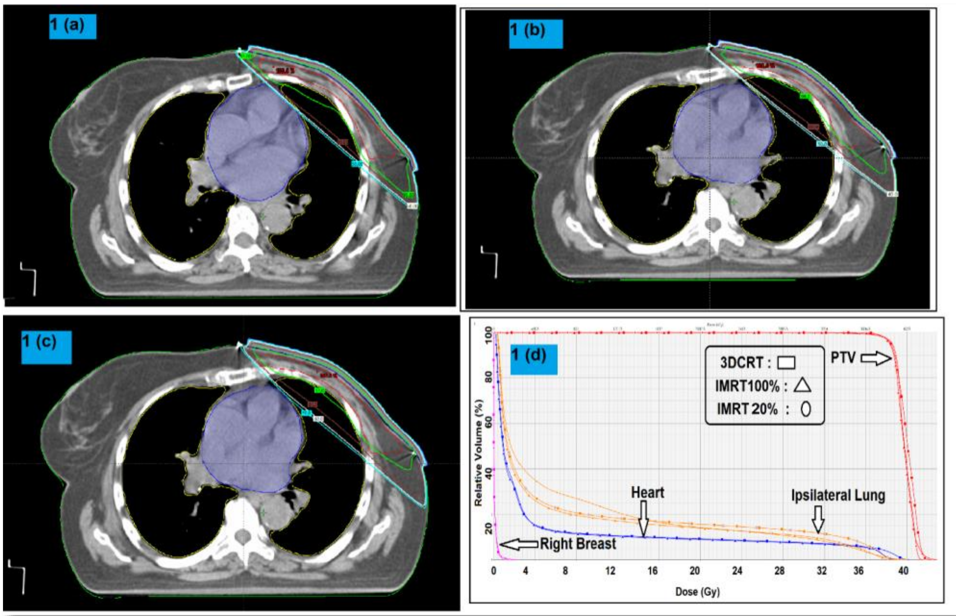

Figure 1. Shows the Isodose Line comparison for Planning Target Volume and Dose volume Histogram for PTV and OARS between 1(a) 3DCRT, 1 (b) $IMRT_{100\%}$ and IMRT20% Treatment Plan. For figure 1(a), 1(b) and 1 (c) Red color: Planning Target Volume (PTV); Green color:isodose line of 95% of prescriptions dose; Brown Color: isodose line of 80% of prescriptions dose ; Cyan color: isodose line of 70% of prescriptions dose, Figure1(d) : DVH of Three different Treatment techniques.

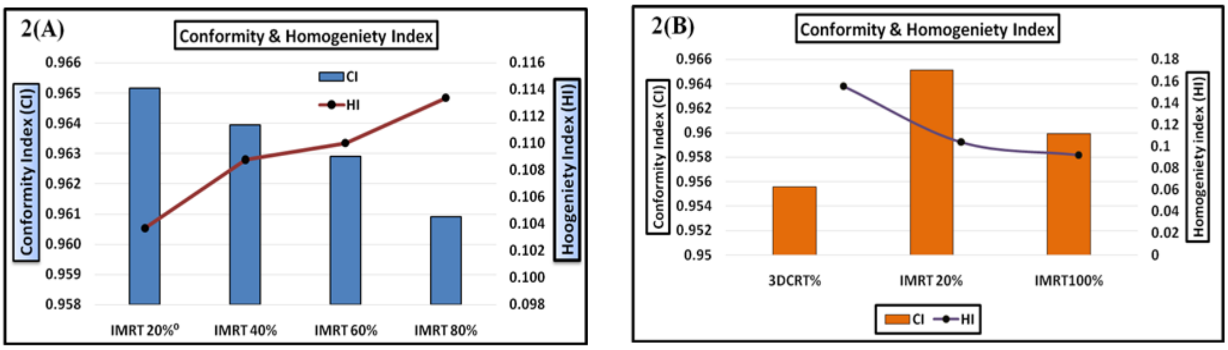

Figure 2. The comparison of CI and HI between 2 (A) All Hybrid IMRT treatment plans and 2(B) 3DCRT, $IMRT_{100\%}$ and Hybrid $IMRT_{20\%}$.

It can be seen from Figure 2 (A) that the Hybrid IMRT$_{20\%}$ treatment plans show the worse CI value and less homogeneous treatment plan. This concludes that increasing the proportion of 3DRCT or decreasing the ratio of IMRT into a Hybrid IMRT Treatment plan results in lower CI and HI values. Figure 2(B) compares CI and HI between 3DCRT, IMRT$_{100\%}$ and Hybrid IMRT$_{20\%.}$ CI value was best for the Hybrid IMRT$_{20\%}$ treatment plan.

When comparing 3DCRT and IMRT 100%, many researchers concluded that the IMRT treatment plan has better CI and HI values than the 3DCRT treatment plan [13]. Additionally, we observed that the CI value for 3DCRT designs is lower than that of the IMRT$_{100\%}$ plan. Hybrid IMRT$_{20\%}$ treatment plans have better conformal doses to the PTV than other Hybrid IMRT plans, as seen by the higher CN value for IMRT$_{20\%}$. However, IMRT$_{20\%}$ with a low CN value indicates the treatment plan has inadequate target coverage or a cold patch within the PTV. Comparing the Hybrid IMRT$_{20\%}$ treatment plan with 3DCRT and IMRT$_{100\%,}$ we found that the CN value was higher for Hybrid IMRT$_{20\%}$.

Figure 3(A) shows the UDI comparison for all Hybrid IMRT treatment plans. Combining all the planning indexes and evaluating the UDI score, the IMRT$_{60\%}$ treatment plan received the optimum UDI score compared to the other hybrid IMRT plan. Our findings showed a minimal variation of UDI score among the Hybrid IMRT plans with a maximum variation of 1% and minimum variation of 0.3%. Figure 3(B) illustrates the UDI score comparison with the 3DCRT and IMRT$_{100\%}$ treatment plan. On comparing the UDI score for Hybrid IMRT$_{20\%}$ with 3DCRT and IMRT$_{100\%}$ treatment plan, we have seen that the UDI score for 3DCRT, IMRT$_{100\%}$ is 12.9% and 6.7% higher than the ideal UDI score of one while it was 11% lower in Hybrid IMRT$_{20\%}$ treatment plan than the Ideal value of UDI.

Radiation-induced cancer rates are predicted to increase due to increased use of MUs and exposure to radiation, increasing the out-of-field leakage dose and scattering of radiation to healthy tissues. Radiation-induced malignancy was determined to be 1% in 3DCRT and 1.75 % in IMRT [10] following a 10-year assessment of secondary neoplasm prevalence. Figure 4 (A) shows the Total Monitor unit and BOT for the Hybrid Treatment plans.

The Monitor unit was significantly lowest in IMRT$_{80\%}$ in the treatment plan. The hybrid IMRT$_{20\%}$ treatment plan has 23.78% Higher MU than the Hybrid IMRT$_{20\%.}$ Figure 4(B) shows the Comparison of Total MU and BOT for 3DCRT, IMRT$_{100\%}$ and IMRT$_{20\%}$ treatment plans. IMRT$_{100\%}$ treatment plans receive 2.35 times more MU than the 3DCRT treatment plan, while only a 55% increase in MU was observed for the Hybrid IMRT$_{20\%}$ treatment plan compared to the 3DCRT treatment plan.

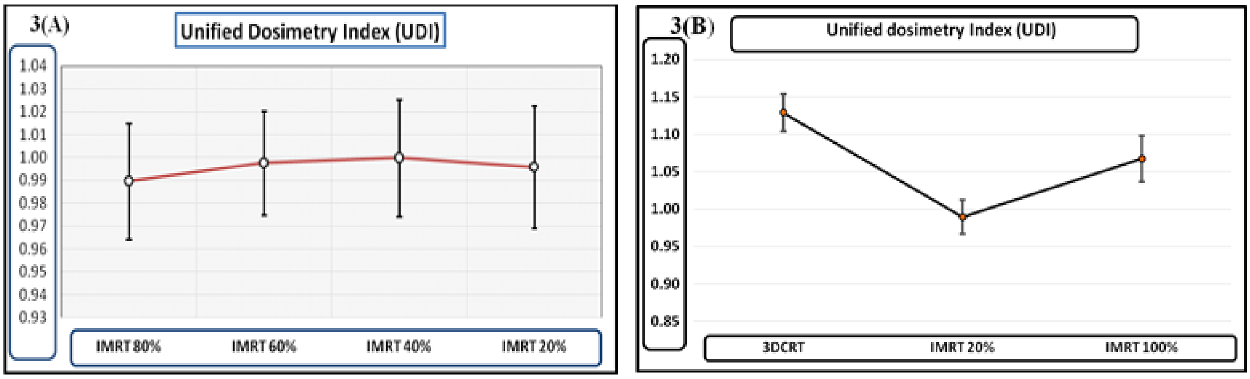

Figure 3. shows the comparison of UDI scores between 3(A) All Hybrid IMRT treatment plans and 3(B) 3DCRT, IMRT100% and Hybrid IMRT20%.

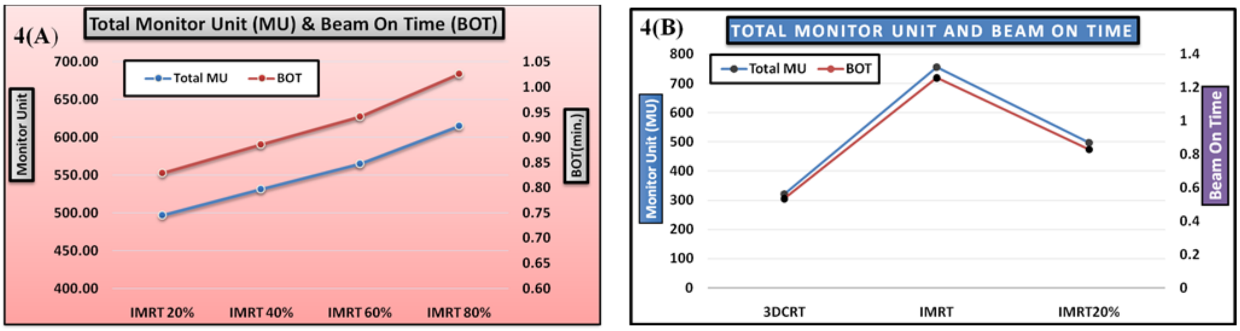

Figure 4. The comparison of Total Monitor Unit and Beam on Time between 4(A) All Hybrid IMRT treatment plans and 4(B) 3DCRT, IMRT100% and Hybrid IMRT20%.

Beam on Time (BOT) is a parameter that has to do with the amount of time the patient spends on the couch while the treatment is being administered. It refers to the time the beam was on, excluding the time spent moving the gantry and setting up the patient. Kry et al. demonstrated that IMRT plans had improved MU and variable dose distribution compared to 3D-CRT, which would result in doubling the incidence of subsequent solid tumours [22]. In our study, Hybrid $IMRT_{20\%}$ is having 21.93%, 13.76 % and 6.3% lesser BOT than the $IMRT_{40\%}$, $IMRT_{60\%}$ and $IMRT_{80\%}$. Respectively. BOT for the 3DCRT treatment plan was only 0.42% of the IMRT $_{100\%}$ treatment plan and jumped to 0.65% for Hybrid $IMRT_{20\%}$.

The hybrid plan aims to reduce radiation doses to the heart, IL, CL, and CB while reducing the risk of late effects such as heart disease and lung pneumonitis. In the study of Darby et al, they have concluded that the occurrence of ischemic heart disease increased by 7.4% for each additional 1Gy of radiation exposure to the average heart dosage, irrespective of the threshold dose [9]. In this study, all Hybrid IMRT plans achieved mean doses for heart less than the 5Gy. Figure 5(A) shows the various volumetric parameters for the heart for Hybrid Treatment plans. Dose-response relationships in heart failure are becoming apparent at higher dosages (30Gy). Studies recommend keeping cardiac dosages at 10% for V25Gy [23]. However, in our study, we studied the V20Gy for the heart, which was well below the 10% in all the hybrid IMRT plans, $IMRT_{100\%}$ and 3DCRT. V20Gy and V10Gy show a good relationship with the risk of heart toxicity. Figure 5 (B) indicates the variation of V20Gy and V10Gy for the heart among the 3DCRT, $IMRT_{100\%}$ and $IMRT_{20\%}$ treatment plans. The risk of cardiac death is raised even at modest radiation doses of 5Gy [23-26].

Pulmonary problems are the second most frequent form of complication observed in breast cancer patients. Immediate onset of radiation pneumonitis, which may subsequently progress to irradiated lung fibrosis, is a potential complication following therapy. Accurately determining the lung volume that received a radiation dosage of 20Gy or higher (V20Gy) is crucial for minimizing the risk of consequences. If the ipsilateral lung V20Gy in breast cancer patients is 30%, the occurrence of clinically severe pneumonitis should be infrequent. Figure 6(A) displays the distribution of the dosage received by the ipsilateral lung, specifically at V20Gy. The Hybrid $IMRT_{20\%}$ treatment plan offers the V20Gy for ipsilateral lung was 4.72% and 3.4% lesser than $IMRT_{80\%}$ and $IMRT_{60\%}$. On another side, V20Gy for the 3DCRT treatment plan was 12.16% higher than Hybrid $IMRT_{20\%}$. Only a 1.2% difference was found between the $IMRT_{100\%}$ and Hybrid $IMRT_{20\%}$ treatment plan for V20Gy of the ipsilateral lung. In this study, Hybrid $IMRT_{20\%}$plans outperformed 3DCRT and IMRT100% plans regarding PTVs and OARs. Abo-Madyan et al. [27] reported that the probability of a second malignancy after 3DCRT was reduced by 34-50% compared to VMAT. Nevertheless, Pignol et al. studied that IMRT significantly reduced the occurrence of wet desquamation in comparison to 3DCRT [28]. Based on these data, it is preferable to use Hybrid IMRT. Mayo et al. found that the hybrid plan requires less time for planning and is not dependent on the planner's level of competence [11].

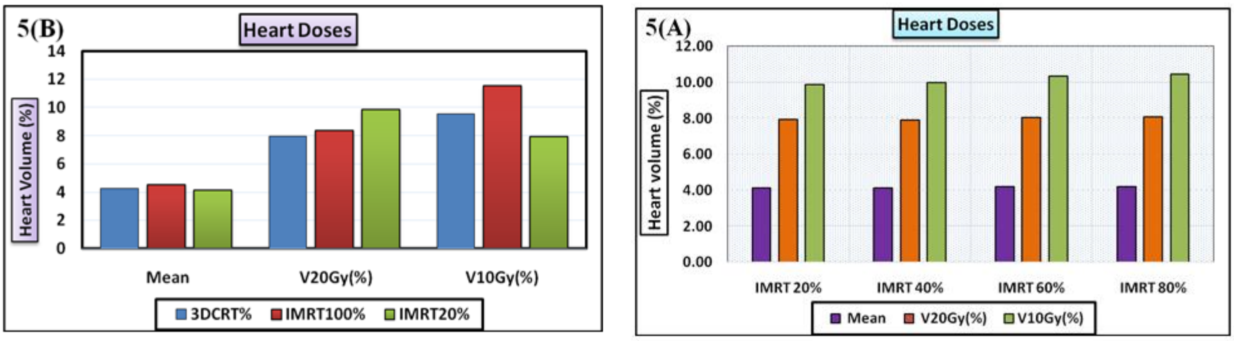

Figure 5. The Mean and Volumetric heart doses, and their comparison for 5(A) All Hybrid IMRT Treatment plans, 5(B) 3DCRT, IMRT100%, and IMRT20%.

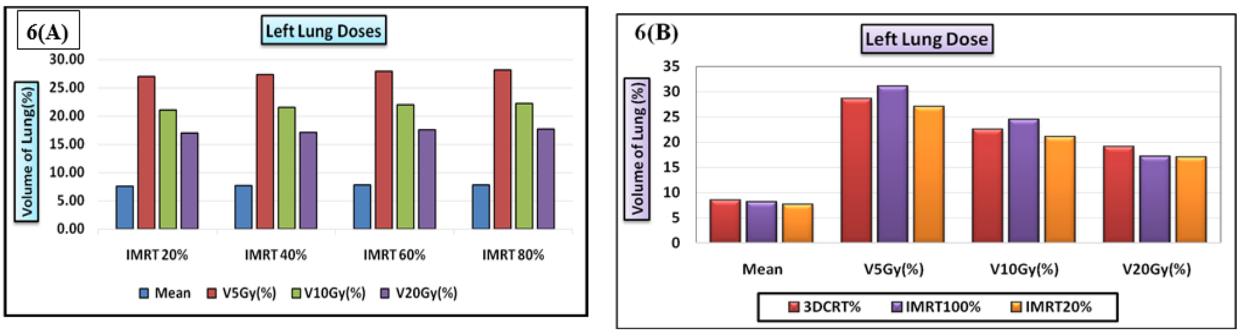

Figure 6. The figure shows the Mean and Volumetric Ipsilateral lung doses and their comparison for 6(A) All Hybrid IMRT Treatment plans,6(B) 3DCRT, IMRT100% and IMRT20%.

In this study, Hybrid $IMRT_{20\%}$plans outperformed 3DCRT and IMRT100% plans regarding PTVs and OARs. Abo-Madyan et al. [27] reported that the probability of a second malignancy after 3DCRT was reduced by 34-50% compared to VMAT. Nevertheless, Pignol et al. studied that IMRT significantly reduced the occurrence of wet desquamation in comparison to 3DCRT [28]. Based on these data, it is preferable to use Hybrid IMRT. Mayo et al. found that the hybrid plan requires less time for planning and is not dependent on the planner's level of competence [11]. In our study, we, too, require less time to develop a Hybrid IMRT plan than 3DCRT and $IMRT_{100\%}$ plans. Also, there is no requirement for patient-specific quality Assurance for the Hybrid IMRT treatment plans as there is limited usage of IMRT beam in the Hybrid Plan. The significant doubts in breast cancer treatment are the setup and breathing effect. However, according to certain studies, the breast/chest wall displacement is 3mm or less [29].

In a recent dosimetric study, Zhou et al. [30] discovered that the free-breathing mode is appropriate for H-IMRT left-breast irradiation. Setup and respiratory errors have a greater influence on IMRT and VMAT compared to 3D-CRT. To minimize the uncertainty in positioning, it is advisable to incorporate a substantial target extension margin and implement daily image guidance. This research utilized the Hybrid IMRT20% technique to effectively minimize the impact of setup and breathing by administering 80% of the radiation using open 3DCRT beams.

Conclusion

The current dosimetric investigation suggests that a weighting of 80% for the base dose 3DCRT plan and an equal weighting of 20% for IMRT is generally optimal for the Hybrid IMRT approach. The hybrid intensity-modulated radiation therapy (IMRT) technique efficiently lowers the doses to the OARs without sacrificing the dosimetric characteristics of the PTV. Lesser doses in Hybrid Treatment planning compared to 3DCRT and IMRT reduce long-term lung and heart toxicity. However, extensive study and evaluation of various hybrid techniques such as PTV size, number of IMRT beams, and Photon energy are required for further plan quality improvement. It is also necessary to conduct randomized clinical tests with extended follow-up periods in patients treated using hybrid approaches.

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