Dosimetric Comparison of Different Dose Calculation Algorithms in Postmastectomy Breast Cancer Patients Using Conformal Planning Techniques

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Abstract

Background: The aim of the current study was to compare three different dose-calculating algorithms, i.e., superposition (SP), fast SP (FSP), and convolution (CV), for breast cancer patients treated with intensity-modulated radiotherapy (IMRT) and field-in-Field forward plan IMRT (FiF-FP-IMRT). **Materials and Methods:** The current retrospective study involved 100 postmastectomy breast cancer patients who were given radiotherapy using IMRT and FiF-FP-IMRT planning techniques. All the initially SP-calculated plans were recalculated with the same monitor units for FSP and CV algorithm without change in any of the other planning parameters. The isodose distribution and various plan evaluating parameters, for example, conformity index (CI), homogeneity index, and uniformity index target volume and normal structure doses were compared and analyzed for all the different algorithm calculated plans. **Results:** In the IMRT plans, all the target and normal structure dose-volume parameters showed a significant difference between all the three different algorithms with $P < 0.05$. In the FiF-FP-IMRT plans, CV algorithm showed a significant difference in most of the target and normal structure dose-volume parameters. Among quality indexes, only CI showed a significant difference between all the algorithms in both the planning techniques. R_{50} showed a significant difference with the CV algorithm in both the planning techniques. **Conclusion:** The change in the dose calculation algorithm resulted in dosimetric changes which must be evaluated by the medical physicists and oncologists while evaluating treatment plans. In the current study with breast patients, the results obtained for target and normal structure doses using the CV algorithm are overestimated as compared to SP and FSP algorithms, producing variable results in air and bony normal structures. However, the ipsilateral lung V_5 parameter and the ipsilateral humeral head mean dose were found to be underestimated by the CV algorithm as compared to the SP and FSP algorithm in both the planning techniques.

Keywords: Breast cancer, dose calculating algorithms, field-in-field forward plan intensity-modulated radiotherapy, intensity-modulated radiotherapy, radiotherapy

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Introduction

Breast cancer affects women more frequently than any other disease in the world, and it is treated with a multidisciplinary approach that may involve surgery, chemotherapy, radiation treatment, and hormone therapy either alone or in combination.[1] With the goal of achieving homogeneous dose distribution in the target with minimal doses to normal structures, radiotherapy uses a variety of techniques, including three-dimensional conformal radiotherapy (3DCRT), intensity-modulated radiotherapy (IMRT), field-in-field forward plan IMRT (FiF-FP-IMRT), image-guided radiotherapy, and volumetric arc therapy.[2-6]

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The predicted dose distribution in the heterogeneous patient body is determined by the treatment planning system (TPS) by making use of a dose-calculating algorithm.[7] Nowadays, a typical TPS is equipped with inbuilt multiple dose calculation algorithms. With the continuous advancement in technology provide successive generations of TPS with

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an increasing ability to calculate more accurate doses. In general, these algorithms often display improved calculation speed or higher dose calculation accuracy, but not both. Therefore, attaining an accurate and fast dose distribution calculation, especially in a heterogeneous medium, is indeed one of the most challenging tasks in radiotherapy which depends on the algorithm used for the dose calculation in TPS.

CMS-XiO TPS provides three algorithms namely superposition (SP), fast SP (FSP), and convolution (CV) for the dose calculation in external beam radiotherapy. Both the XiO fast-Fourier transform (FFT) CV algorithm and the SP algorithm compute the dose by convolving the total energy released in the patient with Monte Carlo-generated energy deposition kernels.[8,9] The major difference between both is that FFT CV does not calculate as accurately as SP in the presence of tissue inhomogeneities. However, significant time savings computation was gained by performing FFT CV calculations rather than SP calculations. The FSP algorithm provides fast mode dose calculation with a speed-up factor of 2.5 at the cost of a small loss in accuracy as compared to the standard SP algorithm.[10]

The primary goal of the current retrospective comparative study was to calculate and compare various dosimetric parameters related to the target volume, normal structures, and treatment plan quality metrics for the currently available algorithms in CMS-XiO TPS for IMRT and FiF-FP-IMRT planning techniques in breast cancer. The novelty of the current study lies in the dosimetric evaluation, comparison, and accuracy testing of three different available dose calculation algorithms in breast cancer.

Materials and Methods

Patient selection, computed tomography simulation, and contouring

The current retrospective study involved 100 postmastectomy breast cancer patients who were given radiotherapy treatment after surgery and chemotherapy. The simulation of the patients was performed on a 16-slice Optima CT 580W CT Simulator machine (Wipro GE Hanwei Medical Systems Co. Limited, China) where computed tomography (CT) images of slice thickness 2.5 mm were taken in the supine position, immobilized with carbon fiber breast board (Quest) and thermoplastic Orfit cast (Humo Healthcare Pvt. Ltd.) with free breathing technique. The universal superflab bolus (Radiation Products Design, Inc.) of square dimensions (1 cm (thickness) × 30 cm × 30 cm) was placed above the patient skin and under the thermoplastic Orfit cast at the time of both CT acquisition and radiotherapy treatment. These CT images were then transferred to contouring station Monaco (Elekta Medical Systems Pvt. Ltd.) through DICOM where the delineation of target volume and normal structures was done by the radiation oncologists according to Radiation Oncology Treatment Group guidelines.

Treatment planning

All the patients were planned using CMS XiO (version 5.1, Computerized Medical Systems, USA) TPS with a dose prescription of 50 Gy in 25 fractions over a period of 5 weeks to the planning target volume (PTV). The PTV includes the chest wall, supraclavicular, axillary lymph nodes, and internal mammary nodes with a 5 mm margin to include error for daily patient setup and organ motion. IMRT and FiF-FP-IMRT techniques were used to make treatment plans for every fifty patients. For IMRT, six to seven beams were positioned so that two to three angles were close to medial tangential, two were close to lateral tangential and one was close to anterior for supraclavicular nodes. For FiF-FP-IMRT plans, five to seven fields were employed by making use of single isocenter and half beam block technique. Similar to the 3DCRT technique FiF-FP-IMRT approach adds, with more fields from medial and lateral tangentially. Initially, all the plans were generated using the SP dose calculation algorithm which is the standard algorithm being used at our institute for all the patients. The IMRT plans were created using a 6 MV photon beam, whereas, FiF-FP-IMRT plans were generated using both 6 MV and 15 MV photon beams or a combination of both energies, to provide optimal target coverage with homogeneous dose distribution and acceptable hotspots. Beams were placed with the intention to improve tumor coverage with minimal damage to the healthy tissue and with special consideration to the contralateral breast and ipsilateral lung. Plan optimization criteria were to achieve at least 95% target volume coverage with 95% of the prescribed dose, $V_{110\%}$ <15%. Meanwhile, the following dose constraints were used for OARs in the optimization: (1) D_{mean} <22 Gy, V_{20} <40%, V_5 <85% for ipsilateral lung; D_{mean} <3 Gy for contralateral lung; D_{mean} <5 Gy for contralateral breast; ipsilateral humeral head <30 Gy; Heart D_{mean} <26 Gy; D_{max} <45 Gy for spinal cord; D_{mean} <30 Gy for trachea.

Algorithm comparison

The study of algorithm comparison was divided into two parts/sections. In part A of the study, the initial SP calculated plan was again calculated with the rest of the other two planning algorithms, for example, FSP and CV algorithm and their monitor units (MU's) were compared. In part B, all the initially SP-calculated plans were recalculated with the same MU's for FS and CV algorithm without changing any planning parameters.[11] For the sake of convenience in the current investigation, these complementary plans were named CompFSP and CompCV plan, respectively for calculation vide FSP and CV algorithm in TPS. The isodose distribution and various plans evaluating quality index parameters, target volume, and normal structure doses were compared and analyzed for all the different algorithm-calculated plans. For target volume, $D_{2\%}$ (dose received by 2% of the target volume), $D_{98\%}$ (dose received by 98% of the target volume), $V_{95\%}$ (target volume receiving 95% of the prescribed dose), $V_{110\%}$ (target volume receiving 110% of the prescribed dose), V_{pres} (volume of reference 95% isodose line i. e 4750 cGy), $V_{50\%}$ (volume of 50% isodose line, i.e., 2500 cGy) were calculated and compared using dose volume histogram (DVH) generated for each plan. The mean, maximum and volumetric doses for normal structures and treatment plan quality indexes namely homogeneity Index (HI), conformity index (CI), uniformity index, and dose spillage index ($R_{50\%}$) were calculated and compared. The various treatment plan quality indices were calculated using different formulae as given by Gaur *et al*.[12]

Patient-specific quality assurance

The IMRT QA was done using PTW Octavius phantom having a 2D-array detector (PTW, Freiburg, Germany) and PTW Verisoft (4.2) dose verification software. The QA plans were generated for each patient in CMS XiO TPS. Using verisoft software, the dose fluence with three different algorithms from TPS for all patients was compared with the fluence measured with 2D-array PTW Octavius detector. The gamma analysis was performed for all patients with passing criteria of 3% dose difference and 3 mm distance to agreement.

Statistical analysis

The difference between all the parameters from the three dose-calculating algorithms for the two planning strategies was evaluated using paired *t*-test. Mean values along with standard deviation and *P* values for all the parameters were noted. Furthermore, Spearman's rho coefficient was calculated to see the strength of the correlation of different parameters with different algorithms and different planning techniques. The *P* values ≤ 0.05 were considered statistically significant or otherwise nonsignificant.

Results

Comparison of monitor units

In part A of the study, MUs of the reference SP plan and that of the same plan recalculated with FSP and CV algorithm were recorded. According to the paired *t*-test, the three algorithms showed a statistically significant difference in the IMRT technique ($P < 0.05$). However, an insignificant difference was observed in FiF-FP-IMRT. Also, the difference between MUs for the reference SP calculated plan with that of FSP and CV plans was calculated. In contrast to FiF-FP-IMRT plans, this difference was more noticeable in IMRT plans. Table 1 shows the mean of calculated MU values and the difference in MUs for the three-dose calculation algorithms for both planning techniques. Figures 1 and 2 show the difference in MU for plans made with FS and CV compared to plans made with SP algorithm for IMRT and FiF-FP-IMRT techniques, respectively.

Dose volume histogram statistics comparison

Target volume

Tables 2 and 3 presents the summary of target volume analysis for plans with IMRT and FiF-FP-IMRT techniques, respectively. All the parameters taken in the study related to target volume showed significant differences ($P \leq 0.05$) when calculated with three different algorithms in IMRT plans. However, CV algorithm showed a significant difference from the other two algorithms for all the target parameters ($P \leq 0.05$) in FiF-FP-IMRT plans. The plans generated by the CV algorithm overestimated the doses as compared to the reference SP algorithm for all the target volume parameters namely $D_{2\%}$, $D_{98\%}$, $V_{95\%}$, $V_{110\%}$, V_{pres}, $V_{50\%}$.

Normal structures

The data of normal structures are summarized in Tables 4 and 5 for IMRT and FiF-FP-IMRT plans, respectively. All the dose parameters are in cGy and volume parameters are in percentage (%). Almost all the normal structure parameters showed significant differences among different algorithms in IMRT plans except contralateral lung. However, in FiF-FP-IMRT plans [Table 5], only ipsilateral lung doses showed a significant difference in their value when calculated with all the three different algorithms. For most of the normal structure parameters, the CV algorithm showed a significant difference with the SP and FSP algorithms in FiF-FP-IMRT. The CV algorithm overestimated Heart doses (mean, V_{45}, V_{30}) as compared to the SP algorithm in both techniques. The CV algorithm overestimated mean doses for the ipsilateral lung; however, V_{20} and V_5 values were lower than SP algorithm estimated doses. In the bony structure of the ipsilateral humeral head, the CV algorithm underestimated the mean doses as compared to the reference SP algorithm. Figures 3 and 4 show the DVH from all three algorithms for IMRT and FiF-FP-IMRT plans, respectively. The difference in DVH for the ipsilateral lung and humeral head for the three algorithms can be easily visualized.

Isodose distribution comparison

Figures 5 and 6 show the isodose distribution from three plans of a patient when calculated with the same MUs but with different algorithms for IMRT and FiF-FP-IMRT plans respectively. In the FiF-FP-IMRT technique, a significant difference in 5 Gy isodose line is observed between the CV calculated plan and that of the plan generated using SP and FSP. This shows that the low dose scatter was found lesser in the CV plan as compared to the other two algorithms. Furthermore, the volume covered by 110% isodose obtained for plans generated

Table 1: Comparison of monitor units, maximum difference between algorithms for both planning techniques

Technique	SP	FSP	CV	Maximum difference between SP and FSP	Maximum difference between SP and CV
IMRT	802±181	800±180	791±182	11±3.2	65±15
FiF-FP-IMRT	490±98	490±99	490±98	3±1.3	5±1.8

SP: Superposition, FSP: Fast SP, CV: Convolution, IMRT: Intensity-modulated radiotherapy, FiF-FP-IMRT: Field-in-Field forward plan IMRT, SD: Standard deviation

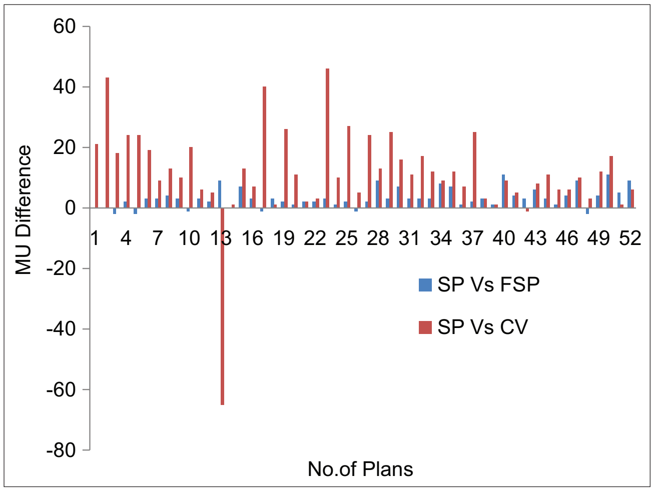

Figure 1: Comparison of difference in MUs from SP IMRT plans with FSP and CV plans. MU: Monitor unit, SP: Superposition, IMRT: Intensity-modulated radiotherapy, FSP: Fast superposition, CV: Convolution

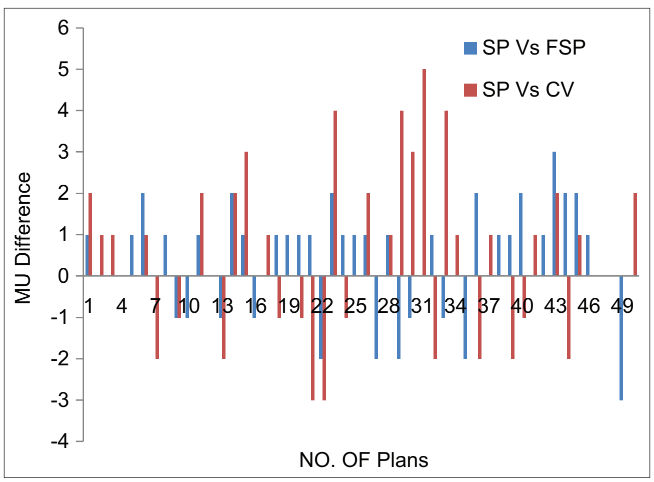

Figure 2: Comparison of difference in MUs from SP FiF-FP-IMRT plans with FSP and CV plans. MU: Monitor unit, SP: Superposition, FiF-FP-IMRT: Field-in-Field forward plan intensity-modulated radiotherapy, FSP: Fast superposition, CV: Convolution

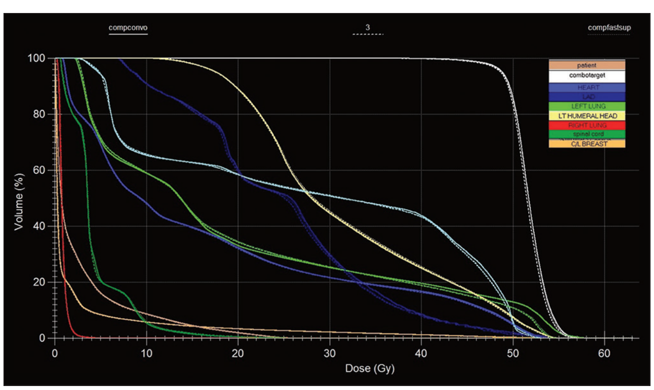

Figure 3: DVH comparison for three algorithm calculated IMRT plan. DVH: Dose volume histogram, IMRT: Intensity-modulated radiotherapy

by the CV algorithm is approximately 30% higher as compared to both SP and FSP algorithms.

Table 2: Comparison of dosimetric data for target volume for intensity-modulated radiotherapy technique

Parameter	SP	FSP	CV
$D_{2\%}$ (cGy)	5583.6±96.1	5591.7±94.7	5654.6±111.7
$D_{98\%}$ (cGy)	4663.6±165.3	4675.1±167.7	4735.4±136.9
$V_{95\%}$ (%)	96.7±2.0	97.0±1.96	97.7±1.47
$V_{110\%}$ (%)	5.67±4.4	6.2±4.8	9.6±6.1
V_{pres} (cc)	2486.1±678.7	2500±682.9	2579.3±681.4
V_{50} (cc)	4550.8±1068.9	4506.6±1029.7	4574.2±1071.1

SP: Superposition, FSP: Fast SP, CV: Convolution, SD: Standard deviation

Table 3: Comparison of dosimetric data for target volume for field-in-field forward plan intensity-modulated radiotherapy technique

Parameter	SP	FSP	CV
$D_{2\%}$ (cGy)	5535.4±113.7	5538.8±107.2	5563.9±120.4
$D_{98\%}$ (cGy)	4687.6±77.4	4685.2±83.9	4724.7±98.2
$V_{95\%}$ (%)	96.8±1.3	96.7±1.4	97.5±1.4
$V_{110\%}$ (%)	4.6±5.1	4.8±5.1	6.1±6.0
V_{pres} (cc)	2682.5±654.8	2699.3±646.4	2763.6±652
V_{50} (cc)	4633.3±898.9	4633.6±900.7	4641±899.3

SP: Superposition, FSP: Fast SP, CV: Convolution, SD: Standard deviation

Quality indexes

Among all quality indexes, only CI showed a significant difference with all three algorithms in both the planning technique. None of the quality indices except CI revealed any appreciable difference between all the three-dose calculation algorithms in IMRT plans. Only the CV algorithm showed a significant difference in R_{50} values in IMRT plans. However, CV algorithm showed significant difference with SP and FSP algorithm for almost all quality indexes except HI in FiF-FP-IMRT. Tables 6 and 7 shows the result for the quality indexes for IMRT and FiF-FP-IMRT plans, respectively.

Gamma analysis

There was no discernible difference in the number of reference locations inside the target volume that met the Gamma passing threshold of 3% in 3 mm among all three dosage calculation algorithms in the IMRT technique. However, a significant difference was found with CV plans in the FiF-FP-IMRT technique. In addition, a significant difference was observed for these values between the two techniques. Table 8 shows the gamma analysis passing values for both techniques. IMRT plans have shown significantly better-passing results than FiF-FP-IMRT. FiF-FP-IMRT plans were shown to have a lower value, owing to the use of a half-beam blocked method for this planning technique and a low dose at the isocenter.

Correlation analysis

Spearman Rho value was calculated for each parameter between the three algorithms and is shown in Table 9. All the parameters showed a high correlation for the three algorithms in both planning techniques.

Table 4: Comparison of dosimetric data for normal structures for intensity-modulated radiotherapy technique

Normal structure	Parameter	SP	FSP	CV
Heart	D_{mean}	1536.6±739	1543.2±741.6	1558.3±742.8
	$V_{45\ Gy}$	5.8±6.05	5.9±6.14	6.39±6.258
	$V_{30\ Gy}$	17.05±14.04	17.2±14.1	17.1±14.2
Ipsilateral lung-PTV	D_{mean}	2088.4±262.6	2102±263	2132.8±269.9
	$V_{20\ Gy}$	39.9±7.7	40.3±7.7	39±8.2
	$V_{5\ Gy}$	86.9±12.6	86.5±12.6	86.4±13
Contralateral breast	D_{max}	4725.8±1290.3	4728.1±1289	4788±1292.2
	D_{mean}	447.1±211.2	437.6±214.5	441.7±216.2
Ipsilateral humeral head	D_{mean}	2829.6±800.5	2807.5±828.9	2786±822.4
Spinal cord	D_{max}	2584.5±1033.8	2600.9±1035.6	2575.8±1032.1
Trachea	D_{max}	5222±614.4	5226±615.1	5290±619.1
	D_{mean}	2898±734.7	2890.8±741.8	2903.3±834.3
Contralateral lung	D_{mean}	271.5±234.9	264.7±234.0	266.2±240.3

SP: Superposition, FSP: Fast SP, CV: Convolution, PTV: Planning target volume, SD: Standard deviation

Table 5: Comparison of dosimetric data for normal structures for field-in-field forward plan intensity-modulated radiotherapy technique

Normal structure	Parameter	SP	FSP	CV
Heart	D_{mean}	999.6±698.4	999.4±698.4	1011.9±700.7
	$V_{45\ Gy}$	8.95±9.3	8.6±8.7	9.2±9.2
	$V_{30\ Gy}$	15.4±14	15.6±14.1	15.7±14.2
Ipsilateral lung-PTV	D_{mean}	2177.7±250.4	2175.1±250.6	2214.4±262.1
	$V_{20\ Gy}$	44.9±5.9	45±5.8	44.0±5.9
	$V_{5\ Gy}$	62.8±6.1	62.6±6.1	57.2±7.0
Contralateral breast	D_{max}	5151.34±676.9	5157.6±677.9	5114.8±962.6
	D_{mean}	366.8±216.2	394.8±301.8	359.4±220.3
Ipsilateral humeral head	D_{mean}	2240.6±1048	2243±1051.7	2222.3±1038.9
Spinal cord	D_{max}	3935.4±928.7	3938.7±927.3	3872.2±952.8
Trachea	D_{max}	4927.4±616.9	4945.8±616.9	4968.1±623.8
	D_{mean}	1905.3±725	1907.7±727.4	1921.3±773.3
Contralateral lung	D_{mean}	82.8±23.4	82.6±21.5	80.5±20.9

SP: Superposition, FSP: Fast SP, CV: Convolution, PTV: Planning target volume, SD: Standard deviation

Table 6: Comparison of quality indexes for intensity-modulated radiotherapy technique

Parameter	SP	FSP	CV
HI	0.18±0.04	0.18±0.04	0.18±0.04
CI	1.78±0.35	1.79±0.35	1.86±0.36
UI	1.14±0.03	1.14±0.03	1.14±0.03
R_{50}	3.29±0.68	3.29±0.68	3.31±0.69

R_{50}: Dose spillage index, SP: Superposition, FSP: Fast SP, CV: Convolution, CI: Conformity index, HI: Homogeneity index, UI: Uniformity index, SD: Standard deviation

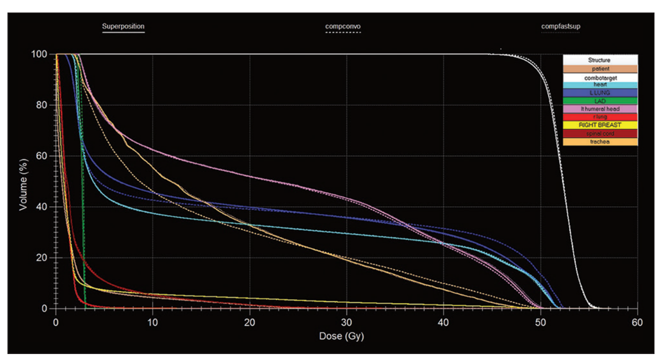

Figure 4: DVH comparison for three algorithm calculated FiF-FP-IMRT plan. DVH: Dose volume histogram, FiF-FP-IMRT: Field-in-Field forward plan intensity-modulated radiotherapy

Discussion

The challenge of implementing a new dose calculation algorithm for a specific treatment site has been discussed in many studies.[13-18] It is useful to have different dose calculation algorithms so that it can be invoked as per planning needs and the clinical outcomes may sometimes be affected by the selection of a dose calculation algorithm. Chaikh *et al*. in their study in 2018, discussed the formalism of the validation of newer algorithms available in TPS.[11] Many studies have evaluated the different dose calculation algorithms in terms of their accuracy in determining the dose distribution.

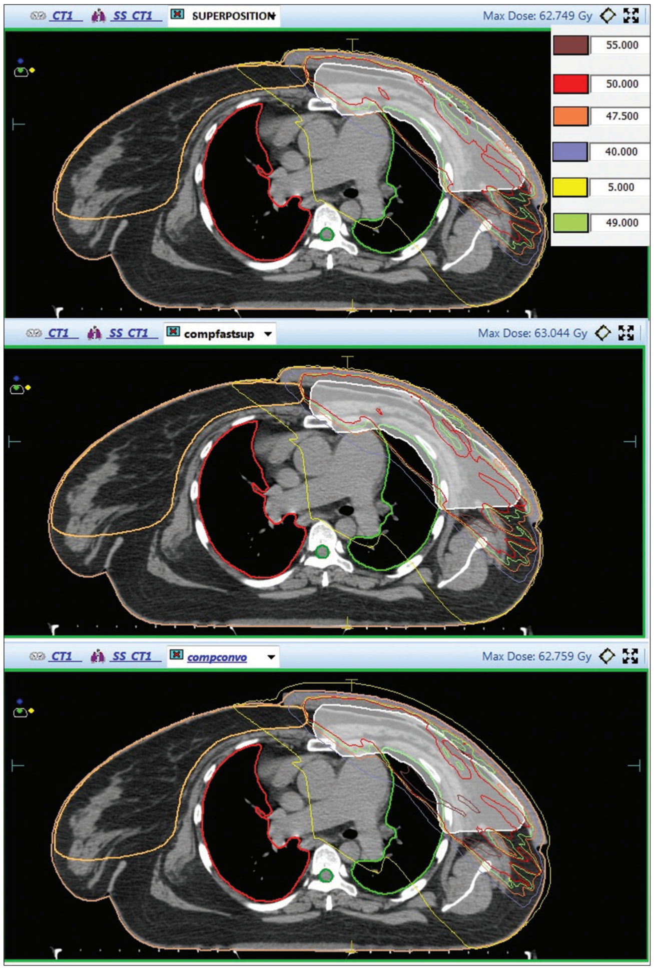

Figure 5: Isodose distribution comparison for IMRT plan calculated with three different algorithms. IMRT: Intensity-modulated radiotherapy

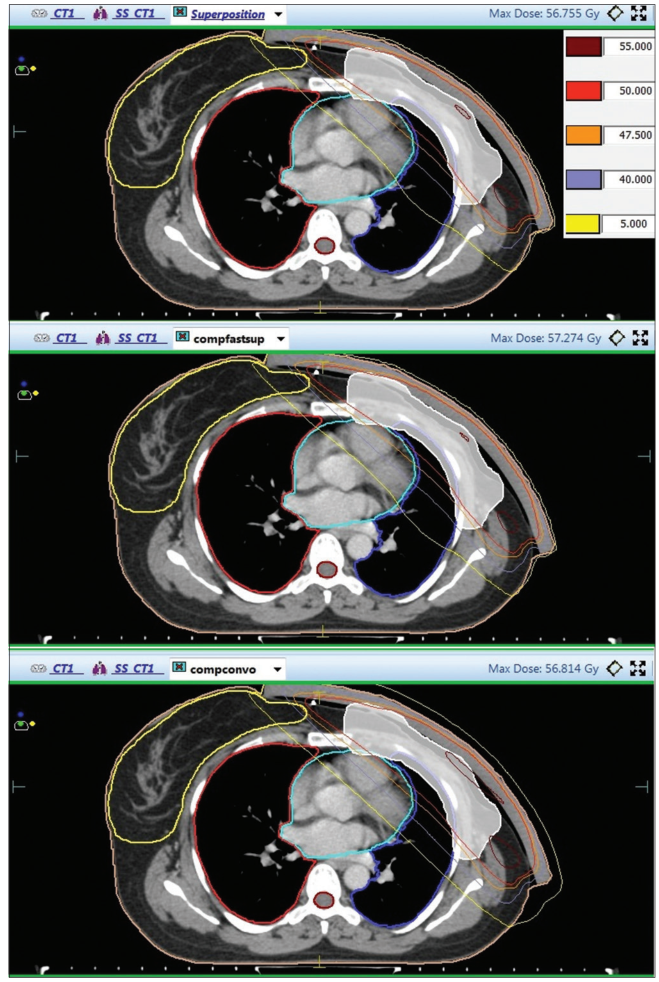

Figure 6: Isodose distribution comparison for FiF-FP-IMRT plan calculated with three different algorithms. FiF-FP-IMRT: Field-in-Field forward plan intensity-modulated radiotherapy

Accurate dose calculation has always remained a challenge in heterogeneous mediums. The calculation of dose in carcinoma breast patients also takes into account heterogeneous media, primarily the lungs, ribs, and muscles of the chest wall.

Muralidhar *et al*. in 2009 did a comparative study of CV, SP, and FSP algorithms in conventional radiotherapy, 3DCRT, and IMRT for four different sites namely Ca Lung, Ca Prostate, Ca Esophagus and Ca Hypopharynx using CMS XiO TPS.[13] Within the target structures, a maximum percentage variation of 3.7% was recorded in Ca Lung with the IMRT technique. The major difference which they found was that CV does not calculate dose as accurately as SP in the presence of tissue heterogeneities. They found variable results for different sites with three algorithms in normal structure doses. Pandu *et al*. in 2022, did a comparative study between Monte Carlo (MC) and collapsed cone superposition (CCS) for IMRT technique and between CCS, MC, and pencil beam (PB) for 3DCRT in head and neck (HN) cancers.[14] They found a significant difference in the PTV and PRV spine doses in the IMRT plans with no significant difference in the 3DCRT plans. Chaikh *et al*. in 2013, in their study compared PB convolution (PBC) and the Clarkson algorithm for four different clinical sites namely

Table 7: Comparison of quality indexes for field-in-field forward plan intensity-modulated radiotherapy technique

Parameter	SP	FSP	CV
HI	0.17±0.03	0.17±0.03	0.18±0.03
CI	1.86±0.36	1.86±0.36	1.91±0.35
UI	1.14±0.02	1.14±0.02	1.13±0.02
R_{50}	3.25±0.67	3.25±0.67	3.24±0.68

R_{50}: Dose spillage index, SP: Superposition, FSP: Fast SP, CV: Convolution, CI: Conformity index, HI: Homogeneity index, UI: Uniformity index, SD: Standard deviation

Table 8: Comparison of gamma passing values for both planning techniques

Technique	Energy (MV)	SP	FSP	CV
IMRT	6	94.4±3.04	94.37±3.19	94.49±3.0
FiF-FP-IMRT	6	90.8±5.3	90.31±0.5	91.33±5.5
	15	88.7±8.4	88.4±8.7	89.4±7.3

SP: Superposition, FSP: Fast SP, CV: Convolution, IMRT: Intensity-modulated radiotherapy, FiF-FP-IMRT: Field-in-Field forward plan IMRT, SD: Standard deviation

Table 9: Spearman correlation coefficient (rho value) and *P* values for both the planning techniques for all the target volume, normal structures, quality indexes and gamma passing parameters

Parameter	Algorithm	IMRT		FiF-FP-IMRT	
		Paired *t*-test (*P*)	Spearman correlation coefficient	Paired *t*-test (*P*)	Spearman correlation coefficient
MU	SP versus FSP	<0.01*	1	0.05	0.999
	FSP versus CV	<0.01*	0.997	0.85	0.995
	SP versus CV	<0.01*	0.997	0.11	0.995
$D_{2\%}$	SP versus FSP	<0.01*	0.992	0.22	0.990
	FSP versus CV	<0.01*	0.950	<0.01*	0.944
	SP versus CV	<0.01*	0.952	<0.01*	0.945
$D_{98\%}$	SP versus FSP	<0.01*	0.999	0.29	0.981
	FSP versus CV	<0.01*	0.968	<0.01*	0.830
	SP versus CV	<0.01*	0.971	<0.01*	0.823
$V_{95\%}$	SP versus FSP	<0.01*	0.957	<0.01*	0.966
	FSP versus CV	<0.01*	0.936	<0.01*	0.804
	SP versus CV	<0.01*	0.914	<0.01*	0.796
$V_{110\%}$	SP versus FSP	<0.01*	0.985	<0.01*	0.978
	FSP versus CV	<0.01*	0.922	<0.01*	0.950
	SP versus CV	<0.01*	0.924	<0.01*	0.935
V_{pres}	SP versus FSP	<0.01*	0.999	0.01*	0.999
	FSP versus CV	<0.01*	0.993	<0.01*	0.991
	SP versus CV	<0.01*	0.992	<0.01*	0.990
V_{50}	SP versus FSP	<0.01*	0.999	0.80	1
	FSP versus CV	<0.01*	0.998	<0.01*	0.999
	SP versus CV	<0.01*	0.998	<0.01*	0.999
Heart					
D_{mean}	SP versus FSP	<0.01*	1	0.45	1
	FSP versus CV	<0.01*	1	<0.01*	1
	SP versus CV	<0.01*	1	<0.01*	1
V_{45Gy}	SP versus FSP	<0.01*	0.998	0.17	0.999
	FSP versus CV	<0.01*	0.998	<0.01*	0.993
	SP versus CV	<0.01*	0.998	0.31	0.992
V_{30Gy}	SP versus FSP	<0.01*	1	0.36	1
	FSP versus CV	<0.01*	1	<0.01*	1
	SP versus CV	<0.01*	1	0.24	1
Ipsilateral lung-PTV					
D_{mean}	SP versus FSP	<0.01*	0.999	<0.01*	1
	FSP versus CV	<0.01*	0.992	<0.01*	0.996
	SP versus CV	<0.01*	0.993	<0.01*	0.996
V_{20Gy}	SP versus FSP	<0.01*	0.998	<0.01*	0.998
	FSP versus CV	<0.01*	0.995	<0.01*	0.990
	SP versus CV	<0.01*	0.996	<0.01*	0.992
V_{5Gy}	SP versus FSP	<0.01*	0.999	<0.01*	0.994
	FSP versus CV	<0.01*	0.998	<0.01*	0.954
	SP versus CV	<0.01*	0.996	<0.01*	0.953
Contralateral breast					
D_{max}	SP versus FSP	0.23	0.999	<0.01*	0.998
	FSP versus CV	<0.01*	0.995	<0.01*	0.985
	SP versus CV	<0.01*	0.994	<0.01*	0.983
D_{mean}	SP versus FSP	<0.01*	1	0.31	0.950
	FSP versus CV	<0.01*	0.999	0.60	0.999
	SP versus CV	<0.01*	0.999	0.33	0.950
Ipsilateral humeral head					
D_{mean}	SP versus FSP	<0.01*	1	0.02	0.999
	FSP versus CV	<0.01*	1	<0.01*	1

Contd...

Table 9: Contd...

Parameter	Algorithm	IMRT		FiF-FP-IMRT	
		Paired *t*-test (*P*)	Spearman correlation coefficient	Paired *t*-test (*P*)	Spearman correlation coefficient
	SP versus CV	<0.01*	1	<0.01*	0.999
Spinal cord					
D_{max}	SP versus FSP	<0.01*	1	0.15	0.998
	FSP versus CV	<0.01*	0.998	<0.01*	0.997
	SP versus CV	0.16	0.998	<0.01*	0.998
Trachea					
D_{max}	SP versus FSP	0.11	0.994	<0.01*	0.997
	FSP versus CV	<0.01*	0.959	<0.01*	0.979
	SP versus CV	<0.01*	0.952	<0.01*	0.980
D_{mean}	SP versus FSP	0.6	0.988	0.01	1
	FSP versus CV	<0.01*	0.984	0.11	0.998
	SP versus CV	<0.01*	0.999	0.07	0.998
Contralateral lung					
D_{mean}	SP versus FSP	0.55	0.988	<0.01*	0.999
	FSP versus CV	0.42	0.984	<0.01*	0.996
	SP versus CV	0.74	0.999	<0.01*	0.997
HI	SP versus FSP	0.31	0.986	0.26	0.967
	FSP versus CV	0.71	0.963	0.15	0.872
	SP versus CV	0.82	0.973	0.33	0.904
CI	SP versus FSP	<0.01*	1	<0.01*	1
	FSP versus CV	<0.01*	0.838	<0.01*	0.915
	SP versus CV	<0.01*	0.838	<0.01*	0.915
UI	SP versus FSP	0.79	0.913	0.94	0.973
	FSP versus CV	0.75	0.957	<0.01*	0.982
	SP versus CV	1	0.903	0.02*	0.958
R_{50}	SP versus FSP	0.06	1	0.51	1
	FSP versus CV	<0.01*	0.969	<0.01*	1
	SP versus CV	<0.01*	0.969	<0.01*	1
Gamma passing values	SP versus FSP	0.39	0.935	0.49 (6 MV) 0.18 (15 MV)	0.932 (6 MV) 0.978 (15 MV)
	FSP versus CV	0.09	0.897	<0.01*	0.914 (6 MV) 0.975 (15 MV)
	SP versus CV	0.06	0.954	<0.01*	0.911 (6 MV) 0.969 (15 MV)

*values are statistically significant. R_{50}: Dose spillage index, SP: Superposition, FSP: Fast SP, CV: Convolution, IMRT: Intensity-modulated radiotherapy, FiF-FP-IMRT: Field-in-Field forward plan IMRT, CI: Conformity index, HI: Homogeneity index, UI: Uniformity index, MU: Monitor unit, PTV: Planning target volume

lung, HN, brain, and prostate.[15] They observed statistically insignificant differences in MUs, isodose curves, DVH, and quality indexes. However, dosimetric parameters were found higher for organs at risk using Clarkson compared to PBC. Cilla *et al*. in 2014, compared PBC and collapsed cone CV algorithm in breast cancer for Forward-IMRT and standard wedged treatment plans and observed an overestimation of PTV coverage by the PBC algorithm.[7] Furthermore, significant difference was observed in Lung doses (mean, V_5, $V_{47.5}$, D_1) and heart mean dose in both techniques. Zhang *et al*. in 2019 investigated Acuros XB algorithm (AXB), anisotropic analytic algorithm (AAA), and PBC algorithm in stereotactic body radiation therapy (SBRT) for non-small cell lung cancer (NSCLC).They concluded that PBC and the AAA algorithm could overestimate target dose coverage as compared to the AXB algorithm and recommended the AXB algorithm for the SBRT plan of NSCLC.[18] Murat *et al*. in 2019 compared and evaluated the efficiency of SP, FSP, and CV algorithms in 3DCRT using CMS-XiO TPS. The assessment of algorithms was done by comparing the point dose calculated with the measured dose from the thorax CIRS anthropomorphic phantom. They found that the SP algorithm produced a relative error of less than ± 3% which passed 100% of all reference points, whilst the CV algorithm and FSP presented a relative error of more than ± 3% which passed 82% and 91% of reference points, respectively.[19] In 2013, Borges *et al*. in their study investigated the impact of treating breast cancer using different radiation therapy (RT) techniques-forwardly-planned intensity-modulated, f-IMRT, inversely planned IMRT, and dynamic conformal arc RT-and their effects on the whole-breast irradiation along with algorithm comparison namely PBC and iMC using BrainLAB TPS. They found that PBC estimated higher doses for the PTV, ipsilateral lung, and heart than the iMC algorithm.[16]

In the present study, the dose distribution resulting from three different dose calculation algorithms namely SP, FSP, and CV for IMRT and FiF-FP-IMRT in breast cancer was thoroughly analysed. The current study was conducted on a large number of patients with a sample size of 100, and the findings were found useful to the Medical Physicists and radiation oncologists by assisting them in adjusting to any changes that may occur while switching between algorithms in TPS for dose calculation. A significant difference was observed in target dose-volume parameters in both techniques. Almost all the normal structural parameters except the contralateral lung showed significant differences among the three algorithms in IMRT plans. However, in FiF-FP-IMRT plans, only the ipsilateral lung showed a significant difference in their value with all the three algorithms. In most of the normal structure parameters, the CV algorithm showed a significant difference with SP and FSP in FiF-FP-IMRT. A significant difference was observed in gamma passing values between the three algorithms in FiF-FP-IMRT. CV algorithm showed better-passing results as compared to other algorithms. So, all three algorithms can be considered similar while planning breast patients with the IMRT technique. However, the CV algorithm can be considered better than other algorithms while planning with the FiF-FP-IMRT technique in breast patients.

Conclusion

The present study illustrates the dosimetric comparison with three different algorithms namely SP, FSP, and CV for modern radiotherapy planning techniques in breast cancer. This study validates the efficacy of these algorithms available in CMS-XiO TPS for breast cancer. In general, the results obtained for target coverage using the CV algorithm are overestimated as compared to SP and FSP, producing variable results in air and bony structures. Significantly higher target dose-volume parameters and lower V_5 value for ipsilateral lung were found with the CV algorithm in IMRT and FiF-FP-IMRT, respectively. All the three algorithms can be considered similar while planning breast patients with the IMRT technique. However, the CV algorithm was found better than other algorithms in FiF-FP-IMRT technique in breast patients because of better gamma passing values. The change in dose calculation algorithm results in dosimetric changes which must be evaluated by the medical physicists and oncologists while evaluating treatment plans. As dosimetric changes from these algorithms have been observed, which may impact clinical results such as tumor control probability and normal tissue complication probability and that can be further studied.

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Conflicts of interest

There are no conflicts of interest.

References

1. Singh R, Oinam AS, Trivedi G, Kainth HS, Shahi JS, Singh B, *et al.* A comparative study for surface dose evaluation in conventional treatment of carcinoma breast patients irradiated with Co-60 and 6 MV radiation beam. J Cancer Res Ther 2019;15:1035-41.
2. Liu H, Chen X, He Z, Li J. Evaluation of 3D-CRT, IMRT and VMAT radiotherapy plans for left breast cancer based on clinical dosimetric study. Comput Med Imaging Graph 2016;54:1-5.
3. Muralidhar KR, Kulkarni BS, Ahamed S. Intensity modulated radiotherapy versus volumetric modulated arc therapy in breast cancer: A comparative dosimetric analysis. Int J Can Ther Oncol 2015;3:1-6.
4. Karpf D, Sakka M, Metzger M, Grabenbauer GG. Left breast irradiation with tangential intensity modulated radiotherapy (t-IMRT) versus tangential volumetric modulated arc therapy (t-VMAT): Trade-offs between secondary cancer induction risk and optimal target coverage. Radiat Oncol 2019;14:156.
5. Krishna GS, Srinivas V, Ayyangar KM, Reddy PY. Comparative study of old and new versions of treatment planning system using dose volume histogram indices of clinical plans. J Med Phys 2016;41:192-7.
6. Hu J, Han G, Lei Y, Xu X, Ge W, Ruan C, *et al.* Dosimetric comparison of three radiotherapy techniques in irradiation of left-sided breast cancer patients after radical mastectomy. Biomed Res Int 2020;2020:7131590.
7. Cilla S, Digesù C, Macchia G, Deodato F, Sallustio G, Piermattei A, *et al*. Clinical implications of different calculation algorithms in breast radiotherapy: A comparison between pencil beam and collapsed cone convolution. Phys Med 2014;30:473-81.
8. Mackie TR, Scrimger JW, Battista JJ. A convolution method of calculating dose for 15-MV X rays. Med Phys 1985;12:188-96.
9. Wiesmeyer MD, Miften MM. A multigrid approach for accelerating three- dimensional photon dose calculation. Med Phys 1999;26:1149.
10. Animesh. Advantages of multiple algorithm support in treatment planning system for external beam dose calculations. J Cancer Res Ther 2005;1:12-20.
11. Chaikh A, Ojala J, Khamphan C, Garcia R, Giraud JY, Thariat J, *et al.* Dosimetrical and radiobiological approach to manage the dosimetric shift in the transition of dose calculation algorithm in radiation oncology: How to improve high quality treatment and avoid unexpected outcomes? Radiat Oncol 2018;13:60.
12. Gaur G, Singh RP, Gurjar OP, Garg P, Grover R, Kang MS, *et al*. Radiotherapy treatment plan quality metrics for postmastectomy breast cancer patients using conformal planning techniques. Iran J Med Phys 2022;19:214-21.
13. Muralidhar KR, Murthy NP, Raju AK, Sresty N. Comparative study of convolution, superposition, and fast superposition algorithms in conventional radiotherapy, three-dimensional conformal radiotherapy, and intensity modulated radiotherapy techniques for various sites, done on CMS XIO planning system. J Med Phys 2009;34:12-22.
14. Pandu B, Khanna D, Mohandass P, Elavarasan R, V TR, Jacob S, *et al*. Dosimetric comparison and plan evaluation of different dose computing algorithms for different radiotherapy techniques in head and neck tumors. Iran J Med Phys 2022;19:346-55.
15. Chaikh A, Giraud J, Balosso J. Clinical comparison of pencil beam convolution and Clarkson algorithms for dose calculation. J Can Ther 2013;4:1485-9.

16. Borges C, Cunha G, Monteiro-Grillo I, Vaz P, Teixeira N. Comparison of different breast planning techniques and algorithms for radiation therapy treatment. Phys Med 2014;30:160-70.
17. Morganti AG, Cilla S, de Gaetano A, Panunzi S, Digesù C, Macchia G, *et al.* Forward planned intensity modulated radiotherapy (IMRT) for whole breast postoperative radiotherapy. Is it useful? When? J Appl Clin Med Phys 2011;12:3451.
18. Zhang J, Jiang D, Su H, Dai Z, Dai J, Liu H, *et al.* Dosimetric comparison of different algorithms in stereotactic body radiation therapy (SBRT) plan for non-small cell lung cancer (NSCLC). Onco Targets Ther 2019;12:6385-91.
19. Murat H, Karim A, Harun H, Kayun Z. Comparison of dose calculation algorithms model: Convolution, superposition, and fast superposition in 3-D Conformal Radiotherapy (3D-CRT) treatment plan. J Phys: Conference Series. 2019;1248.012047. doi 10.1088/1742-6596/1248/1/012047.