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RESEARCH ARTICLE

EVALUATION STUDY OF USING THREE DIFFERENT ALGORITHMS IN INTENSITY MODULATED RADIOTHERAPY TECHNIQUE FOR BREAST TUMORS

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ABSTRACT

Our aim is to evaluate and compare between three different dose calculations algorithms (fast superposition (FSUP), superposition (SUP), and convolution (CON)) in IMRT (intensity modulated radiotherapy) treatment planning technique for breast cancer patients. Ten patients with left-side breast cancer were selected for this study. Dose of 5000 cGy was prescribed to planning target volume (PTV). For each patient, IMRT plans were created with non-coplanar and non-opposing photon beams of 6 MV quality. CMS XiO system of treatment planning (TPS) was the system for the process of planning. The percent of maximum variation observed between the three algorithms for PTV was 2.33% in average conformity index (CI), and for OARs was 2.68% in average D_{mean} in case of contralateral breast. Significant variations between three algorithms were observed. Due to our study, because the results between the three different algorithms show clear difference in some comparisons, considerable precaution unavoidable in treatment plans evaluation, because the dose calculation algorithm selection could effect on the process of treatment planning (TP) and also on the end medical results.

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INTRODUCTION

Conformal radiotherapy (also known as three-dimensional conformal radiotherapy or 3D-CRT) is a method of delivering radiotherapy that uses computer planning and treatment systems to tailor the size and shape of the dose area to the ideal target volume, with maximum exclusion of the surrounding healthy tissue. However, it should be noted that there exists a more advanced form of 3D-CRT called IMRT. In IMRT, the intensity of radiotherapy beam can be varied during the treatment, usually by computer-controlled movement of the multi leaf collimator (MLC) leaves. MLC is an automated device that is built into the head of the treatment machine. The main advantage of IMRT over conventional 3D-CRT is that it allows even greater conformity of dose to the target volume (Medical Services Advisory Committee, 2001). It is of paramount importance for the modern conformal radiotherapy technique to have accuracy in dose calculations in almost all relevant clinical situations (Garcia-Vicente *et al.,* 20013).

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The accuracy of dose calculation and the strict quality assurance program is essential in order to make sure that dose delivery to the tumor is 100% or close to 100% of the calculated dose. The dose calculations accuracy had been ameliorated by shifting from homogeneity corrections algorithms through algorithms of pencil beam arriving to kernel-dependent CON/SUP calculations algorithms (Vanderstraeten *et al.,* 2006). The efficiency of the system of TPare extremely reclined on the dose calculation algorithm used in treads of the process of planning. The algorithm is an arithmetic progression of directives that run on a group of input information, changing that data into a group of output consequences which are useful to the employer (Animesh, 2005). Both the CON algorithm of the XiO system and the SUP (Wiesmeyer and Miften, 1999) algorithm calculate the dose in the patient through total energy convolving with Monte Carlo kernels, discussed via Mackie *et al.* (1985). The selection of an algorithm is a significant regard while using "high-ended" planning ways and comparing between them (Beavis *et al.,* 2005; Miften *et al.,* 2002; Jeraj *et al.,* 2002). The present study is devoted to evaluate and compare three different dose calculation algorithms (FSUP, SUP, and CON) in IMRT TP technique for breast cancer patients.

MATERIALS AND METHODS

Ten patients with diagnosis of left-side breast cancer were selected for this study. Dose of 5000 cGy was prescribed to PTV. The mean age of patients was 52 years. Ipsilateral lung, heart, and contra lateral breast were delineated as OARs in all patients. TP targets for PTV and OARs were presented in table (1). IMRT plans were done for each patient with seven non-coplanar and non-opposing photon beams having 6 MV energy using CON, SUP, and FSUP algorithms.CMS XiO TPS was the system for the process of planning. Siemens artiste linear accelerator (linac; ART L4) treatment system was used in this study, the machine head is provided with MLC has two opposing sets, having 160-leaf with leaf width of 0.5 cm. The radiation therapy oncology group (RTOG) was recommended to use the conformity index$_{RTOG}$ in IMRT guidelines. The CI had been reported to define the conformity of the prescription isodose to the tumor as shown in the following equation:

$$CI_{RTOG} = \frac{V_{RI}}{TV} \quad \text{.......................................} \quad (1)$$

Where,
V_{RI}: Volume of the reference isodose (e.g. 95% isodose);
TV: Target volume (volume of the PTV; V_{PTV}).

The RTOG guidelines defined a ratio is situated between 1.0 and 2.0, treatment is considered to comply with the treatment plan, with values nearest to one mean the better conformation (Shaw *et al.,* 1993). The conventionally used homogeneity index (HI) is defined as the ratio of the maximum dose in PTV to reference isodose according to RTOG (Huchet *et al.,* 2003; Shaw *et al.,* 2000), with values nearest to one mean the best homogeneity. HI is given by:

$$HI_{RTOG} = \frac{D_{max}}{RI} \quad \text{.......................................} \quad (2)$$

Where,
D_{max}: Maximum isodose in the PTV;
RI: Reference isodose (e.g. 95% isodose).

For each plan, dose-volume histogram (DVH) was generated using CMS XiO TPS. D_{mean}, D_{max}, and D_{min} were recorded for OARs and PTV. HI and CI were computed for PTV in all patients. Maximum variations of D_{min}, D_{max} and D_{mean} were tabulated. The percent of maximum variations between the different algorithms were evaluated for OARs and PTV. To evaluate the doses to OARs, D_{max} was used. All treatment plans were evaluated with the evaluation parameters of the ICRU (International Commission on Radiation Units and Measurements) report 62 International Commission on Radiation Units and Measurements, 1999; Wu *et al.,* 2004).

RESULTS AND DISCUSSION

Comparisons between CON, SUP and FSUP algorithms for PTV

Figure (1) shows dose-volume histograms (DVHs) for breast cancer patient number one with IMRT treatment planning technique using CON, SUP, and FSUP algorithms. Figure (2) shows treatment plans of patient number one with IMRT technique using three different algorithms. Figure (3) shows a comparison between CON, SUP and FSUP according to D_{max} as percent of prescription dose for PTV in ten patients. The RTOG constraints for D_{max} for breast is that, $D_{max} \leq 110\%$ of prescription dose. It is clear from Figure (3), that D_{max} often cases in three algorithms not exceed than 110%. This means that all the plans for ten patients in three different algorithms are accepted and satisfied the RTOG constraints for D_{max}. Figure (4) shows a comparison between three algorithms according to D_{95} as percent of prescription dose for PTV in ten patients. The RTOG constraints for D_{95} in the plans of breast is that, $D_{95} \geq 95\%$ (> 90% accepted). It is clear that D_{95} of ten patients in CON, SUP and FUP are more than 90%. This means that all the plans for ten patients in three algorithms are accepted and satisfied the RTOG constraints for D_{95}.

Comparison between the three algorithms according toD$_{mean}$ relative differences with prescribed dose

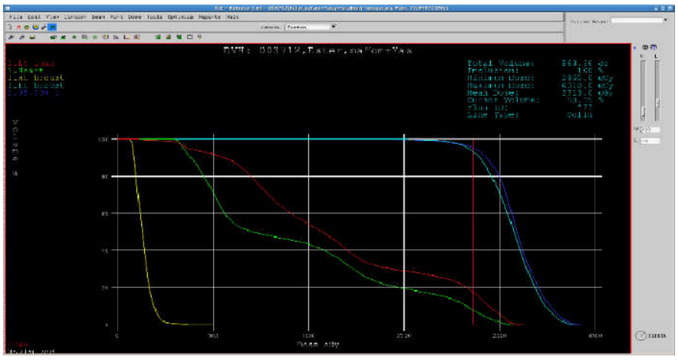
Figure (5) shows a comparison between CON, SUP and FSUP algorithms according to the average D_{mean} relative differences with prescribed dose for PTV of breast cancer patients with IMRT TP technique. The percent of maximum variation between the three algorithms was 0.50%. FSUP algorithm gave the minimum value of average D_{mean} relative difference with prescribed dose (0.04%). This means that, FSUP algorithm gives the minimum percent of deviation with the prescribed dose. So that, FSUP algorithm is better algorithm in IMRT technique for PTV of breast cancer patients when comparing the three algorithms according to the D_{mean} relative difference with prescribed dose.

Comparison between the three algorithms according to the homogeneity index (HI)

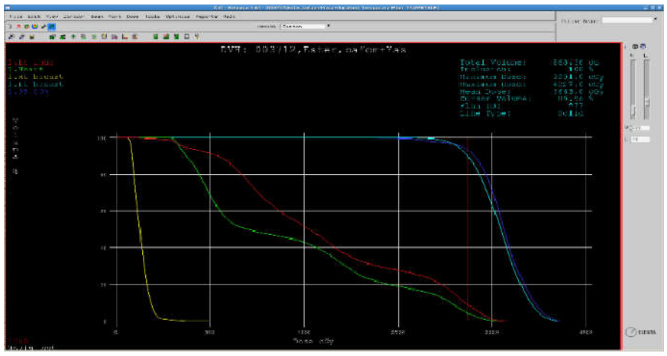
A comparison between CON, SUP and FSUP dose calculation algorithms according to the average homogeneity indexes for PTV of breast cancer patients with IMRT technique is shown in figure (6).SUP algorithm shows the minimum value of average HI (closer value to one). So that, SUP is better algorithm in IMRT treatment planning technique for PTV of breast cancer patients when comparing the three algorithms according to the homogeneity index. The difference between the SUP and FSUP algorithms is not large. Maximum percentage of variation between three algorithms for average HI values is 0.44%.

Table 1. Prescription of IMRT for PTV and OARs in breast cancer patients

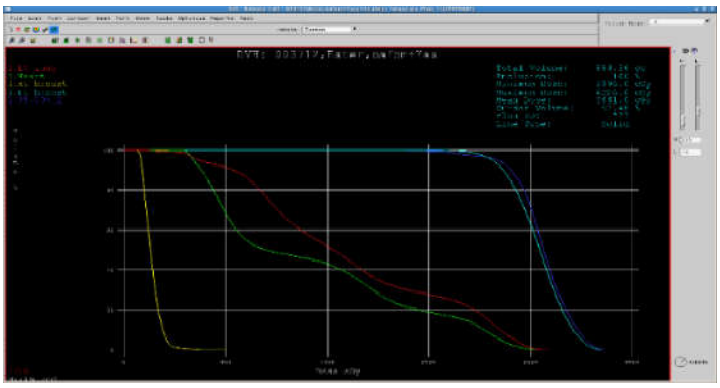
Site	IMRT Prescription		Rank	Objective	Dose	Volume	Weight	Power
	Structure	Type			(cGy)	(%)		
Breast	PTV	Target	1	Maximum	5100	0	100	3.3
				Goal	5000	100	-	1.0
				Minimum	4950	100	100	2.7
	Ipsilateral Lung	OAR	2	Maximum	1800	0	100	2.3
				Dose Volume	1500	15	100	2.3
	Heart	OAR	3	Dose Volume	900	15	100	2.2
	Contralateral Breast	OAR	4	Maximum	500	0	100	2.0



(a)

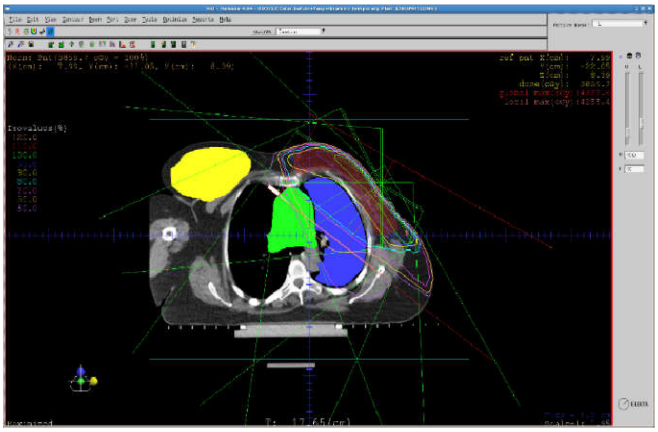


(b)

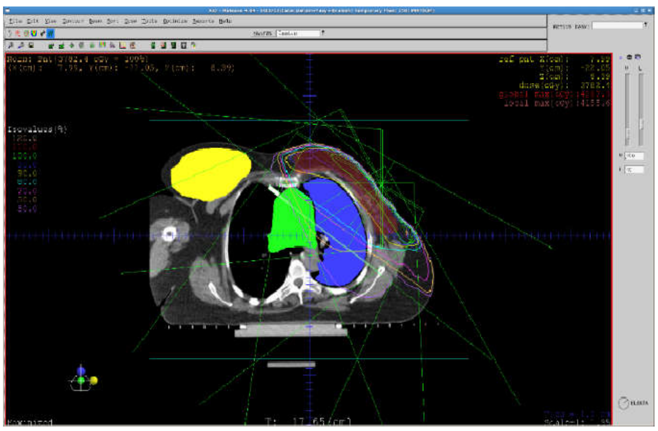


(c)

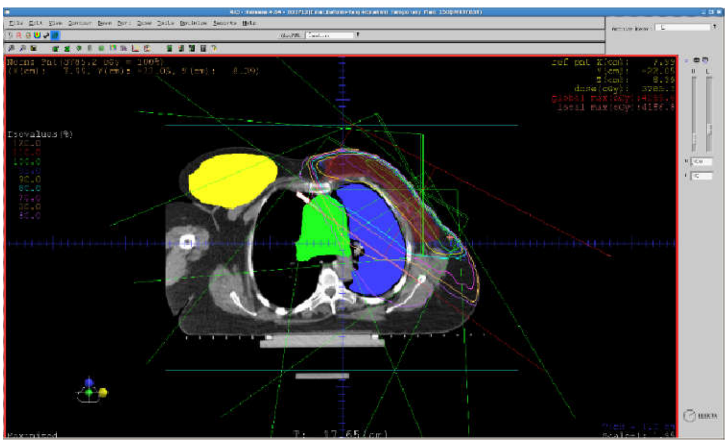
Figure 1. IMRT DVHs for breast cancer patient number one using (a) CON; (b) SUP; (c) FSUP algorithms



(a)



(b)



(c)

Figure 2. IMRT plans for breast cancer patient number one using (a) CON; (b) SUP; (c) FSUP algorithms

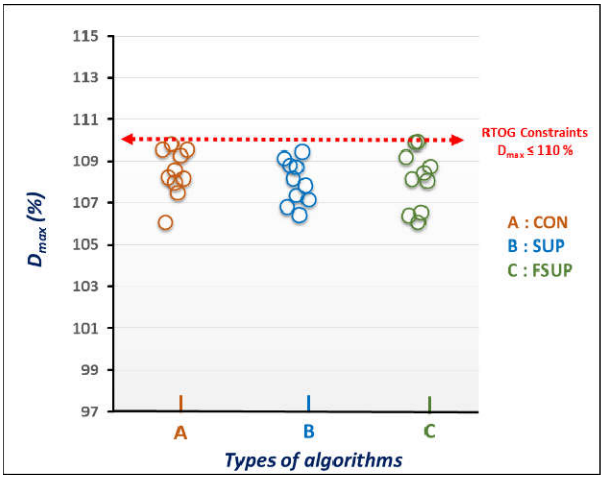


Figure 3. Comparison between three algorithms according to D_{max} for breast PTV with IMRT in ten patients

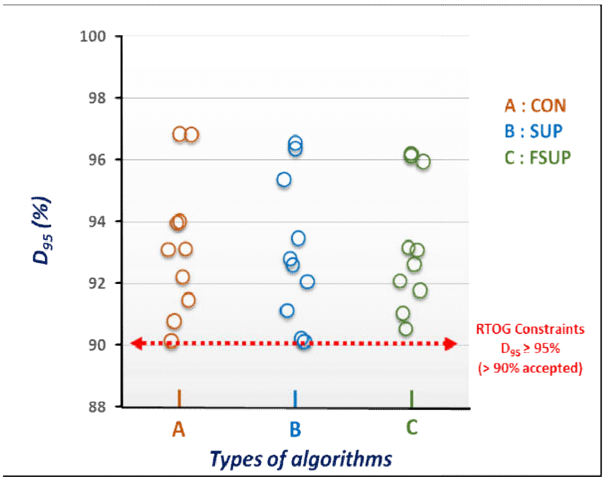


Figure 4. Comparison between three algorithms according to D_{95} for breast PTV with IMRT in ten patients

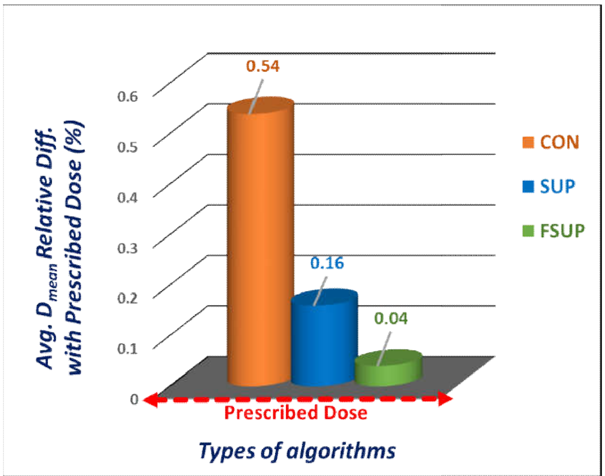


Figure 5. Comparison between three algorithms according to the average D_{mean} relative differences with prescribed dose for breast PTV with IMRT

Comparison between the three algorithms according to the conformity index (CI)

Figure (7) shows a comparison between three different algorithms according to the average conformity indexes for PTV of breast cancer patients with IMRT technique. CON algorithm shows the minimum value (1.176) of average CI.

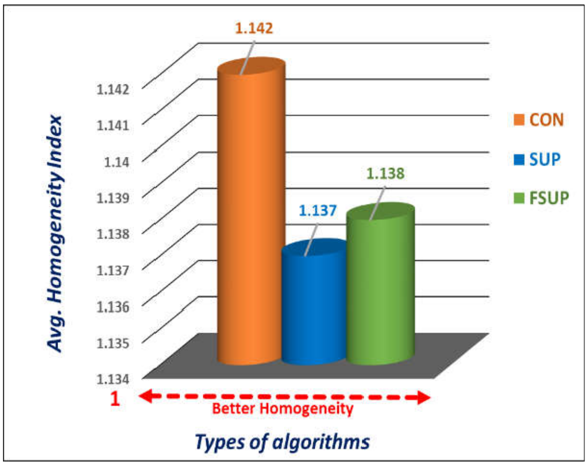


Figure 6. Comparison between three algorithms according to the average homogeneity indexes for breast PTV with IMRT

When the value of CI is one, this means that the conformity of the prescription isodose to tumor volume (PTV) is 100%, and as the value of CI close to one this indicates a better conformation. So, CON algorithm is better algorithm in IMRT technique for PTV of breast cancer patients when comparing the three algorithms according to the CI. The percent of maximum variation recorded between the three algorithms in average CI is 2.33%.

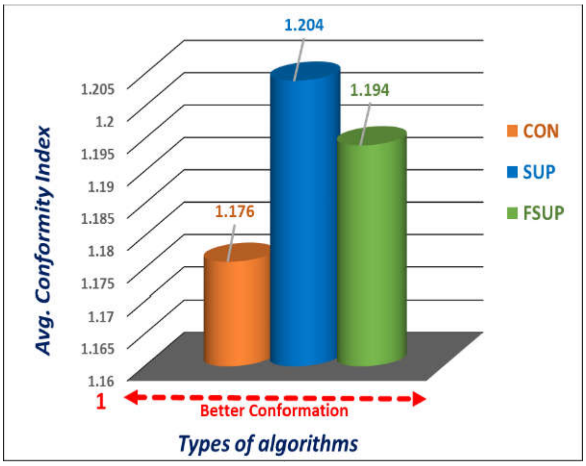


Figure 7. Comparison between three algorithms according to the average conformity indexes for breast PTV with IMRT

Comparisons between CON, SUP and FSUP algorithms for OARs

Comparison between three algorithms in ipsilateral lung

A comparison between CON, SUP and FSUP algorithms according to D_{30} for ipsilateral lung with IMRT technique in ten breast cancer patients is presented in figure (8). Figure (9) shows a comparison between three different algorithms according to average D_{30} for ipsilateral lung. The RTOG had defined the dose constraints of ipsilateral lung as an organ at risk in TP of breast as, D_{30} of ipsilateral lung ≤ 2000 cGy (which equal to 40% of the prescription dose; 5000 cGy). It is clear that all the values of D_{30} and average D_{30}in ten patients are under the RTOG constraints, and thus all the treatment plans are accepted and satisfied the RTOG constraints due to the dose received by the ipsilateral lung. Figure (10) shows a comparison between three algorithms according to D_{max} for ipsilateral lung in ten patients.

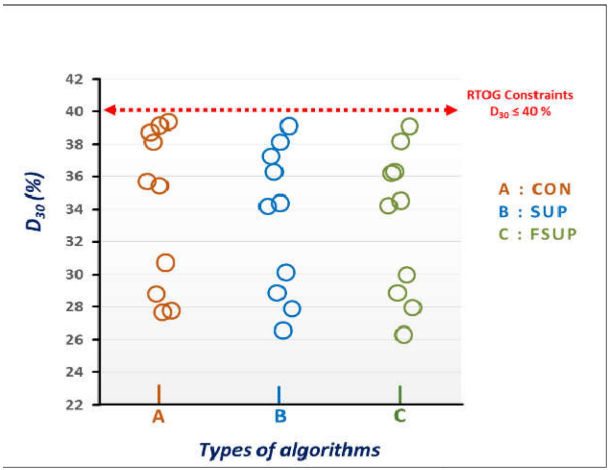


Figure 9. Comparison between three algorithms according to average D_{30} for ipsilateral lung with IMRT

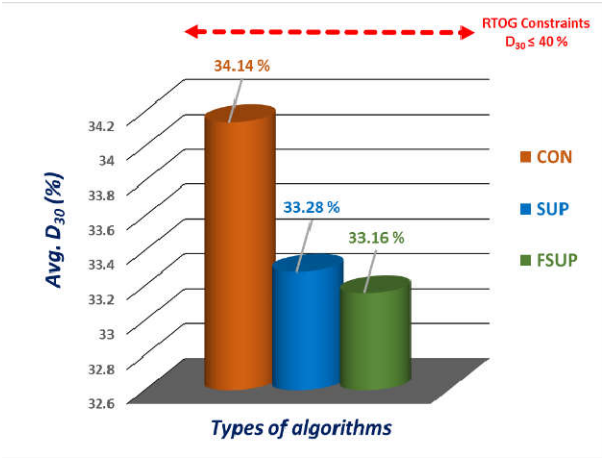


Figure 8. Comparison between three algorithms according to $D_{30}$for ipsilateral lung with IMRT in ten patients

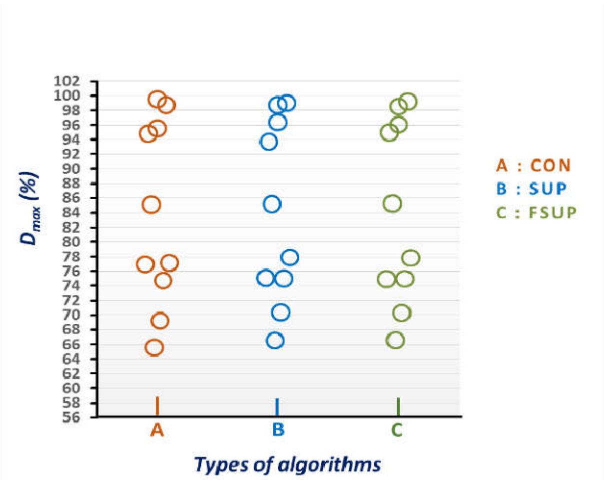


Figure 10. Comparison between three algorithms according to D_{max} for ipsilateral lung with IMRT in ten patients.

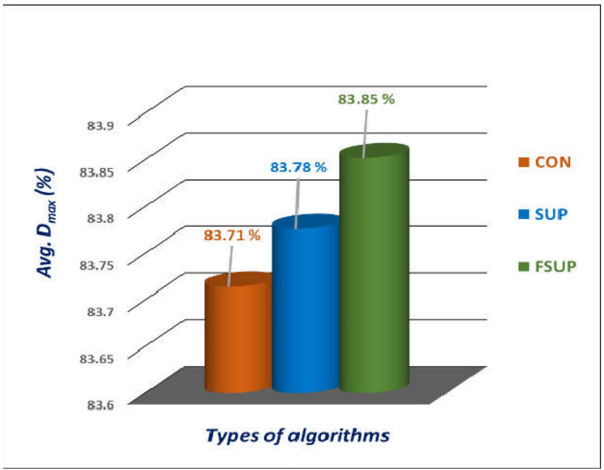


Figure (11): Comparison between three algorithms according to average D_{max} for ipsilateral lung with IMRT.

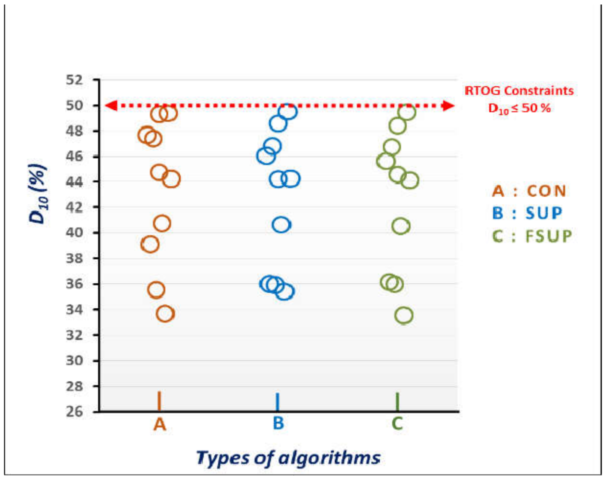


Figure 12. Comparison between three algorithms according to D_{10} for heart with IMRT in ten patients.

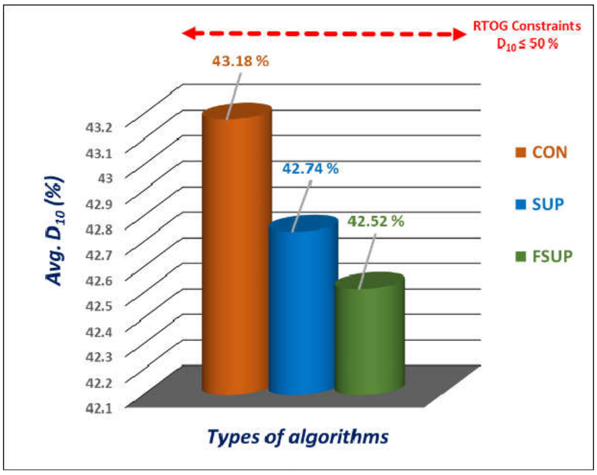


Figure 13. Comparison between three algorithms according to average D_{10} for heart with IMRT.

Figure (11) shows a comparison between three algorithms according to the average D_{max}. It can be noticed that the maximum value of average D_{max} is with FSUP (83.85%) and the minimum value is with CON (83.71%). This means that, ipsilateral lung gets the highest doses with FSUP and gets the lowest doses with CON algorithm. So that, CON is better algorithm in IMRT TPfor breast cancer patients when comparing the three algorithms according to the maximum dose received by the ipsilateral lung.

Comparison between three algorithms in heart

A comparison between CON, SUP and FSUP algorithms according to D_{10} for heart in ten patients is presented in figure (12). Figure (13) shows a comparison between three algorithms according to average D_{10}. The RTOG dose constraints of heart is $D_{10} \leq 2500$ cGy (50% of the prescription dose). All the plans are accepted and satisfied the RTOG constraints.

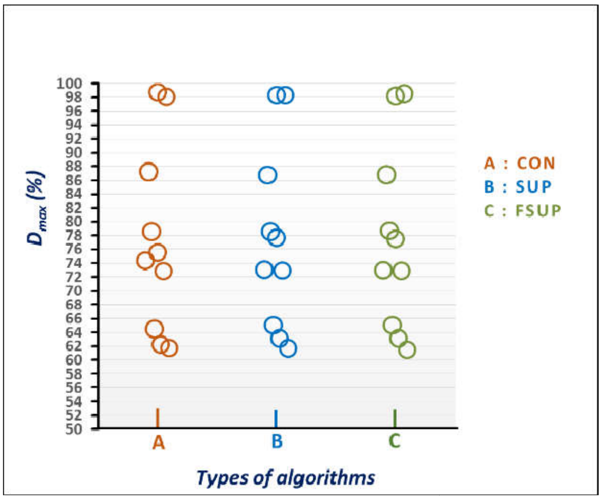


Figure 14. Comparison between three algorithms according to D_{max} for heart with IMRT in ten patients

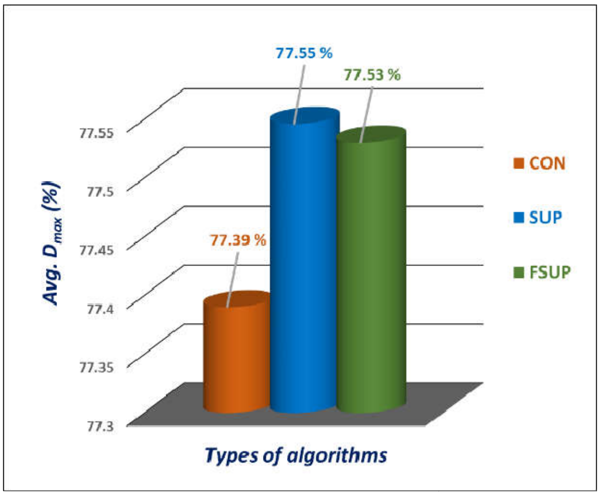


Figure 15. Comparison between three algorithms according to average D_{max} for heart with IMRT

Figure (14) shows a comparison between three algorithms according to D_{max}. Figure (15) shows a comparison between three algorithms according to average D_{max}. The maximum value of average D_{max} is with SUP (77.55%) and the minimum is with CON (77.39%). So, CON is better algorithm in IMRT TP for breast when comparing three algorithms according to the maximum dose received by heart. The difference between the FSUP and the SUP algorithms is not large.

Comparison between three algorithms in contralateral breast

Figure (16) shows a comparison between three algorithms according to D_{max} for contra lateral breast in ten patients. Figure (17) shows a comparison between three algorithms according to the average D_{max}. The RTOG constraints of contra lateral breast is D_{max} < 496 cGy (9.92 % of the prescription dose; 5000 cGy).All the values of D_{max} are less than the constraints, and thus all the plans are accepted and satisfied the RTOG constraints. The maximum value of average D_{max} is with FSUP (8.51%) and the minimum value is with SUP algorithm (8.38%). Thus, the contra lateral breast gets the highest doses with FSUP and gets the lowest doses with SUP algorithm. So that, SUP algorithm is better algorithm in IMRT TP for breast cancer patients.

Summary of the results

Table (2) shows a summary of the percent of maximum differences between three algorithms for average D_{mean}, D_{max}, and D_{min} of PTV and OARs. The minimum value of maximum percentage of difference between three algorithms is 0.45% in average D_{max} in case of PTV, while the maximum value is 2.68% in average D_{mean} in case of contra lateral breast. Significant variations between the three algorithms can be observed from the table.

Table 2. Summary of maximum differences (%) between three algorithms in average D_{min}, D_{max}, and D_{mean} of PTV and OARs

Organ		Breast
		IMRT
PTV	Maximum % of difference in avg. D_{mean}	0.50
	Maximum % of difference in avg. D_{max}	0.45
	Maximum % of difference in avg. D_{min}	1.00
	Minimum avg. D_{mean} relative difference is with	FSUP
	Maximum Avg. D_{max} is in	CON
	Minimum Avg. D_{max} is in	SUP
OAR 1		Ipsilateral Lung
	Maximum % of difference in avg. D_{mean}	2.42
	Minimum avg. D_{mean} is with	SUP
	Maximum Avg. D_{max} is in	FSUP
	Minimum Avg. Dmax is in	CON
OAR 2		Heart
	Maximum % of difference in avg. D_{mean}	0.72
	Minimum avg. D_{mean} is with	FSUP
	Maximum Avg. D_{max} is in	SUP
	Minimum Avg. Dmax is in	CON
OAR 3		Contralateral Breast
	Maximum % of difference in avg. D_{mean}	2.68
	Minimum avg. D_{mean} is with	SUP
	Maximum Avg. D_{max} is in	FSUP
	Minimum Avg. Dmax is in	SUP

Table 3. Summary of algorithmssuitability to the breast and the IMRT technique according to the minimum average D_{max} for OARs

Site	OAR	Technique	Algorithm
Breast	Ipsilateral Lung	IMRT	CON
	Heart		CON
	ContralateralBreast		SUP

Table 4. Summary of algorithms suitability to the breast and the IMRT treatment planning technique according to the PTV

Comparisons	Technique	Site
		Breast
D_{mean} relative difference with prescription dose	IMRT	FSUP
CI		CON
HI		SUP

Table (3) shows a summary of minimum average D_{max} for OARs. The organs get the lowest doses with the algorithms shown in the table. So, these algorithms is the most suitable with respect to the breast and IMRT due to the minimum D_{max}. Table (3): Summary of algorithms suitability to the breast and the IMRT technique according to the minimum average D_{max} for OARs. Table (4) shows a summary of the algorithms suitability to the breast and IMRT. The algorithms in the table showed the minimum values of average D_{mean} relative difference with the prescription dose and the minimum values of CI and HI. So that, these algorithms are the most suitable and the better than the other algorithms.

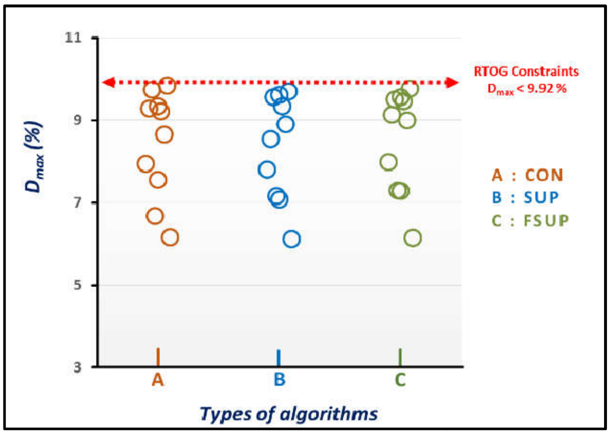


Figure 16. Comparison between three algorithms according to D_{max} for contralateral breast with IMRT in ten patients

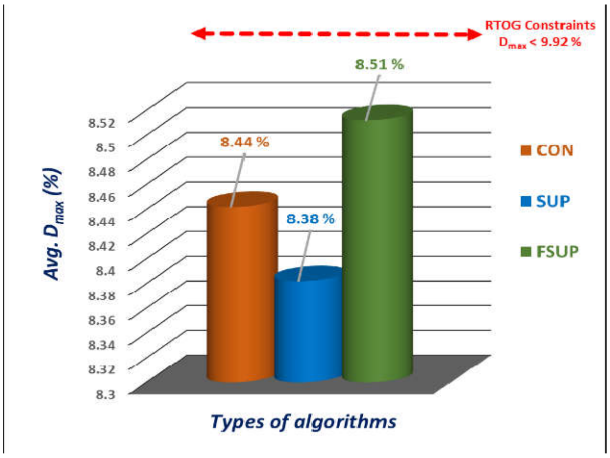


Figure 17. Comparison between three algorithms according to average D_{max} for contralateral breast with IMRT

Conclusion

- The percent of maximum variation observed between the three algorithms involved in our study for the PTV was 2.33% in average CI, and for the OARs was 2.68% in average D_{mean} in case of contra lateral breast.
- Significant variations between the three algorithms were observed according to the dosimetric results obtained from this study.
- Due to our study, because the results of the three different algorithms show clear difference in some comparisons, considerable precaution unavoidable in treatment plans evaluation, because the dose calculation algorithm selection could effect on the process of TP and also on the end medical results.
- We recommend to use the CON algorithm with IMRT technique in treatment planning of the left side breast. This recommendation is based on the better conformation of the prescription isodose to the tumor volume and the sparing of OARs which were achieved by this algorithm.

REFERENCES

Animesh, 2005. Advantages of multiple algorithms support in treatment planning system for external beam dose calculations. *J. Cancer Res. Ther.*, 1(1): 12-20.

Beavis AW, Abdel-Hamid A, Upadhyay S. 2005. Re-treatment of lung tumor using a simple intensity modulated radiotherapy approach. *Br. J. Radiol*., 78: 358-361.

Garcia-Vicente F, Minambres A, Jerez I, Modocell I, Perez L, Torres JJ. 2003. Experimental validation tests of fast-Fourier transform convolution and multigrid superposition algorithm for dose calculation in low density media. *J. Radiother. Oncol*., 67: 239-249.

Huchet A, Caudry M, Belkacemi Y, *et al*. 2003. Volume-effect and radiotherapy part two: Volume-effect and normal tissue. *Cancer Radiother*., 7: 353-362.

International Commission on Radiation Units and Measurements. "Prescribing, Recording and Reporting Photon Beam Therapy (Supplement to ICRU Report 50)". J. ICRU, ICRU Report 62, Washington DC: ICRU, 1999.

Jeraj R, Keall PJ, Siebers JV. 2002. The effect of dose calculation accuracy on inverse treatment planning. *J. Phys. Med. Biol*., 47: 391-407.

Mackie TR, Scrimger JW, Battista JJ. 1985. A convolution method of calculating dose for 15 MV x-rays. *J. Med. Phys*., 12: 188-196.

Medical Services Advisory Committee. *Conformal radiotherapy*. MSAC application 1038: http://www.msac.gov.au, 2001.

Mhtml:file://IN:\RadiationOncology-Toxicity-RTOG – Wiki books, open books for an open world, 2013.

Miften MM, Beavis AW, Marks LB. 2002. The influence of the dose calculation model on treatment plan evaluation in conformal therapy: A three case study. *J. Med. Dosim*., 27: 51-57.

Shaw E, Scott C, Souhami L, *et al*. 2000. Single dose radiosurgical treatment of recurrent previously irradiated primary brain tumors and brain metastases: Final report of RTOG protocol 90-05. *Int. J. Radiat. Oncol. Biol. Phys*., 47: 291-298.

Shaw, E. *et al*. 1993. Radiation Therapy Oncology Group: radiosurgery quality assurance guidelines. *Int. J. Radiat. Oncol. Biol. Phys*., 27: 1231-1239.

Vanderstraeten B, Reynaert N, Paelinck L, Madani I, De Wagter C, De Gersem W, *et al*. 2006. Accuracy of patient dose calculation for lung IMRT: A comparison of Monte Carlo, convolution/superposition, and pencil beam computations. *J. Med. Phys*., 33: 3149.

Wiesmeyer MD, Miften MM. 1999. A multigrid approach for accelerating three-dimensional photon dose calculation. *J. Med. Phys*., 26: 1149.

Wu VW, Sham JS, Kwong DL. 2004. Inverse planning in three-dimensional conformal and intensity modulated radiotherapy of mid-thoracic esophageal cancer. *Br. J. Radiol*., 77: 568-572.

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