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Plan evaluation of intensity modulated radiation therapy and volumetric modulated arc therapy in bilateral breast irradiation with 3-isocenter technique

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ABSTRACT

Background: Bilateral breast irradiation needs a sophisticated treatment planning due to large treated volume and the concern regarding low dose to the volume of irradiated normal lungs and heart.

Objectives: Aim of this study was to compare the dosimetric parameter between intensity modulated radiation therapy (IMRT) and volumetric modulated arc therapy (VMAT) plan with 3-isocenter technique for bilateral breast irradiation.

Materials and methods: Retrospective cases from 5 bilateral breast cancer were reviewed. Eclipse treatment planning version 11.0.31 was used for IMRT and VMAT optimization. The prescribed dose was 50 Gy in 25 fractions. Three isocenters were used to setup position; left, middle and right of PTV volume in lateral direction changes while the longitudinal and vertical directions were fixed. PTV of $D_{95\%}$, conformity index ($V_{prescribed}/V_{PTV}$) and dose homogeneity ($D_{5\%}$-$D_{95\%}$), mean lung dose (MLD) and volume receiving 20 Gy (V_{20Gy}), heart volume received dose 25 Gy (V_{25Gy}), maximum dose of left anterior descending coronary artery (LAD), and the number of MUs per fraction were compared for both techniques.

Results: Mean $D_{95\%}$ of PTV was 48.7±0.2 Gy for IMRT and 48.7±0.8 Gy for VMAT. Mean CI for IMRT and VMAT techniques were 0.97±0.0 and 0.98±0.0, respectively. IMRT plans showed significantly better for homogeneity of dose distribution in PTV volume than VMAT with the values of 5.6±0.7 Gy for IMRT and 7.6±1.1 Gy for VMAT. MLD was not significantly different between the plans 16.2±0.6 Gy (IMRT) and 16.6±0.9 Gy (VMAT). However, V_{20Gy} of lung showed significant difference for IMRT (25.8±4.8%) and VMAT (31.6±2.4%). The volume of heart received dose 25 Gy was 8.3±3.3% (IMRT) and 12.2±5.0% (VMAT). Two tails student t-test exhibited no significant differences between IMRT and VMAT in almost all parameters. Ratio of MU_{IMRT} to MU_{VMAT} was 3.0 which was the crucial part of using VMAT plan for treatment.

Conclusion: The 3-isocenter technique of VMAT plan for bilateral breast irradiation shows comparable plan quality to IMRT with shorter treatment delivery time. It demonstrates feasible to apply in clinical used due to short treatment time and easy setup.

Introduction

Bilateral breast cancer is a rare clinical manifestation and treatment of bilateral breast is a real challenge. Bilateral breast irradiation needs a sophisticated treatment planning due to the large treated volume and the concern regarding low dose to the volume of irradiated normal lungs and heart. The 3D tangential fields seem to be an appropriate technique because of shorter treatment time but the gap junction between medial fields of both sides is a technical issue. IMRT technique is time-consuming in treatment delivery from high number of MUs. VMAT technique is

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investigated to be feasible for irradiation in many clinical cases including breast cancer.[1-6] There is an advantage over IMRT in terms of treatment time efficiency. However, the use of gantry rotation in VMAT has limited the efficacy of its planning for bilateral breast irradiation. Single isocenter is not capable for dose coverage in the treatment target. We, therefore, study the feasibility of using 3-isocenter technique for bilateral breast irradiation and compare DVH parameter between IMRT and VMAT plan with this technique.

Materials and methods

This study was the retrospective of 5 bilateral breast cancer cases. Patient's position was supine on breast board (CIVCO Medical Solution, Iowa, USA) with both hands overhead. Knee support (Civco Radiotherapy, Iowa, USA) was used for patients to feel more comfortable during simulation and treatment. The Computed Tomography (CT) data was acquired with Siemens Somatom Definition AS Open 64 slices (Siemens, Erlangan, Germany) in 2 mm slice thickness. PTV volume and the main organs at risk (OARs), lung, heart and left anterior descending coronary artery (LAD) were delineated following the study from Dijkema *et. al*.[7] by the same radiation oncologist. PTV volume was removed from skin surface for 5 mm using Boolean function. Three isocenters were used to setup position: left, middle and right of PTV volume while the longitudinal and vertical were similar. Eclipse treatment planning version 11.0.31 was used for IMRT and VMAT optimization by using Varian clinac iX (Varian Oncology systems, Palo Alto, CA, USA) 6 MV with 120 MLCs. All plans were optimized by the same medical physicist. Beam angles for IMRT were 220°, 235°, 320°, 45° and 60° for the right lateral isocenter, 0° for the middle isocenter and 310°, 325°, 45°, 60°, and 115° for the left lateral isocenter. For VMAT technique, the gantry angles of partial arcs were utilized from 220° to 50° (CW-CCW-CW) for right lateral isocenter, 140° to 310° (CCW-CW) for the middle isocenter and 310° to 140° (CCW-CW-CCW) for the left lateral isocenter. Collimator was rotated about 5° to 10° to minimize the tongue and groove effect.[8] Isocenter setup and beam angles for IMRT and VMAT plans are shown in Figure 1. The prescribed dose was 50 Gy in 25 fractions. Criteria for dose optimization were 95% of PTV volume receiving the prescribed dose. The maximum dose was lower than 107%. The mean lung dose (MLD) and volume receiving 20 Gy (V_{20Gy}) were lesser than 16 Gy and 22%, respectively. The dose in all plans were kept as low as possible to spare lung, heart and LAD including minimize mean and maximum dose. The PTV volume of $D_{95\%}$, Conformity index (volume of prescribed dose divided by the PTV volume: $V_{prescribed}/V_{PTV}$) and dose homogeneity ($D_{5\%}$-$D_{95\%}$), MLD and V_{20Gy} of lung, the heart volume received dose 25 Gy (V_{25Gy}), maximum dose of LAD and the number of MUs per fraction were compared for both techniques.

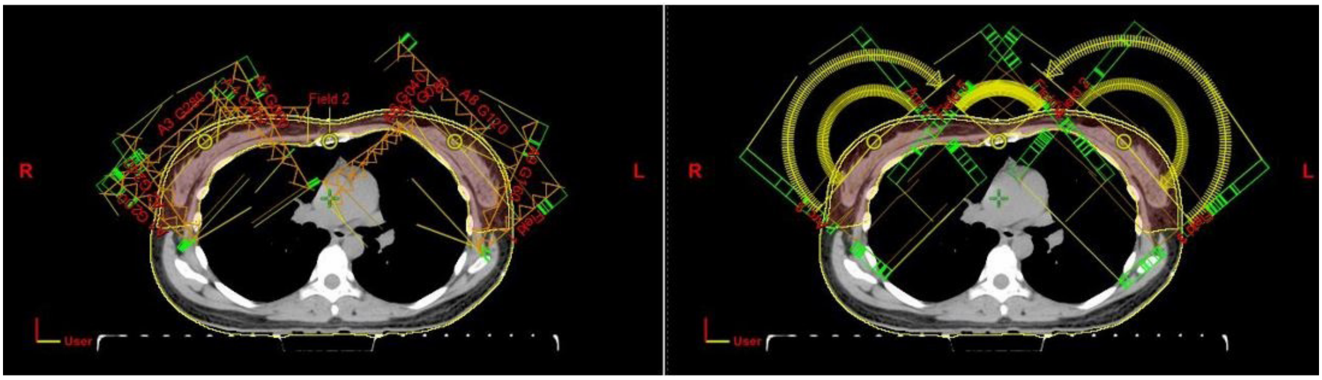

Figure 1 *Isocenter setup and beam angles for IMRT (left) and VMAT (right) planning.*

Results

Mean lung volume and PTV volume were 2624±93 cm^3 and 1459±440 cm^3, respectively. Mean dose of $D_{95\%}$ for PTV volume was 48.7±0.2 Gy for IMRT and 48.7±0.8 Gy for VMAT. Mean CI between IMRT and VMAT plans presented small differences with the value of 0.97±0.0 for IMRT and 0.98±0.0 for VMAT. IMRT plans showed significantly better dose homogeneity of dose distribution in PTV volume than VMAT plans was supported by p value. PTV dose homogeneity was 5.6±0.7 for IMRT and 7.6±1.1 for VMAT. Lung volume of V_{20Gy} showed higher dose than criteria (22 Gy), 25.8±4.8% for IMRT and 31.6±2.4% for VMAT, which was significantly difference. MLD was still within the criteria, 16.2±0.6 Gy (IMRT) and 16.6±0.9 Gy (VMAT). The volume of heart received dose 25 Gy was 8.3±3.3% (IMRT) and 12.2±5.0% (VMAT). Maximum dose of LAD was 37.3±3.0 and 37.0±6.4 for IMRT and VMAT, respectively. Ratio of MU_{IMRT} to MU_{VMAT} of 3.0 represented longer treatment time in IMRT. Summary of DVH based analysis is explored in Table 1. VMAT plan showed V_{20Gy} of lung higher significantly than the IMRT plan because the VMAT plan has more beam entry angles.[8] However, the mean lung dose was not significantly different in both plans and was within the criteria. This was consistent with Nicolini *et at*.[9] study where they found VMAT produced better sparing at the mid- to high- dose levels compared with IMRT. In addition, VMAT generates lower number of MU needed compared with IMRT plan. Another major factor to evaluate was the treatment time. The longer treatment time may induce intrafraction motion which lead to increased doses to OARs.[10] Overall, the VMAT showed more effective plan than the IMRT plan in regards to the non-significant differences in two tails student t-test in almost parameters and lesser the treatment time. Isodose distribution as an example of both techniques is shown in Figure 2. DVH of PTV and OARs of the same case are shown in Figure 3.

Table 1 Summary of DVH based analysis of bilateral breast cancer.

Organs/parameters	Criteria	IMRT	VMAT	*p* value
PTV				
- $D_{95\%}$ (Gy)	At least 47.5 Gy	48.7±0.2	48.7±0.8	0.94
- CI	Close to 1	0.97±0.0	0.98±0.0	0.55
- Dose homogeneity	Close to 0	5.6±0.7	7.6±1.1	<0.05*
Lung				
- Mean (Gy)	22 Gy	16.2±0.6	16.6±0.9	0.54
- V_{20Gy} (%)	20%	25.8±4.8	31.6±2.4	<0.05*
Heart				
- V_{25Gy} (%)	25%	8.3±3.3	12.2±5.0	0.27
Max. LAD (Gy)	50 Gy	37.3±3.0	37.0±6.4	0.93
Total MUs		2621.05±390.3	865.7±81.4	<0.05*

**Significant relative difference tested by two-tailed student t-test*

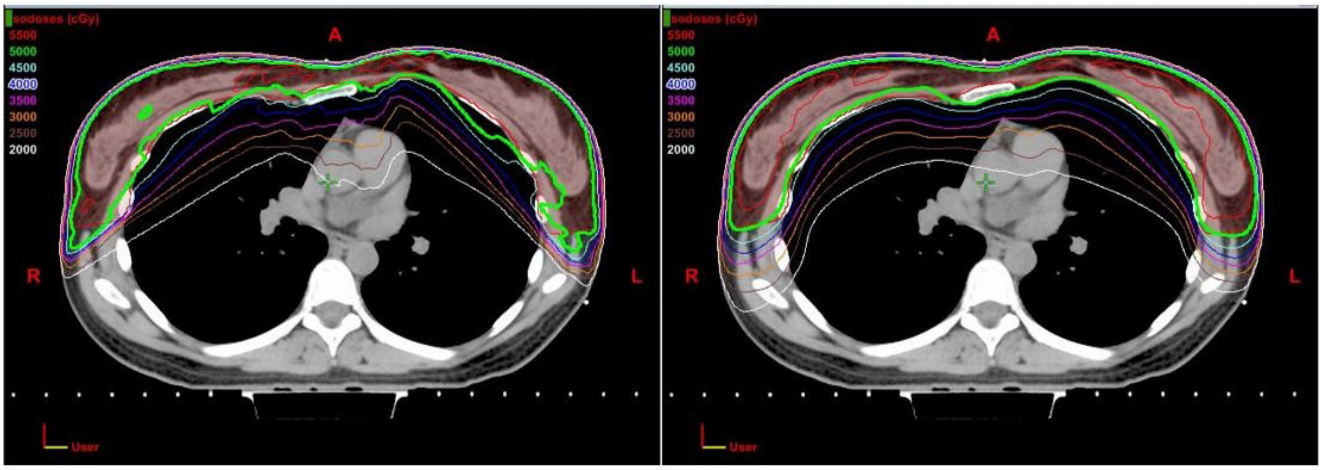

Figure 2. *Isodose distribution of the example case for IMRT (left) and VMAT (right) plan.*

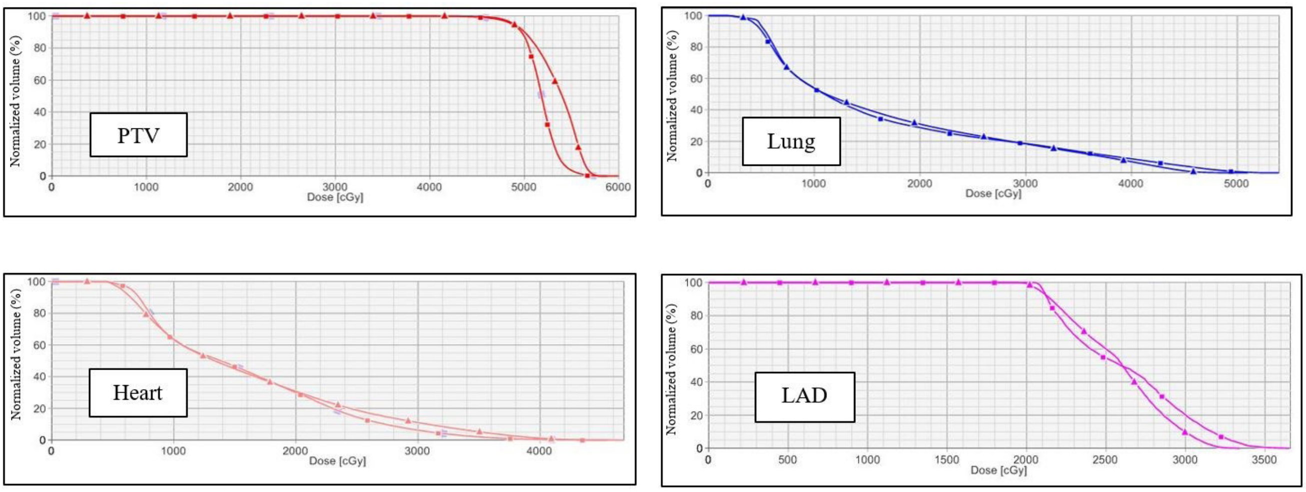

Figure 3. *Isodose distribution of the example case for IMRT (square) and VMAT (triangle) plan.*

Discussion

Our study discovered that IMRT and VMAT techniques for bilateral breast irradiation were comparable for DVHs analysis which which agreed well to the results from Nicolini *et al*.[8] However, the study by Nicolini had created the treatment plans with only single isocenter due to the supine position without breast board. In our study, patient was supine on the breast board with both hands overhead. If the plans were performed using a single isocenter, the isodose distribution to PTV volume would not be covered by the prescribed dose due to the limitation of the gantry rotation and the couch position. The other consideration taken into account was the treatment delivery of VMAT. Delivery time of VMAT plan was significantly shorter than IMRT technique.

Conclusion

Overall, the 3-isocenter technique of VMAT plan presented comparable plan quality to IMRT for bilateral breast irradiation although larger volume of lung receiving low dose was discovered in regards to more beam entry angles. However, the delivery time of VMAT was found shorter 3 times in comparison to IMRT. In addition, the setup technique was easy for technologist as it only shifted the couch position to lateral direction. Therefore, it is feasible to apply this technique in clinical situation.

Conflict of interest

We hereby state that there is no conflicts of interest.

Acknowledgments

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