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Non-Coplanar VMAT Improves Plan Quality for Locoregional Radiotherapy of Left-Sided Breast Cancer with Internal Mammary Nodes

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INTRODUCTION

Internal mammary nodes (IMN) are commonly founded in around 20%~30% breast cancer patients. Adjuvant radiotherapy after breast conserving surgery is proved to be effective in reducing the risk of recurrence and death from breast cancer. For breast cancer radiotherapy, IMN and supraclavicular nodes (SCN) are often included in the planning target volume (PTV) to improve the local control. However, it is well known that irradiation of IMN region inevitably increase the dose delivering to heart and lungs, which increases the risk of radiation pneumonitis and cardiac mortality.

Non-coplanar technology has the reputation for extending the beam angle arrangements and therefore better sparing OARs. This can be realized with C-arm linac by rotating the treatment couch around the isocenter. In this study, 4 arcs non-coplanar volume modulated arc therapy (ncVMAT) plans with 2 non-coplanar arcs and 2 coplanar arcs were optimized for locoregional radiotherapy of left-sided breast cancer, and dosimetric parameters such as target coverage, conformity index, homogeneity index and OAR sparing were compared with coplanar VMAT (coVMAT) plan.

AIM

A planning study was performed to evaluate ncVMAT for locoregional radiotherapy of left-sided breast cancer with internal mammary nodes comparing with coVMAT.

METHOD

The retrospective study was approved by the institutional review board and informed consent was waived. 10 patients with left-sided breast cancer including internal mammary nodes after breast-conserving surgery were selected for our study. The planning target volumes (PTV) were contoured encompassing the whole breast/chestwall, internal mammary nodes (IMN) and supraclavicular nodal (SCN) region.

6 MV photon beams delivering with a Elekta Versa HD linear accelerator were utilized for planning. The ncVMAT was optimized with 4 arcs composing with 2 coplanar arcs and 2 non-coplanar arcs. The 2 coplanar arcs ranged from 310° to 140° with both clockwise and counter-clockwise rotation. The non-coplanar arc varies from 345° to 40° (both clockwise and counter-clockwise) with couch rotating to 90°. For coVAMT plans, identical coplanar beam angles were used for each patient with two arcs for optimization. All plans were optimized to cover at least 95% of PTVall with prescription dose and decrease the dose delivering to OARs as much as possible. For each patient, the optimizing parameters were similar between ncVMAT and coVMAT plan with minor adjustments.

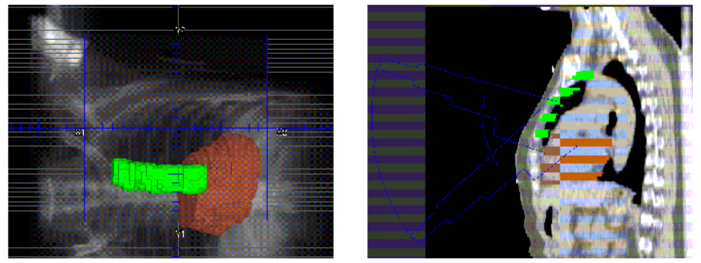

Figure 1. Illustration of 345° beam eye view (left) and the beam angle (right) for non-coplanar arc. (Colorwash: green--PTVimn, brown--heart)

RESULTS

As an example, the axial dose distribution of both non-coplanar and coplanar plans are illustrated in Figure 2. It is obvious in Figure 2 that a better conformity of doselines from 500 cGy to 4000 cGy is shown with non-coplanar VMAT on this layer. This can be also seen in the dose volume histogram of PTV and selected OARs in Figure 3. For this case, non-coplanar plan provided better sparing for LAD, heart and bilateral lung and better homogeneity for PTVimn.

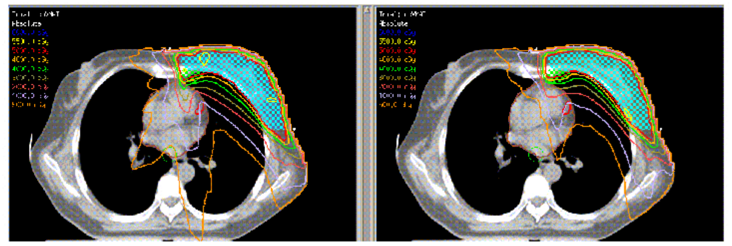

Figure 2. Comparison of axial dose distribution between coVMAT (left) and ncVMAT (right) (Colorwash: Green—PTVimn, Skyblue--PTVbreast; Contour: red--LAD, brown--heart)

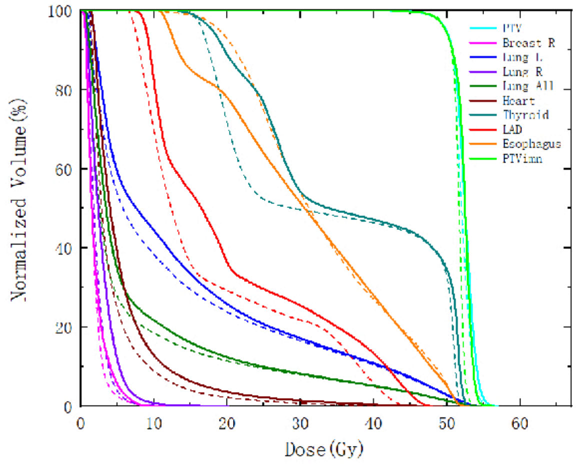

Figure 3. The dose volume histogram of PTV and selected OARs. (Solid line--coVMAT, dash line--ncVMAT)

Table 1. Comparison of dosimetric parameters between coVMAT and ncVMAT for PTV

	Parameters	coVMAT	ncVMAT	*p*
PTVall	CI	0.82±0.02	0.86±0.01	0.005
	HI	1.11±0.02	1.10±0.02	0.009
	V_{55} (%)	11.40±7.88	7.97±7.10	0.059
PTVimn	V_{45} (%)	98.40±1.30	99.89±0.05	0.007
	V_{50} (%)	88.77±3.09	96.14±0.68	0.005
	V_{55} (%)	13.73±7.77	3.26±4.05	0.005
PTVsc	V_{50} (%)	94.51±1.76	95.01±0.35	0.575
	V_{55} (%)	5.76±6.03	4.27±7.05	0.005
PTVbreast	V_{50} (%)	95.98±0.39	95.42±0.55	0.047
	V_{55} (%)	13.28±8.95	9.28±7.82	0.047

- ***PTV:*** All plans were normalized to cover 95% volume of PTVall with the prescription dose 50 Gy. The 110% prescripition dose volume V_{55} in PTVbreast, PTVscn, PTVimn decreased obviously with ncVMAT from 13.28±8.95%, 5.76±6.03%, 13.73±7.77% to 9.28±7.82% (p=0.047), 4.27±7.05% (p=0.005), 3.26±4.05% (p=0.005), separately. Furthermore, the mean conformity index of the PTVall increased from 0.82±0.02 to 0.86±0.01 (p=0.005), and the homogeneity index decreased slightly (p=0.009).
- ***Lungs:*** The mean V_{20}, V_{10}, V_5 of left lung decline significantly from 24.95±2.61%, 45.44±6.45%, 72.82±13.00% to 22.22±3.42% (p=0.005), 38.57±5.04% (p=0.005), 64.38±9.43% (p=0.005), separately. The mean V_{10} and V_5 of contralateral lung also decreased from 1.53±0.85% and 14.67±6.21% to 0.66±0.53% (p=0.007) and 8.05±3.56% (p=0.005), seperately. The mean lung dose (MLD) of left lung and right lung were both reduced from 14.80±1.61 Gy and 3.19±0.48 Gy to 13.50±1.50 Gy (p=0.005) and 2.61±0.33 Gy (p=0.005).

Table 2. Comparison of dosimetric parameters between coVMAT and ncVMAT for heart and lung

	Parameters	coVMAT	ncVMAT	*p*
Heart	V_5 (%)	72.03±16.79	58.23±13.77	0.007
	V_{10} (%)	33.98±15.73	22.19±10.88	0.005
	V_{20} (%)	12.18±7.29	8.76±5.33	0.007
	V_{30} (%)	5.13±3.22	4.44±3.03	0.074
	Dmean (Gy)	10.47±2.97	8.60±2.37	0.005
Left lung	V_5 (%)	72.82±13.00	64.38±9.43	0.005
	V_{10} (%)	45.44±6.45	38.57±5.04	0.005
	V_{20} (%)	24.95±2.61	22.22±3.42	0.005
	Dmean (Gy)	14.80±1.61	13.50±1.50	0.047
Contralateral lung	V_5 (%)	14.67±6.21	8.05±3.56	0.005
	V_{10} (%)	1.53±0.85	0.66±0.53	0.007
	Dmean (Gy)	3.19±0.48	2.61±0.33	0.047

- ***Heart:*** It is illustrated in Table 2, the average V_{20}, V_{10}, V_5 of heart decline significantly from 12.18±7.29%, 33.98±15.73%, 72.03±16.79% to 8.76±5.33% (p=0.007), 22.19±10.88% (p=0.005), 58.23±13.77% (p=0.007), separately. There was no significant difference in V_{30} of heart comparing non-coplanar arcs with coplanar arcs (p>0.05). The mean dose of heart was reduced from 10.47±2.97 Gy to 8.60±2.37 Gy (p=0.005), and there was a decrease of 17.8% in D_{mean} of heart.

Table 3. Comparison dosimetric parameters between coVMAT and ncVMAT for other OARs

	Parameters	coVMAT	ncVMAT	*p*
Contralateral breast	V_5 (%)	8.90±5.64	5.95±2.89	0.009
	V_{10} (%)	0.50±0.70	0.09±0.19	0.008
	Dmean (Gy)	2.45±0.64	2.17±0.42	0.005
LAD	Dmax (Gy)	45.41±8.74	43.39±9.46	0.008
	Dmean (Gy)	23.77±6.73	20.61±6.78	0.005
Left humeral head	V_{30} (%)	6.59±14.27	4.54±6.03	0.893
	Dmean (Gy)	17.74±6.69	16.43±5.51	0.059
Esophagus	Dmax (Gy)	53.09±0.38	53.03±1.01	0.878
	Dmean (Gy)	30.85±3.96	32.13±4.63	0.059
Left brachial plexus	Dmax (Gy)	54.30±0.62	53.89±0.83	0.114
	Dmean (Gy)	50.42±1.33	50.41±0.69	0.799
Thyroid	V_{30} (%)	49.42±8.80	48.41±6.72	0.575
	Dmax (Gy)	54.58±0.95	54.19±1.03	0.139
	Dmean (Gy)	31.30±4.03	31.57±3.25	0.445
Spinal cord	Dmax (Gy)	30.26±4.58	30.65±4.40	0.445

- ***LAD and Right breast:*** The V_{10}, V_5 and D_{mean} of contralateral breast and the average maximum does (D_{max}) and D_{mean} in LAD descending coronary artery were reduced comparing ncVMAT with coVMAT (p<0.01).
- ***Other OARs:*** There is no significant difference for other OARs.

CONCLUSIONS

Non-coplanar VMAT for locoregional radiotherapy of left-sided breast cancer with internal mammary nodes was studied comparing with normal coplanar VMAT. With introducing two additional non-coplanar arcs, the conformity, homogeneity and the hot spot V_{55} of PTV were all improved obviously. For OARs, non-coplanar VMAT provided better dose sparing in heart, bilateral lung, LAD and right breast with no significant difference for other OARs. In conclusion, ncVMAT has potential benefits for reducing the risk of toxicities in left-sided breast cancer.

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