Original Article

Dosimetric comparison of anterior posterior-posterior anterior 2-field three-dimensional conformal radiotherapy, 4-field three-dimensional conformal radiotherapy and "forward" plan intensity modulated radiotherapy techniques in female lymphoma patients irradiated to neck and mediastinum

Nilsu Çini, Cenk Umay[1], Okan Özdemir[2], İlknur Alsan Çetin[3], Hakan Epik[4], Ayşe Nur Demiral[1]

Department of Radiation Oncology, Dr. Lütfi Kırdar Kartal Training and Research State Hospital, Kartal, [3]Department of Radiation Oncology, Marmara University Medical Faculty, Göztepe, Istanbul, [1]Department of Radiation Oncology, Dokuz Eylül University Medical Faculty, [4]Department of Physics, Dokuz Eylül University Science Faculty, Tınaztepe, Izmir, [2]Department of Radiation Oncology, Erzurum Regional Training and Research State Hospital, Yakutiye, Erzurum, Turkey

For correspondence:
Dr. Cenk Umay, Department of Radiation Oncology, Dokuz Eylül University Medical Faculty, İnciraltı 35340, Izmir, Turkey. E-mail: umaycenk@gmail.com

ABSTRACT

Aim: Dosimetric comparison of three different techniques in female lymphoma patients who had radiotherapy (RT) to the neck and mediastinum.

Setting and Design: Retrospective clinical study.

Materials and Methods: Computerized tomography-simulator images of eight patients were obtained retrospectively. Using 6 MV-X photon energy, RT plans were formed with three different techniques (anterior posterior-posterior anterior 2-field three-dimensional conformal RT [AP-PA 2-field 3D-CRT], 4-field 3D-CRT and "forward" plan intensity modulated RT [FPIMRT]). Comparisons were in terms of homogeneity index (HI), conformity index (CI), and inhomogeneity coefficient for planning target volume (PTV); mean lung dose, V_{5Gy}, V_{10Gy}, V_{20Gy}, V_{30Gy} for lung; D_{mean}, $V_{7.5Gy}$, V_{15Gy}, V_{25Gy} for heart; D_{mean}, $V_{3.5Gy}$, V_{10Gy}, V_{20Gy} for breast; D_{max} for spine; D_{mean}, V_{10Gy}, V_{18Gy}, V_{25Gy}, V_{30Gy} for thyroid.

Statistical Analysis Used: Since nonparametric tests had to be used due to the study population being < 30, Friedman and Wilcoxon signed-rank tests were implemented in trilateral and bilateral comparison of techniques, respectively. For statistical significance, *P* value was required to be <0.05.

Results: When FPIMRT was compared with AP-PA and 4-field techniques with respect to, HI (AP-PA/FPIMRT *P*: 0.017; 4-field/FPIMRT *P*: 0.03) and CI (AP-PA/FPIMRT *P*: 0.018; 4-field/FPIMRT *P*: 0.042), FPIMRT was more advantageous. In addition, FPIMRT was found more useful in terms of D_{max} (AP-PA/FPIMRT *P*: 0.012; 4-Field/FPIMRT *P*: 0.012) for spinal cord and D_{mean} (AP-PA/FPIMRT *P*: 0.012; 4-field/FPIMRT *P*: 0.012) for thyroid.

Conclusion: FPIMRT was superior in terms of PTV homogeneity and conformity. However, it was observed that for normal tissues, FPIMRT was advantageous only for spinal cord and thyroid; but it was not the most advantageous technique for some of the dose-volume parameters of the breast, lung, and heart.

KEY WORDS: Dose-volume parameters, female, "forward" plan intensity modulated radiotherapy, lymphoma, three-dimensional conformal radiotherapy

INTRODUCTION

In the treatment of lymphoma, combined modality therapy is used.[1] Relatively large treatment

Access this article online

Website: www.cancerjournal.net

DOI: 10.4103/0973-1482.193108

Quick Response Code:

Cite this article as: Çini N, Umay C, Özdemir O, Çetin İA, Epik H, Demiral AN. Dosimetric comparison of anterior posterior-posterior anterior 2-field three-dimensional conformal radiotherapy, 4-field three-dimensional conformal radiotherapy and "forward" plan intensity modulated radiotherapy techniques in female lymphoma patients irradiated to neck and mediastinum. J Can Res Ther 2018;14:1389-96.

fields, as well as high cure rates, cause an increased risk of late adverse effects and secondary cancers in these young patients.[2] Decreasing field sizes, as well as different treatment planning techniques, are used to reduce these problems.

In this context, this study aimed to compare three different techniques (anterior posterior-posterior anterior 2-field three-dimensional conformal radiotherapy [AP-PA 2-field 3D-CRT], 4-field 3D-CRT and "forward" plan intensity modulated radiotherapy [FPIMRT]) in terms of planning target volume (PTV) dose homogeneity and conformity as well as doses received by normal tissues in lymphoma patients receiving RT to the neck and mediastinum.

MATERIALS AND METHODS

This study was performed after the institutional review board approval was obtained.

The treatment planning system (TPS) archive of the Radiation Oncology Department was screened to find the lymphoma patients who were compatible with the inclusion criteria treated between 2010 and 2012. Computerized tomography (CT)-simulator device data of a group of eight female patients were used in the study. Treatment planning was implemented for each patient using three different predetermined techniques (AP-PA 2-field 3D-CRT, 4-field 3D-CRT, FPIMRT). Three techniques were compared with respect to the dose-volume parameters for the specified organs, as well as the parameters related to PTV homogeneity and conformity.

Inclusion criteria were having a diagnosis of lymphoma, having only neck and mediastinum lymphatics within the radiation field, being treated with 3D-CRT, female gender, >10 years of age, and having both breasts intact. Exclusion criteria were having mandibula within the radiation field, involvement of axillary lymphatic area, male gender, <10 years of age, and any one of the breasts having surgical excision.

In the study, the images had been obtained previously using the X-ray CT-simulator device of "Siemens" brand, and "Emotion" model. While taking the images, the patients had been placed in supine position with either both arms on the side or in akimbo (hands on waist) position. The patients had been immobilized at treatment position on the CT-simulator table. Furthermore, Nucletron "Oncentra Masterplan®" TPS system was used in the study.

In all cases, CTV and organs at risk were contoured by a radiation oncology specialist or else checked and revised as necessary if they had been contoured previously [Figure 1]. CTV contouring was performed according to involved field RT recommendations.

Afterward, the treatment plan was implemented for each patient with three different techniques (AP-PA 2-field 3D-CRT,

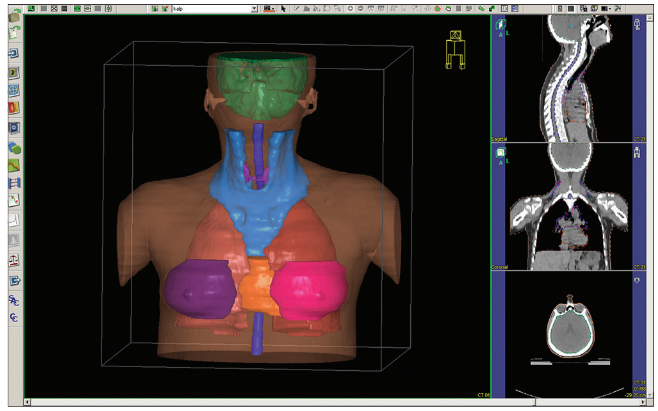

Figure 1: Three-dimensional image of the sample case obtained with contouring of target volume and normal tissues by the radiation oncologist on sections transmitted to the planning computer from the computerized tomography-simulation device; views of sagittal, coronal, and axial sections

4-field 3D-CRT, FPIMRT). In all three techniques, 6 MV-X radiation energy was used. The reason for using 6 MV-X was to ensure the desired dose distribution in PTV, because of the presence of neck, a relatively thin structure, as well as the proximity of neck lymphatics to the surface. Virtual RT plans were created using conventional fractionation scheme of 14.4–30.6 Gy total dose in 5 fractions/week with 1.8 Gy fraction dose. Total predetermined doses that had been adjusted according to the patients' age, lymphoma subtype, and patients' response to chemotherapy were not altered. Since this study is on wide RT fields, treatment planning was not performed for boost fields in the study.

In the AP-PA 2-field 3D-CRT technique, gantry angles 0° and 180° were used with the isocenter being at the geometrical center of PTV [Figure 2]. Treatment fields were formed giving 8 mm safety margin to PTV in "auto-MLC" mode. To ensure a more homogeneous dose distribution at PTV, extra MLC margin was allowed for the upper and lower margins of the RT fields. Since PTV was closer to the front, anterior beam weighting (AP 60%, PA 40%) was implemented.

In the 4-field 3D-CRT technique, gantry angles of 0°, 180°, 318°, and 42° were used with the isocenter being at the geometrical center of PTV. Treatment fields were formed giving 8 mm safety margin to PTV in "auto-MLC" mode. To ensure a more homogeneous dose distribution at PTV, extra MLC margin was allowed for the upper and lower margins of the RT fields. Wedges of 15° were used in anterior-oblique fields [Figure 3]. Thus, while the doses are reduced in the anterior neck region, where maximum doses tend to occur due to its thinness, the doses in the lateral and deep parts of PTV could be compensated. Anterior beam weighting was performed (AP 30%, anterior-oblique fields 15% each, PA 40%).

In the FPIMRT (field-in-field) technique, it was aimed to get a homogeneous dose distribution using AP-PA sub-fields together with AP-PA main fields. Main AP-PA fields were formed giving 8 mm safety margin to PTV in "auto MLC" mode. In the first step of the field-in-field technique, treatment planning was implemented in such a way that 95% of PTV could receive at least 93% of the prescribed dose using merely main AP-PA fields. Optimum sized AP-PA sub-fields were added that exclude high dose regions but include low dose regions [Figure 4]. In all fields and sub-fields, treatment planning was implemented using 6 MV-X energy. Beam weighting was 10% from AP-PA sub-fields and 90% from main AP-PA fields. Thus, whereas high-dose regions were removed, the dose reduction, particularly in the mediastinum, was decreased. As a result, it was attempted to obtain a more homogeneous and conformal dose distribution.

In all three techniques, "collapsed cone" was used as dose calculation algorithm. Again, in all three techniques, 95% of PTV was covered by at least 93% of the prescribed dose ($D_{95\%}$ >93%), while the minimum dose in PTV was kept at least 83% ($D_{min} \geq 83\%$).

The parameters mean lung dose (MLD), V_{5Gy}, V_{10Gy}, V_{20Gy}, V_{30Gy} for lungs[2-5] the parameters D_{mean}, $V_{7.5Gy}$, V_{15Gy}, V_{25Gy} for heart[1,6-9] were recorded from the dose-volume histogram (DVH's). Although there are no settled evaluation parameters in the literature for the breast, it was decided to use D_{mean}, $V_{3.5Gy}$, V_{10Gy}, V_{20Gy} parameters.[2,3,9-11] D_{max} for spinal cord[1,12] and the parameters D_{mean}, V_{10Gy}, V_{18Gy}, V_{25Gy}, V_{30Gy} for thyroid[9,13-15] were recorded. Moreover, homogeneity index (HI), conformity index (CI), and inhomogeneity coefficient (IC) were recorded from DVHs for PTV, as suggested in the literature.[3,11]

$$HI = D_2 - D_{98}/D_p.$$

D_p: Prescribed dose; D_2: dose received by 2% of volume; D_{98}: dose received by 98% of volume.

$$CI = V_{95\%}/PTV.$$

$V_{95\%}$: PTV receiving 95% of prescribed dose

$$IC = D_{max} - D_{min}/D_{mean}.$$

D_{max}: PTV maximum dose; D_{min}: PTV minimum dose; D_{mean}: PTV average dose.

Dependent variables in the study were MLD, V_{5Gy}, V_{10Gy}, V_{20Gy}, V_{30Gy} for lungs; D_{mean}, $V_{7.5Gy}$, V_{15Gy}, V_{25Gy} for heart; D_{mean}, $V_{3.5Gy}$, V_{10Gy}, V_{20Gy} for breast; D_{max} for spinal cord; D_{mean}, V_{10Gy}, V_{18Gy}, V_{25Gy}, V_{30Gy} for thyroid, and HI, CI, and IC parameters for PTV. On the other hand, independent variables were different planning techniques (AP-PA 2-field 3D-CRT, 4-field 3D-CRT, FPIMRT).

Comparisons were performed for lungs, heart, breast, spinal cord, thyroid, and PTV, with regard to relevant parameters among three techniques. SPSS Statistics 17.0 (IBM Corporation,

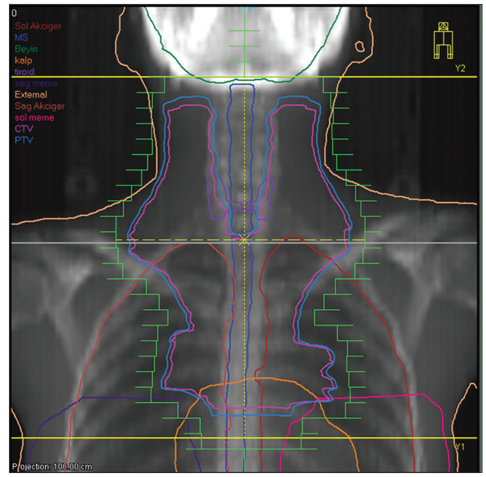

Figure 2: Digitally reconstructed radiograph image of the radiotherapy field from the gantry angle 0° in a sample case planned with anterior posterior-posterior anterior 2-field three-dimensional conformal radiotherapy technique

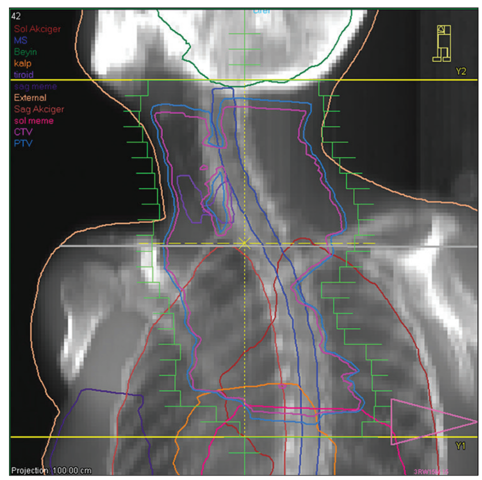

Figure 3: Digitally reconstructed radiograph image of the radiotherapy field from the gantry angle 42° in a sample case planned with 4-field three-dimensional conformal radiotherapy technique

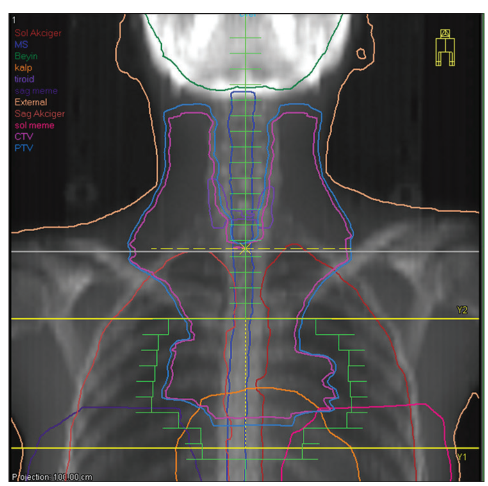

Figure 4: Digitally reconstructed radiograph image of the radiotherapy field from the gantry angle 0° in a sample case planned with "forward" plan intensity modulated radiotherapy technique

New York, USA) program was used. Since nonparametric tests had to be used due to the study population being <30, Friedman and Wilcoxon signed-rank tests were implemented in trilateral and bilateral comparison of techniques, respectively. For statistical significance, P value was required to be <0.05.

RESULTS

Mean age was found as 23.4 (12-35). Seven of the eight cases were diagnosed as Hodgkin lymphomas (HL), and one was non-HL (NHL). The mean total dose given to the involved neck + mediastinum regions was 25.2 (14.4–30.6) Gy.

Isodose distributions related to the treatment plans created using three techniques for a patient are shown in Figure 5. Figure 5 shows the maximum isodose within the field, 100% isodose, reference isodose selected for the relevant plan, and 83% isodose which was the D_{min} for PTV.

Planning target volume

In Table 1, the data related to PTV homogeneity and conformity are shown, which were obtained from the treatment planning of eight cases with three different techniques. In Table 2, comparison results of three techniques with respect to HI, CI, and IC are demonstrated.

It can be seen that from HI and CI standpoint, FPIMRT technique was significantly superior to both AP-PA and 4-field techniques in bilateral comparisons. Therefore, it is concluded that this technique can provide the desired homogenous and adequate dose distribution within PTV.

Lungs

For V_{5Gy}, 4-field technique resulted in higher values compared to the others. AP-PA technique was found more advantageous in terms of V_{5Gy} compared to FPIMRT. Among the bilateral comparisons for V_{10Gy}, only AP-PA versus FPIMRT comparison showed statistical significance in favor of AP-PA technique. In terms of V_{20Gy}, the lowest values were detected in 4-field technique. AP-PA technique was the most advantageous one for D_{mean} [Table 3].

Heart

Among the bilateral comparisons for $V_{7.5Gy}$, AP-PA versus FPIMRT comparison showed statistical significance in favor of AP-PA technique. As a result of bilateral comparisons for V_{15Gy}, V_{25Gy}, and D_{mean}, the most disadvantageous technique was FPIMRT while the most advantageous one was 4-field technique [Table 4].

Thyroid

In the bilateral comparisons for thyroid DVH parameters, the only significant difference was determined for D_{mean}. D_{mean}

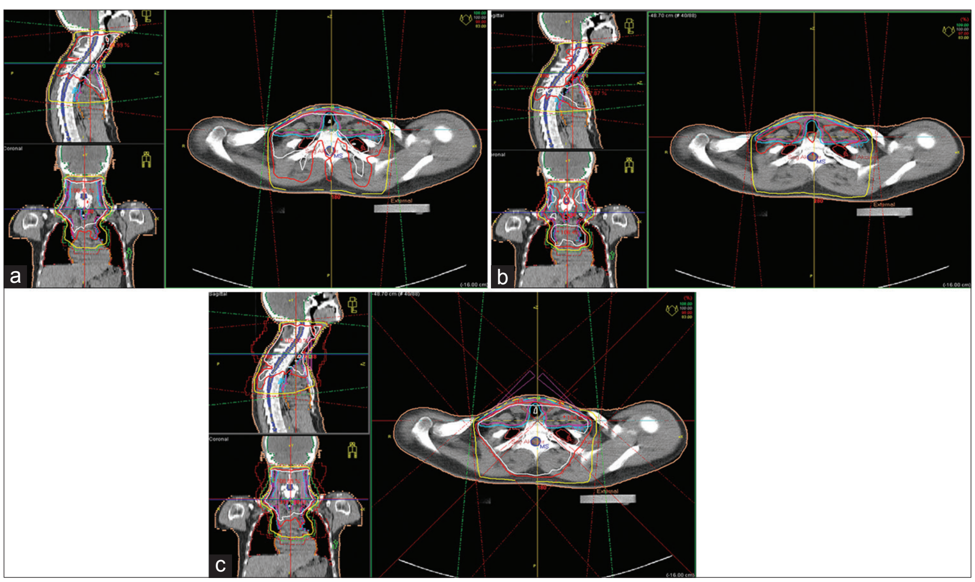

Figure 5: Images of isodose distributions on sagittal, coronal, and axial sections of cases. (a) Anterior posterior-posterior anterior technique. (b) 4-field technique. (c) “Forward” plan intensity modulated radiotherapy

Table 1: Parameters of planning target volume homogeneity and conformity

Value	PTV								
	HI			CI			IC		
	AP-PA	4-field	FPIMRT	AP-PA	4-field	FPIMRT	AP-PA	4-field	FPIMRT
Minimum	0.15	0.14	0.14	0.90	0.90	0.94	0.24	0.23	0.22
Maximum	0.23	0.15	0.17	0.95	0.97	0.98	0.31	0.32	0.28
Mean±SE	0.2±0.01	0.20±0.01	0.15±0.004	0.92±0.006	0.93±0.01	0.96±0.005	0.28±0.01	0.28±0.01	0.26±0.008

PTV=Planning target volume, HI=Homogeneity index, CI=Conformity index, IC=Inhomogeneity coefficient, AP-PA=Anterior posterior-posterior anterior, FPIMRT=“Forward” plan intensity modulated radiotherapy, SE=Standard error was the lowest in FPIMRT whereas it was the highest in AP-PA [Table 5].

Right breast

In the trilateral comparison, the one that gave the highest value for $V_{3.5Gy}$ was 4-field technique. In AP-PA/FPIMRT comparison, AP-PA technique was found more advantageous. In the bilateral comparisons for V_{10Gy} and D_{mean}, the most advantageous technique was AP-PA, while the most disadvantageous one was 4-field. V_{20Gy} was the lowest in 4-field, while it was the highest in FPIMRT [Table 6].

Left breast

The trilateral comparison gave the same result as in the right breast. Out of the bilateral comparisons regarding V_{10Gy}, a significant difference was determined only in AP-PA/FPIMRT comparison. AP-PA technique caused a decrease in V_{10Gy}. Furthermore, the results were similar to the ones of the right breast, regarding V_{20Gy} and D_{mean} [Table 7].

Spinal cord

In the bilateral comparisons, the lowest D_{max} dose for spinal cord was obtained with FPIMRT [Table 8].

DISCUSSION

In lymphoma treatment, the risk of RT-induced secondary cancer is higher in females due to the presence of larger breast tissue.[3] Thus, it becomes essential to reduce the dose to the breasts in lymphoma patients. In this context, adult women or adolescent girls with newly developing breast tissue were included in the study.

As an alternative to conventional AP-PA technique, 3D-CRT, FPIMRT or "inverse" plan IMRT (IPIMRT) techniques were used in different studies.[1,3,6,9,16-19] These techniques were compared with conventional AP-PA technique.

In the study of Goodman *et al*. performed in lymphoma patients with mediastinal involvement, the comparisons of IPIMRT/AP-PA and IPIMRT/3D-CRT with regard to dose-volume parameters resulted in 12% and 14% reductions in MLD with IPIMRT, respectively. At the same time, although IPIMRT could provide a better PTV coverage compared to AP-PA, it was found similar to 3D-CRT in this respect.[18] Girinsky *et al*. showed that IPIMRT did not only provide higher dose conformity in PTV compared to 3D-CRT but also could protect the heart, coronary artery, esophagus, and spinal cord to a greater extent.[16] However, the most important problem with IPIMRT is the fact that large size of volumes receives low doses. This creates a concern over a significant increase in secondary cancer risk. Besides, the fact that IPIMRT planning and application for relatively wide fields is time and energy consuming has caused this technique not to be preferred too much.

Table 2: Comparison results of three techniques in terms of homogeneity index, conformity index, and inhomogeneity coefficient values

	PTV		
Comparison type	*P*		
	HI	CI	IC
AP-PA/4-field/ FPIMRT	0.023	0.015	0.180
AP-PA/4-field	0.23	0.167	1.000
AP-PA/FPIMRT	0.017	0.018	0.182
4-field/FPIMRT	0.03	0.042	0.204

PTV=Planning target volume, HI=Homogeneity index, CI=Conformity index, IC=Inhomogeneity coefficient, AP-PA=Anterior posterior-posterior anterior, FPIMRT="Forward" plan intensity modulated radiotherapy

Table 3: Comparison results of three different techniques in terms of lung dose-volume parameters

	Lung				
Comparison type	*P*				
	V_{5Gy}	V_{10Gy}	V_{20Gy}	V_{30Gy}	D_{mean}
AP-PA/4-field/ FPIMRT	0.005	0.006	0.016	0.097	0.008
AP-PA/4-field	0.018	0.161	0.042	0.109	0.017
AP-PA/FPIMRT	0.027	0.011	0.310	0.276	0.012
4-field/FPIMRT	0.017	0.345	0.028	0.109	0.208

AP-PA=Anterior posterior-posterior anterior, FPIMRT="Forward" plan intensity modulated radiotherapy, V_{5Gy}=Percentage volume receiving >5 Gy, V_{10Gy}=Percentage volume receiving >10 Gy, V_{20Gy}=Percentage volume receiving >20 Gy, V_{30Gy}=Percentage volume receiving>30 Gy, D_{mean}=Mean dose

Table 4: Comparison results of three different techniques in terms of heart dose-volume parameters

	Heart			
Comparison type	*P*			
	$V_{7.5Gy}$	V_{15Gy}	V_{25Gy}	D_{mean}
AP-PA/4-field/ FPIMRT	0.088	0.001	0.002	0.001
AP-PA/4-field	0.208	0.028	0.028	0.017
AP-PA/FPIMRT	0.018	0.012	0.027	0.012
4-field/FPIMRT	0.499	0.012	0.028	0.012

AP-PA=anterior posterior-posterior anterior, FPIMRT="Forward" plan intensity modulated radiotherapy, $V_{7.5Gy}$=Percentage volume receiving >7.5 Gy, V_{15Gy}=Percentage volume receiving >15 Gy, V_{25Gy}=Percentage volume receiving >25 Gy, D_{mean}=Mean dose

Table 5: Comparison results of three different techniques in terms of thyroid dose-volume parameters

	Thyroid				
Comparison type	*P*				
	V_{10Gy}	V_{18Gy}	V_{25Gy}	V_{30Gy}	D_{mean}
AP-PA/4-field/ FPIMRT			0.135	0.135	0.002
AP-PA/4-field	1.00	1.00	0.18	0.18	0.035
AP-PA/FPIMRT	1.00	1.00	0.18	0.18	0.012
4-field/FPIMRT	1.00	1.00	0.18	0.18	0.012

AP-PA=Anterior posterior-posterior anterior, FPIMRT="Forward" plan intensity modulated radiotherapy, V_{10Gy}=Percentage volume receiving >10 Gy, V_{18Gy}=Percentage volume receiving >18 Gy, V_{25Gy}=Percentage volume receiving >25 Gy, V_{30Gy}=Percentage volume receiving >30 Gy, D_{mean}=Mean dose

Table 6: Comparison results of three different techniques in terms of the right breast dose-volume parameters

Comparison type	Right breast			
	P			
	$V_{3.5Gy}$	V_{10Gy}	V_{20Gy}	D_{mean}
AP-PA/4-field/FPIMRT	0.001	0.003	0.005	0.000
AP-PA/4-field	0.012	0.018	0.042	0.012
AP-PA/FPIMRT	0.317	0.016	0.046	0.012
4-field/FPIMRT	0.012	0.028	0.027	0.012

AP-PA=Anterior posterior-posterior anterior, FPIMRT=Forward plan intensity modulated radiotherapy, $V_{3.5Gy}$=Percentage volume receiving >3.5 Gy, V_{10Gy}=Percentage volume receiving >10 Gy, V_{20Gy}=Percentage volume receiving >20 Gy, D_{mean}=Mean dose

Table 7: Comparison results of three different techniques in terms of the left breast dose-volume parameters

Comparison type	Left breast			
	P			
	$V_{3.5Gy}$	V_{10Gy}	V_{20Gy}	D_{mean}
AP-PA/4-field/ FPIMRT	0.001	0.006	0.004	0.000
AP-PA/4-field	0.012	0.050	0.042	0.012
AP-PA/FPIMRT	0.109	0.018	0.042	0.012
4-field/FPIMRT	0.012	0.093	0.027	0.012

AP-PA=Anterior posterior-posterior anterior, FPIMRT=Forward plan intensity modulated radiotherapy, $V_{3.5Gy}$=Percentage volume receiving >3.5 Gy, V_{10Gy}=Percentage volume receiving >10 Gy, V_{20Gy}=Percentage volume receiving >20 Gy, D_{mean}=Mean dose

Table 8: Comparison results of three different techniques in terms of spinal cord doses

Comparison type	Spinal cord *P* (D_{max})
AP-PA/4-field/FPIMRT	0.002
AP-PA/4-field	0.161
AP-PA/FPIMRT	0.012
4-field/FPIMRT	0.012

AP-PA=Anterior posterior-posterior anterior, FPIMRT=Forward plan intensity modulated radiotherapy, D_{max}=Maximum dose

MacDonald *et al*. have emphasized that FPIMRT would be necessary in IFRT for the patients with neck and mediastinal involvement.[19] While 3D conformal IFRT targeting neck and mediastinum was planned, sub-fields were formed with asymmetric jaws and MLCs instead of wedges and other physical compensators. The sub-fields were designed on the basis of AP-PA main fields, mostly as at least one pair out of two pairs of them would avoid high dose regions.[19]

In their study, Cella *et al*. compared AP-PA technique and FPIMRT in HL patients with extensive treatment volume.[2] In the study of Cella *et al*., FPIMRT proved to be significantly superior from PTV standpoint.[2] Similarly, in this study significantly higher conformity and homogeneity was obtained in PTV with FPIMRT compared to AP-PA technique. D_{mean}, $V_{95\%}$, and IC were 101%, 96.8%, and 0.31, respectively, for FPIMRT in Cella's study. In this study, $V_{95\%}$ and IC were observed to be 95.7% and 0.26, respectively. Although FPIMRT $V_{95\%}$ was higher than that of our study, IC was superior in this study.

Nieder *et al*. applied 3D-CRT with 4-field technique at 0°, 180°, 90°, and 270° gantry angles in lymphoma cases with mediastinal involvement.[1] In their study, the patients were positioned as arms held over their head. However, in this study, this technique was modified such that anterior-oblique fields were used. The reasons for this modification are neck involvement accompanying mediastinal involvement in our patients, having akimbo position or arms at sides as treatment position, ensuring some more decrease in the low dose volumes obtained with two anterior oblique fields with respect to two lateral fields and the attempt to cover PTV better particularly by taking advantage of its position closer to anterior neck. In that study, which compares 4-field, AP-PA and IPIMRT techniques in small, medium, and large PTV volumes, median $V_{95\%}$ for PTV was 97% and 95% with AP-PA and 4-field techniques, respectively showing no significant difference.[1] Similarly, in this study, mean $V_{95\%}$ were not significantly different, 91.8% in AP-PA technique and 93% in 4-field. In Nieder *et al*.'s study, PTV D_{max} was the lowest in the 4-field technique for medium and large PTV volumes.[1] In this study, however, it was lower in AP-PA technique compared to 4-field. The reason for that might be the difference in gantry angles of additional two fields in these two studies.

Despite the presence of various dosimetric studies, there are few studies with clinical results using IMRT in lymphoma.[20,21] In Lu *et al*.'s study, dosimetric and clinical results of mediastinal involved field IMRT in early-stage HL were evaluated. The median MLD and lung V20 were 13.8 Gy and 25.9%, respectively. The 3-year local control was 97.9%, and no grade 4 or 5 acute or late toxicities were reported.[20] In Xu *et al*.'s study, dosimetric parameters, treatment outcomes, and toxicity of IMRT in NHL were assessed. The median MLD and lung V20 were 16.3 Gy and 30.6%, respectively. The 5-year local control was 89.8%, and no grade 4 or 5 acute or late toxicities occurred.[21] These clinical studies support the use of IMRT in selected lymphoma patients.

No study exists that compare 4-field technique and FPIMRT. In this study, which appears to be the only one, it can be seen that FPIMRT is superior to 4-field technique with regard to HI and CI.

When we evaluate FPIMRT and IPIMRT in terms of PTV coverage, $V_{95\%}$ with IPIMRT is 95.8%,[3] 96%,[1] and 98%;[18] and with FPIMRT 96.8%[2] and in our study 95.7%. $D_{95\%}$ with IPIMRT is 101%;[18] and in our study 93.6%. The conformity of IPIMRT seems superior to FPIMRT, as expected.

In terms of normal tissue sparing, there seems to be an advantage only for thyroid and spinal cord with FPIMRT compared to AP-PA technique in Cella's study.[2] On the other hand, expected dose reduction regarding heart, lungs, and breasts was not observed due to their proximity to sub-fields, and all results came out similar, except for a significant superiority for FPIMRT in lung V_{30Gy} and lung normal tissue change *P* values.[2] Similarly, in our study, FPIMRT has proved advantageous only for spinal cord and thyroid against both AP-PA and 4-field techniques. However, in our study, different from Cella *et al*.'s study, FPIMRT was significantly disadvantageous regarding all parameters of heart and breast, as well as all parameters of lungs except for V_{30Gy}. This may be due to the smallest V_x parameter in Cella's study being V_{20Gy}. On the other hand, the smallest V_x was determined as $V_{3.5Gy}$ in our study to accomplish more comprehensive dosimetric evaluations and comparisons.

The results of the studies using FPIMRT and those in the studies using IPIMRT can also be evaluated. Lung V_{20Gy} is 64% with IPIMRT;[18] 45.1%,[2] and 20.8% (our study) with FPIMRT. As expected, FPIMRT seems more advantageous with respect to IPIMRT regarding V_{20Gy} parameter. This advantage becomes more evident in V_{10Gy} and V_{5Gy} parameters, which were analyzed in our study. The right breast V_{20Gy} is 7.8% with IPIMRT[3] and 2.8% (our study) with FPIMRT. The left breast V_{20Gy} is 10.1%with IPIMRT[3] and 4.3% (our study) with FPIMRT. FPIMRT seems to spare both breasts more extensively with respect to IPIMRT. Thyroid V_{30Gy} is 64.1% with IPIMRT;[3] 20.8%[2] and 35.3% (our study) with FPIMRT. FPIMRT seems more advantageous compared to IPIMRT regarding thyroid.

As for almost all organs within the RT field, it is anticipated that the low dose volumes will be larger in IPIMRT with respect to FPIMRT. For this reason, since the risk of late side effects and secondary malignancy might increase in lymphoma patients due to the high cure rates and incidence in relatively younger ages, IPIMRT application is controversial in lymphoma treatment.

CONCLUSION

In the sole comparative study so far on FPIMRT in lymphoma, this technique has been compared with only AP-PA 2-field 3D-CRT.[2] However, our study which compared FPIMRT with both AP-PA 2-field and 4-field 3D-CRT techniques, aimed to determine the most appropriate technique for both PTV and normal tissues.

Relatively a low number of cases, retrospective nature of the study, and lack of clinical endpoints are among the weak points of this study.

Nonetheless, we have demonstrated that FPIMRT was superior to 4-field and AP-PA techniques in PTV homogeneity and conformity. However, in terms of normal tissues, it was more advantageous than AP-PA and 4-field techniques only for spinal cord and thyroid, and it was not the most advantageous one in some dose-volume parameters of breasts, lungs, and heart. For this reason, in particular for female patients with lymphoma where breasts and heart are prominently within the field, it is necessary to be more cautious when using FPIMRT.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Nieder C, Schill S, Kneschaurek P, Molls M. Comparison of three different mediastinal radiotherapy techniques in female patients: Impact on heart sparing and dose to the breasts. Radiother Oncol 2007;82:301-7.
2. Cella L, Liuzzi R, Magliulo M, Conson M, Camera L, Salvatore M, *et al.* Radiotherapy of large target volumes in Hodgkin's lymphoma: Normal tissue sparing capability of forward IMRT versus conventional techniques. Radiat Oncol 2010;5:33.
3. Antoni D, Natarajan-Ame S, Meyer P, Niederst C, Bourahla K, Noel G. Contribution of three-dimensional conformal intensity-modulated radiation therapy for women affected by bulky stage II supradiaphragmatic Hodgkin disease. Radiat Oncol 2013;8:112.
4. Zhang XJ, Sun JG, Sun J, Ming H, Wang XX, Wu L, *et al.* Prediction of radiation pneumonitis in lung cancer patients: A systematic review. J Cancer Res Clin Oncol 2012;138:2103-16.
5. Marks LB, Bentzen SM, Deasy JO, Kong FM, Bradley JD, Vogelius IS, *et al.* Radiation dose-volume effects in the lung. Int J Radiat Oncol Biol Phys 2010;76 3 Suppl: S70-6.
6. Cella L, Conson M, Pressello MC, Molinelli S, Schneider U, Donato V, *et al.* Hodgkin's lymphoma emerging radiation treatment techniques: Trade-offs between late radio-induced toxicities and secondary malignant neoplasms. Radiat Oncol 2013;8:22.
7. Chung E, Corbett JR, Moran JM, Griffith KA, Marsh RB, Feng M, *et al.* Is there a dose-response relationship for heart disease with low-dose radiation therapy? Int J Radiat Oncol Biol Phys 2013;85:959-64.
8. Andratschke N, Maurer J, Molls M, Trott KR. Late radiation-induced heart disease after radiotherapy. Clinical importance, radiobiological mechanisms and strategies of prevention. Radiother Oncol 2011;100:160-6.
9. Fiandra C, Filippi AR, Catuzzo P, Botticella A, Ciammella P, Franco P, *et al.* Different IMRT solutions vs 3D-conformal radiotherapy in early stage Hodgkin's lymphoma: Dosimetric comparison and clinical considerations. Radiat Oncol 2012;7:186.
10. Shilkrut M, Belkacemi Y, Kuten A; Association of Radiotherapy and Oncology of the Mediterranean arEa (AROME). Secondary malignancies in survivors of breast cancer: How to overcome the risk. Crit Rev Oncol Hematol 2012;84 Suppl 1:e86-9.
11. Jin GH, Chen LX, Deng XW, Liu XW, Huang Y, Huang XB. A comparative dosimetric study for treating left-sided breast cancer for small breast size using five different radiotherapy techniques: Conventional tangential field, filed-in-filed, tangential-IMRT, multi-beam IMRT and VMAT. Radiat Oncol 2013;8:89.
12. Kirkpatrick JP, van der Kogel AJ, Schultheiss TE. Radiation dose-volume effects in the spinal cord. Int J Radiat Oncol Biol Phys 2010;76 3 Suppl: S42-9.
13. Boomsma MJ, Bijl HP, Langendijk JA. Radiation-induced hypothyroidism in head and neck cancer patients: A systematic review. Radiother Oncol 2011;99:1-5.
14. Emami B, Lyman J, Brown A, Coia L, Goitein M, Munzenrider JE, *et al.* Tolerance of normal tissue to therapeutic irradiation. Int J Radiat Oncol Biol Phys 1991;21:109-22.
15. Jereczek-Fossa BA, Alterio D, Jassem J, Gibelli B, Tradati N, Orecchia R. Radiotherapy-induced thyroid disorders. Cancer Treat Rev 2004;30:369-84.
16. Girinsky T, van der Maazen R, Specht L, Aleman B, Poortmans P, Lievens Y, *et al.* Involved-node radiotherapy (INRT) in patients with early Hodgkin lymphoma: Concepts and guidelines. Radiother Oncol 2006;79:270-7.

17. De Sanctis V, Bolzan C, D'Arienzo M, Bracci S, Fanelli A, Cox MC, *et al.* Intensity modulated radiotherapy in early stage Hodgkin lymphoma patients: Is it better than three dimensional conformal radiotherapy? Radiat Oncol 2012;7:129.
18. Goodman KA, Toner S, Hunt M, Wu EJ, Yahalom J. Intensity-modulated radiotherapy for lymphoma involving the mediastinum. Int J Radiat Oncol Biol Phys 2005;62:198-206.
19. MacDonald S, Bernard S, Balogh A, Spencer D, Sawchuk S. Electronic compensation using multileaf collimation for involved field radiation to the neck and mediastinum in non-Hodgkin's lymphoma and Hodgkin's lymphoma. Med Dosim 2005;30:59-64.
20. Lu NN, Li YX, Wu RY, Zhang XM, Wang WH, Jin J, *et al.* Dosimetric and clinical outcomes of involved-field intensity-modulated radiotherapy after chemotherapy for early-stage Hodgkin's lymphoma with mediastinal involvement. Int J Radiat Oncol Biol Phys 2012;84:210-6.
21. Xu LM, Li YX, Fang H, Jin J, Wang WH, Wang SL, *et al.* Dosimetric evaluation and treatment outcome of intensity modulated radiation therapy after doxorubicin-based chemotherapy for primary mediastinal large B-cell lymphoma. Int J Radiat Oncol Biol Phys 2013;85:1289-95.