Comparison and Evaluation of Different Treatment Plans with IFRT Field and 6 and 18 MV Energies in Hodgkin's Lymphoma Involvement Neck and Mediastinum

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ABSTRACT

Background: Radiotherapy with large mantle field is an effective technique in increasing the risk of secondary cancers among HL (Hodgkin Lymphoma) patients; therefore, it is essential to choose an effective treatment field including the least medical conditions in radiotherapy.

Objective: The present study aimed to plan separate fields for neck and mediastinum using various energies, to compare dose distribution with MLC and to block field formation.

Materials and Methods: In this study, 3D conformal treatments, Siemens Oncor accelerator equipped with multi-leaf collimator (MLC) were performed to create anterior-posterior fields. CT-scan data of 18 female patients with neck and mediastinal involvement was imported in TIGRT treatment planning system, and then treatment plans were introduced.

Results and Conclusion: Using treatment plan 1, photon 6 MV in neck weighting 1 from interior, 0.5 from posterior, photon 18MV in mediastinum weighting 1 from interior and 0.5 from posterior, it was shown that regarding the common treatment plan used with photon 6 MV, mean dose delivered to breast, lung, esophagus and larynx reduced 6, 7, 41 and 10 percent, respectively and uniformity index improved by 10 percent. Using block compared to MLC in all treatment plans offered improved average dose in all organs under study. To protect breast and lung while using MLC and block in the first treatment plan seemed to be more appropriate; however, using blocks in comparison to MLC increased delivered mean dose in all organs under study. Using separate fields with Pb blocks, though, showed smaller increase.

Keywords

Treatment Planning, Radiotherapy, Hodgkin, MLC, 3D Conformal

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Introduction

Hodgkin's is a cancer of the immune cells, which affects lymph nodes and organs. This type of cancer includes 10 percent of all lymphoma and 1 percent of all cancers in the United States of America [1, 2]. Because of the sensitivity of lymphoma to radiation, radiation therapy is the treatment of choice in early stages. Almost 75 percent of patients with Hodgkin Lymphoma (HL), regardless of disease stage, have long-term survival after treatment [1, 3-5]. However, the increased risk of secondary cancers as a complication of treatment with several factors is undeniable [3, 6, 7]. In 1960, due to the beneficial results from mantle, this field was recognized as a standard for thoracic diaphragm [8]. Considering the studies to this date, it is shown that radiotherapy with large mantle field is an influential factor in increasing the risk of secondary cancers including leukemia, breast and lung in patients with HL [9]. Therefore, selection of an effective treatment with minimal side effects associated with radiation therapy is one of the main issues. Planning a treatment field for patients with HL has significantly changed during the last decade. Recent studies have shown that mere chemotherapy causes Translation error of the recurrence of cancer in the lymph nodes involved initially. Nowadays though, combination of chemotherapy with radiation therapy regimens reduces side effects of different treatments as well as reducing the size of radiation field from mantle field to the smaller fields including IFRT and INRT [10]. Involved filed Radiation Therapy (IFRT) was generally defined as radiation to lymph nodes involved and making use of smaller radiation fields decreased side effects in the development of combinational therapies for all stages of Hodgkin's lymphoma. Nowadays, using radiation therapy with IFRT is common due to less radiation to normal tissues, and it has been known as a standard therapy to combinational treatments [11, 12]. Koh et al. compared mantle and IFRT and suggested that using IFRT reduced the relative risk of breast and lung cancer among women to 65 percent and lung cancer among men to 35 percent [9]. The common method for patients with HL is AP-AP fields and usually in patients with neck and mediastinal involvement using IFRT fields, a general field including mediastinum, supraclavicular and bilateral hila areas correspond to the given area in Perez's radiation oncology book [9, 12]. However, different thickness in neck and mediastinum could result Non-uniformity in dose distribution as 10% or more[13].. In the present study, we aimed to plan separate fields for neck and mediastinum areas using various energies where total field of neck and mediastinum was divided into two separate parts by MLC, and radiotherapy plans were developed using various weights of 6 and 18 MV photons. The most important role of MLC includes forming automatic fields and, as a result, saving treatment time, reducing production expenses and avoiding or rejecting to keep heavy lead and custom blocks [14-16]. Though, it is still common to use lead blocks in centers where the tools lack MLC in their heads [17] and it causes difficulties such as maintenance, the need to build separate blocks for each patient and increasing treatment costs. Construction of the blocks in some centers lacking MLC is difficult, therefore, ready to use rectangular blocks are used. Consequently, the present study investigated the difference of dose distribution in field planning with rectangular lead blocks and MLC.

Material and Methods

AP-PA fields (parallel opposed) and 6 MV photon beam energy are mostly used in standard treatment plans for most conformal 3D clinical cases [13, 18-23]. The present study made use of 3D conformal with multi-leaf collimator (MLC), Oncor Siemens accelerator to create anterior-posterior fields. Prescriptive dose of 36 Gy was delivered to the normalization point. CT scan information from 18 female patients with neck and mediastinum engagement was used. All data were imported to TIGRT treatment plan system in Milad Hospital, Isfahan, Iran and contouring treatment volume and organs of the breast, lung, thyroid, heart and esophagus was contoured with an oncologist. Treatment planning software will automatically calculate the absorbed dose for each contoured organ after calculating DVH diagram for each treatment planning. When the required information to compare treatment plans was gathered, mean dose delivered to organ at risk , maximum dose and uniformity index were used.

On the first step, four treatment plans with anterior-posterior fields for separate neck and mediastinum fields with MLC were used. As shown in Figure 1, the first field included neck and supraclavicular, and the second field-included mediastinum. Then, 6 and 18 MV photons with various weights were combined to form four treatment plans as following (Table 1).

For the second step, to compare MLC and block, treatment plans implemented by MLC were repeated by prepared blocks. Using prepared fields junction is important if lead blocks are used in multiple fields. The present study used half beam block to avoid overlap in edges of the fields due to different target volumes and contour irregularities. Comfortable setting and non-oblique beam on the surface of the skin are half beam block advantages compared to other common methods. In this method, moving one of the collimator independent jaws toward the middle or using Cerrobend blocks, half of the beam would be blocked causing a non-divergent central field with a right edge at central axis. Figure 2 presents the implementation of separate fields for neck and mediastinum by block.

In both steps, the homogeneity index was defined as maximum point dose divided by the prescribed dose (HI RTOG=Imax/RI). HI RTOG≤2 is considered complaint with protocol [24, 25].

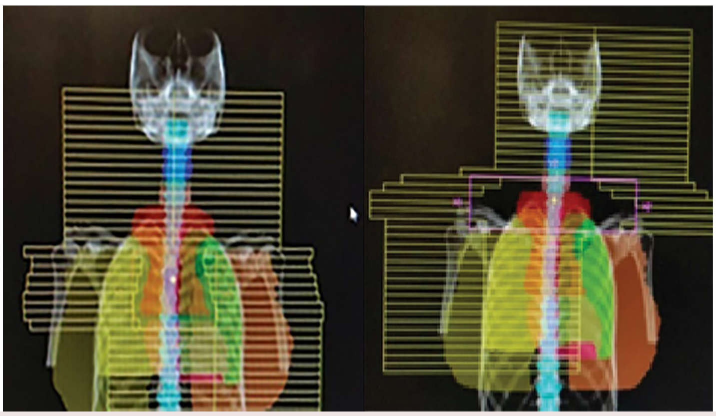

Figure 1: Implementation of separate fields for the neck and mediastinum by MLC A. mediastinal B. neck

Table 1: Profile treatment plans implemented by MLC

Number	Filed	Energy and weight radiation – anterior	Energy and weight radiation – posterior
Plan 1	Neck	1-6	0.5-6
	mediastinal	1-18	0.5-18
Plan 2	Neck	1-6	1-6
	mediastinal	1-6	1-6
Plan 3	Neck	1-18	1-18
	mediastinal	1-18	1-18
Plan 4	Neck	1-18	1-6
	mediastinal	1-18	0.5-18

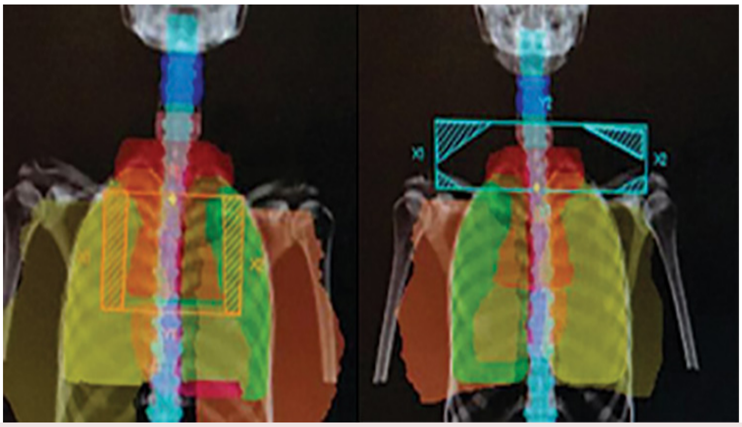

Figure 2: Implementation of separate fields for the neck and mediastinum by block A. mediastinal B. neck

Results

Received Doses to Planning Target Volume (PTV)

Considering the data in Table 2, comparing four treatment plans implemented by MLC, the mean dose delivered to PTV in the treatment plan number one (neck field with AP(6-1) PA(6-0.5) and mediastinum AP(18-1)PA(18-0.5)) was less than 2% in comparison to all other treatment plans, though it satisfied criteria treatment plan ±105 for prescribed dose. Considering formula 1, uniformity index from oncology group and radiotherapy (RTOG) (HI_RTOG≤2), it was seen that the treatment plan number one with 1.09 index offered the best uniformity in therapy volume. Comparing data from Table 3, it was suggested that uniformity at the present treatment plan increased 10% compared to common treatment

Table 2: Mean dose delivered to under study organs at 4 treatmnt plans, uniformity index, D_{mean} (cGy), D_{max} (cGy) for treatment volume

Mean Dose Dmean (cGy)		Plan1	Plan2	Plan3	Plan4	p-value
		Neck AP(6-1)PA(6 - 0.5)	Neck AP(6-1)PA(6 - 1)	Neck AP(18-1)PA(18 - 1)	Neck AP(18-1)PA(6 - 1)	
		Mediastinal AP(18-1)PA(18- 0.5)	Mediastinal AP(6-1)PA(6- 1)	mediastinal AP(18-1)PA(18- 1)	mediastinal AP(18-1)PA(18- 0.5)	
Left Breast		88.29 ±7.78	119.49 ±8.2	93.33 ±10.56	107.18 ±6.35	0.001
Right Breast		143.22 ±12.21	178.39 ±11.78	151.14 ±14.01	158.56 ±14.95	0.000
Esophagus		2611.74 ±116.00	2679.09 ±135.21	2688.76 ±121.01	2707.92 ±118.12	0.001
Heart		510.34 ±28.56	564.18 ±23.45	518.49 ±63.24	551.43 ±45.75	0.001
Larynx		157.88 ±15.31	180.87 ±14.68	196.56 ±19.20	242.22 ±23.24	0.000
Left Lung		1300.55 ±61.25	1390.11 ±78.26	1316.13 ±111.12	1363.20 ±55.83	0.001
Right Lung		1080.39 ±119.24	1151.65 ±87.35	1078.64 ±110.55	1126.98 ± 97.65	0.005
Thyroid		120.55 ±10.56	122.85 ±15.32	124.95 ±14.36	124.15 ±17.98	0.120
PTV	Dmax (cGy)	3949.20±89.24	4137.46±145.21	4040.00±112.36	4230.98±114.56	0.021
	Uniformity Index	1.09±0.89	1.14±0.78	1.12±0.24	1.17±0.45	0.102
	Dmean (cGy)	3424.01 ±135.00.	3481.93 ±156.45	3465.14 ±115.62	3445.40 ±96.34	0.031

Table 3: Comparing mean dose delivered to organs under study, uniformity index, and breast and lung; Volume percentage in three treatment plans

Mean Dose D_{mean} (cGy)	Plan1 AP(6-1) PA(6-1)	Plan2 AP(18-1) PA(18-1)	Plan3 Neck: AP(6-1)PA(6-0.5) Mediastinal: AP(18-1)PA(18-0.5)
Left Breast	153.14	122.88	88.29
Right Breast	214.34	185.30	143.22
Esophagus	2795.69	2772.88	2611.74
PTV	3606.93	3538.43	3424.01
Heart	283.91	216.73	510.34
Larynx	176.82	121.16	157.88
Left Lung	1563.51	1485.25	1300.55
Right Lung	1245.36	1161.99	1080.39
Thyroid	91.23	88.31	120.55
Uniformity Index	1.20	1.11	1.09
% V_4 Left Breast	5.49	7.05	3.40
% V_4 Right Breast	10.92	8.36	6.01
% V_{20} Left Lung	36.58	36.37	33.71
% V_{20} Right Lung	28.22	27.94	26.91

with 6MVphoton.

Received Doses to Breast

Treatment plan 1 showed the smallest mean dose compared to other plans (Table 2). Results from our previous studies showed that mean doses delivered to breast using 6MV photon from anterior and posterior with the same weight were 153 and 214 cGy for right and left, respectively, and using 18MV photon from anterior and posterior were 122 and 185, respectively [26]. Results are shown in Table 3. Mean dose delivered to whole breast decreases by 41 and 27 percent in comparison to other two treatment plans if separate fields in Table 3 are used. Considering the high risk of secondary breast cancer seen in dose 4 Gy [10], it is essential to measure breast V_4 and even keep it small. According to data from Table 3, using separate fields with 6MV photon at neck and 18MV photon at mediastinum, the volumetric percent of breast receiving 4Gy(V_4) at whole breast decreased 42 and 38 percent in comparison to conventional treatments 1 and 2, respectively.

Received Doses to Lung

As seen in Table 2, mean dose delivered to whole lung in treatment plan 1 decreased about 4-6 percent compared to other treatment plans. Considering dose and volume tolerance to total lung, V_{20} <30% and D_{mean}<20Gy[19], it was seen that these parameters were smaller using separate fields compared to other treatment plans (See Table 3). According to Table 3, V_{20} for whole lung decreased in treatment plan 3 by 7 and 6% for plans 1 and 2, respectively.

Received Doses for heart, Esophagus, Larynx and Thyroid

According to data from Table 2, mean doses delivered to heart, esophagus, larynx and thyroid in treatment plan 1 were the smallest compared to three other plans. All four plans showed acceptable delivered dose to esophagus (D_{mean}<34 Gy); however, mean dose decreased from 2 to 4 % in the treatment plan

1 compared to other treatment plans. Mean dose delivered to heart in treatment plan 1 decreased almost 10% comapard to other plans. According to Table 3, mean dose in treatment plan 3 using separate fields at neck and mediastin for esophagus decreased almost 7%, but increased in heart and thyroid.

Treatment Plans Implemented by Lead Blocks

Four treatment plans implemented by MLC were practiced by block. Among these four plans, using 6MV photon at neck weighting 1 from anterior and 0.5 from posterior, and using 18 MV photon at mediastinum weighting 1 from anterior and 0.5 from posterior were the best treatment plans because they decreased the mean dose delivered to healthy organs and caused more uniform dose distribution in treatment volume. Table 4 shows the results from this treatment plan for more comparison. Considering Table 4, using prepared blocks increased mean dose delivered to whole breast. The increase was 19.6, 45 and 43% in three treatment plans, respectively. Using separate fields (treatment plan 3) caused 3.3% increase in mean dose delivered to whole lung. However, using treatment plan 1 increased mean dose delivery by 29%. As seen in Table 4, using block relative to MLC in all implemented treatment plans caused an increase in mean dose delivered to all organs.

Discussion

Considering the results from Table 2 to protect breast, D_{mean}<2 Gy and minimum dose delivered to breast, it is suggested that treatment plan 1, or using 6 MV photon at neck weighting 1 from anterior and 0.5 from posterior, and 18 MV photon at mediastinum weighting 1 from anterior and 0.5 from posterior, was suitable which corresponded to results from our previous studies [22]. In addition, if forced to use prepared blocks, Table 4, it would be optimal to use treatment plan 3 including using separate fields and decreasing average dose delivered to breast.

According to the results from our previous studies, applying the common treatment of using 6 MV photon from anterior and posterior at

Table 4: Comparison of Mean dose delivered to studied organs, with and without MLC

Mean dose D_{mean} (cGy)	Plan with Block			Plan with MLC		
	Plan1	Plan2	Plan3	Plan1	Plan2	Plan3
	AP(6-1) PA(6-1)	AP(18-1) PA(18-1)	Neck: AP(6-1)PA(6-0.5) Mediastinal: AP(18-1) PA(18-0.5)	AP(6-1) PA(6-1)	AP(18-1) PA(18-1)	Neck :AP(6-1)PA(6-0.5) Mediastinal: AP(18-1) PA(18-0.5)
Left Breast	207.77	219.41	149.19	153.14	122.88	88.29
Right Breast	232.95	227.52	181.17	214.34	185.30	143.22
Esophagus	2854.79	2842.12	2652.60	2795.69	2772.88	2611.74
PTV	3616.48	3573.52	3499.21	3606.93	3538.43	3424.01
Heart	327.48	270.84	281.78	283.91	216.73	510.34
Larynx	232.05	174.67	288.79	176.82	121.16	157.88
Left Lung	1623.24	1520.15	1350.46	1563.51	1485.25	1300.55
Right Lung	2013.69	1208.10	1110.01	1245.36	1161.99	1080.39
Thyroid	135.23	163.75	147.05	91.23	88.31	120

the same weight could offer a better coverage to treatment volume [26]. Though, using treatment plan 3, as this table shows, decreased average dose compared to other plans, but satisfied treatment-planning criterion (±105 prescribed dose) and caused acceptable coverage. Moreover, treatment plan 3 or using separate fields was the best plan to protect lung considering the smallest V_{20} and D_{mean}. According to data in Table 3 and considering all treatment planning criteria such as better coverage of treatment volume (maximum dose delivered to treatment volume), uniform dose distribution and minimum dose delivered to healthy organs surrounding tumors, it was suggested that treatment plan 1 or using 6 MV photon at neck weighting 0.5 from anterior and 1 from posterior, and 18 MV photon at the same weight for anterior and posterior was the most suitable plan.

In conclusion, Table 3 represents the comparison of three treatment plans selected and implemented by MLC. Since ease of treatment planning, treatment setting and treatment calculations included planning considerations, in a compromise to choose treatment technique using treatment plan 3 in Table 3, or using separate fields with 6 and 18 MV photons with MLC, could reduce mean dose delivered to organs by some percent and reduce V_{20} volume percentage in lung and V_4 in breast and also therefore could provide better uniformity. Nevertheless, due to setup, treatment plan 3 was more time consuming compared to plans 1 and 2 due to its layout. Therefore, in clinical applications in more crowded centers, it is more practical to use treatment plan 2 (using 18 MV photon with the same weights anterior and posterior) in neck and mediastinum fields which offers better agreement with treatment plan criteria in comparison to plan 1.

Using rectangular blocks to form a field instead of MLC is still very common in many health care centers. However, due to the inability of these blocks in strict compliance with complex fields, probability of exposure of healthy organs increased and as a result, secondary cancers would be more probable if they were used. According to the results from the present study, although in comparison to MLC, using blocks to form a field increased mean dose to all organs, using separate fields with lead blocks to form a field decreased mean doses delivered to organs. Therefore, in health care centers using lead blocks, making use of separate fields at neck and mediastinum could reduce doses distributed to breast, heart, esophagus, larynx and thyroid due to better field correspondence to treatment volume. Accordingly, it effectively decreases the risk of secondary cancer resulting from radiation to whole field of neck and mediastinum.

Conflict of Interest

None

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