Dosimetric Comparison of Butterfly VMAT and Different Radiotherapy Plans in Early Stage Hodgkin Lymphoma, Evaluation of Clinical Considerations

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Abstract

Radiotherapy for early-stage Hodgking's lymphoma (HL) has recently been subjected to a variety of planning techniques, with the use of intensity modulated radiotherapy (IMRT) associated with radiation volumes. Currently, IMRT can be planned and delivered by various techniques and this role is not completely clear. In this study, we aimed to evaluate different IMRT planning designs regarding plan quality and treatment delivery efficiency. **Materials and Methods:** A 17-year-old patient affected by early-stage mediastinal HL was planned. Three different treatment techniques were compared: 3D-CRT, B-VMAT ("butterfly", multiple arcs), B-IMRT ("butterfly", intensity modulated radiotherapy). The beam energy was 6 MV and all IMRT planning solutions were optimised by reverse planning with specific dose volume constraints on the OAR (lungs, thyroid gland, heart, oral cavity). Our plan was planned as 30Gy and 10 fractions. Dose-volume histograms (DVHs) and Conformity Index (CI) were calculated and then compared between the target and OAR by statistical analysis. **Results:** V95% ≥95% was achieved in all plans within the PTV; The highest mean CI was obtained with B-VMAT (1.50) and B-IMRT (1.80). For the lungs, B-VMAT (V_20=38.1% and mean=17.3%), B-IMRT (V_20=42.1% and mean=18.4%) and B-VMAT doses provided better protection in terms of volumes received. Thyroid glands were close to each other as B-VMAT (Mean=20.5%), B-VMAT (Mean=19.25%). Heart doses B-VMAT (Mean=24,7%), B-IMRT (Mean=17,9%) provided better protection in B-IMRT(Table 1.) The values were within the limits. Conclucions: B-VMAT techniques showed superior target coverage with lower doses to healthy tissues (lungs) as expected. The B-IMRT technique, as an alternative planning solution in terms of conformity index and evaluation of other OARs, has emerged as the planning solution that can provide the most balanced compromise between OAR volumes.

Keywords: Hodgkin Lymphoma • Radiotherapy •Planning •OAR

Introduction

Hodgkin lymphoma (HL) originates from lymphoid tissues and is a lymphoproliferative disease characterized by malignant Reed Stenberg cells. It constitutes 1% of all cancers and approximately 10% of all lymphomas. It is a disease seen in developed countries around the age of 20 and over the age of 60. Radiotherapy is considered a primary treatment for HL, as it is for many disease groups in terms of historical development. Radiotherapy is a preferred treatment type due to its increased efficacy, Augreased morbidity, and increased long-term survival rates. HL is a type of cancer that begins in the lymphatic system and is characterized by the accumulation of cancer cells in the lymph nodes, spleen, and other lymphatic tissues. Early-stage HL (stages I-II) is highly treatable and is usually treated with a combination of radiotherapy (RT) and chemotherapy. Treatment options are considered together with 3D planning and advanced treatment techniques in patients who are considered for radiotherapy. The limited areas to be treated are determined by a combination of imaging techniques such as contrast-enhanced computed tomography (CT), positron emission tomography (PET), and magnetic resonance imaging (MRI). When defining target volumes, the concepts of gross tumor volume, clinical target volume, internal target volume and planning target volume determined by the International Commission on Radiation Units and Measurements are used. Treatment options are applied by 3-dimensional conformal radiotherapy (3D-CRT), intensity-modulated radiotherapy (IMRT), volumetric arc therapy (VMAT), or a combination of these. The primary purpose of applying treatment techniques is to significantly reduce the risk of average tissue damage and achieve the target local tumor control. There is evidence that combined treatment techniques are higher for disease control compared to the doses of current RT techniques and those used in the past. Therefore, it would be beneficial to evaluate combined treatment techniques both to deliver the maximum possible dose to the target tumor and to ensure normal tissue tolerances. In this study, the efficacy and side effects of different radiotherapy plans used in early-stage HL will be compared on patient data.

Early Stage Hodgkin Lymphoma

It is a type of disease with no stage I-II and no adverse conditions. The prognosis of early-stage HL is quite good and the overall survival time is extended [1]. Complications such as second malignancies such as breast and lung [2,3] and cardiovascular disease [4,5] are significant after treatment for most HL patients. With increasing awareness of the long-term complications of large RT fields, there has been a trend toward narrowing the treatment fields in these treatment plans. Anticipatory therapy is essential for early-stage Hodgkin's lymphoma. Treatment requires a balance to eliminate the tumor, provide adequate treatment, and minimize possible side effects after treatment. This is especially important in early-stage HL, where treatment response is good, and treatment-related complications [6]. That's why it's so important to balance safety with the intensity of initial therapy when treating patients with HL [7]. The aim of this study is to optimize the doses as much as possible and protect critical organs, especially in early-stage HL, which is complicated and wide-ranging, without reducing the chance of recovery.

Radiation Dose

The primary goal of radiation therapy for HL is to destroy cancer cells while minimizing damage to healthy tissue [8]. Unlike adults, treatment protocols in children [9] are not selected solely based on risk categories (including tumor stage, extent of disease, and presence of B symptoms) and analysis of intermediate response by positron emission tomography and/or measurement of metabolic tumor volume [10]. Previously, a 40 Gy radiation dose was used in HL treatments. However, today, combined modality treatments (CMT) and randomized studies have shown that lower doses will be equally effective in treating this disease, depending on the patient's risk factors and the systematic treatment used [11]. A radiation dose of 30 Gy to 40 Gy is recommended for patients with relapsed or radiotherapy-resistant HL, but no randomized trials have been conducted for this purpose [12]. According to the National Comprehensive Cancer Network (NCCN), the acceptable radiation dose ranges for these patients are 20-30 Gy for non-volume areas and 30-36 Gy for volume areas. The range is defined as 1.5-2 Gy per fraction [8]. In this study, considering the young age of the patient, we defined the radiation dose as 30 Gy, thinking that the treatment would be equally effective by keeping the risk factors at a minimum level and adhering to systematic treatment.

Material and Methods

The study was conducted at the Radiation Oncology Clinic of Atatürk University Faculty of Medicine. The patient was 17 years old and male. The patient's consultation was reviewed before the start of the treatment. The Radiation Oncologist evaluated the patient in terms of radiotherapy. Since the disease involved the head and neck region, a special thermoplastic mask was made for the patient to remain immobile. Before the treatment planning, appropriate immobilization procedures were performed to define the targeted volumes and contour the critical organs, and a CT scan was performed. The targeted volumes and critical organs were determined by the Radiation Oncologist according to the International Commission on Radiation Units and Measurements (ICRU) protocol.

Radiotherapy Planning

After the patient's personalized contouring procedures are completed, determining the appropriate treatment regimen is one of the most critical stages. The most important stage is preparing treatment plans with different techniques, comparing Dose Volume Histograms (DVH), and making a clinical judgment about which treatment technique to use. IMRT technique can significantly limit the dose to normal tissues in large volume areas in HLs [13]. It has been suggested that 3D Conformal Radiotherapy reduces the dose, especially to the breast, in HL. Some authors have shown that the IMRT technique can also be used to reduce the dose to the heart [14]. We applied and evaluated different planning techniques for this patient to provide both appropriate dose optimization and to limit the dose to normal tissues. The beam energy was 6 MV. We made three plans, 3D conformal radiotherapy, B-IMRT, and B-VMAT, and compared their critical organ doses and conformity indices (Table 1). The 3D conformal radiotherapy plan consisted of 2 anterior-posterior parallel opposing fields (gantry angles 0°-180°) shaped with multileaf collimators.

Table 1. OAR doses in different treatment plans

Critical Organs	**B-VMAT**	**B-IMRT**	**3D-KRT**
Oral Cavity	Mean : 22.4 Gy	Mean : 16.4 Gy	Mean : 32.2 Gy
Parotid_R	Mean : 20.5 Gy	Mean : 19.2 Gy	Mean : 28.6 Gy
Parotid_L	Mean : 22.02 Gy	Mean : 18.6 Gy	Mean : 29.5 Gy
Total Lung	V_{20}=%38.1 Mean :17.3Gy	V_{20}= %42.1 Mean :18.4 Gy	V_{20}=%55.4 Mean :19.9 Gy
Heart	Mean : 24.7 Gy	Mean : 17.9 Gy	Mean : 29.1 Gy
Conformity İndex	1,5	1,8	4.6

The arc angles we use to reduce lung and breast dose exposure and to provide complete optimization are two single arcs of 360° (gantry starting angle 0-180°) and a 2-arc plan (B-VMAT); this approach consists of 2 coplanar arcs of 250° (gantry starting angles 50° and 300°), 330° collimator angle and 90° table angle (Figure 1).

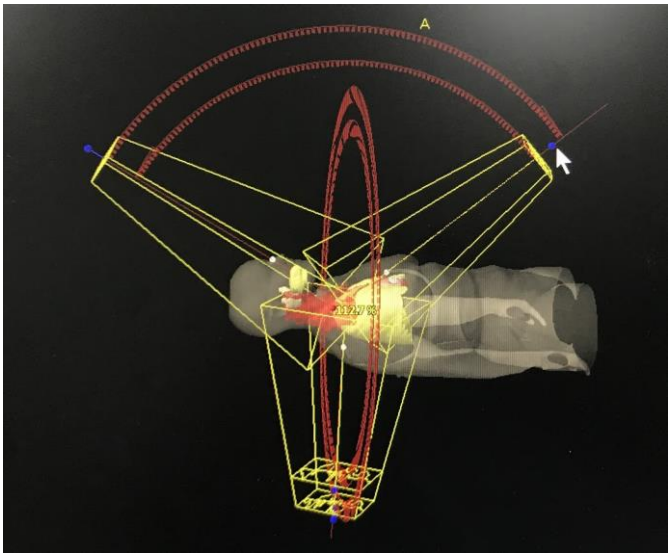

Figure 1.3D Graphical Representation of Arc/Beams Configuration Used in Butterfly VMAT (B-VMAT) Treatment Planning

Discussion

Modern RT for HL is a highly individualized treatment with limited treatment volumes. Each of the radiotherapy techniques used in early stage Hodgkin lymphoma has its own advantages and disadvantages. Modern imaging and RT techniques should be used to limit the amount of normal tissue irradiated and thus minimize the risk of long-term complications. Figure 2 shows the dose distributions of the patient's planning with different techniques.

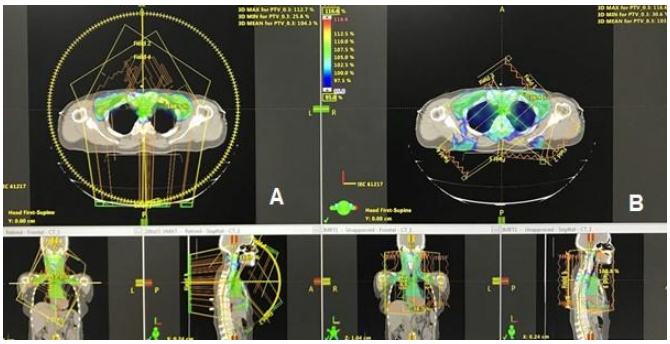

Figure 2. Representation of Dose Distributions in Different Treatment Plans, A: VMAT (B-VMAT), B: IMRT

Figure 3 shows the 2D cross-sectional view of the treatment planning made with B-VMAT. The mean values of the patient, taking into account all doses and distributions, were evaluated (Table 1).

When the dose distributions of different radiotherapy techniques used in this study were evaluated, it was seen that the mean doses for the lungs were similar in all plans. In contrast, the dose values for the heart were identical in different plans. The most suitable conformity index was obtained in the B-VMAT plan with 1.5. The mean parotid doses were close to each other in all techniques. The heart dose was provided with the B-IMRT plan with 17.9 Gy for all treatment plans. The B-IMRT plan's 16.4 Gy dose value was the most appropriate for oral cavity.

These findings suggest that different radiotherapy techniques offer various advantages and that the choice should be made according to the patient's specific clinical situation in the treatment of early-stage HL. The findings of this study highlight important points to consider in treatment planning and provide essential clues for future studies.

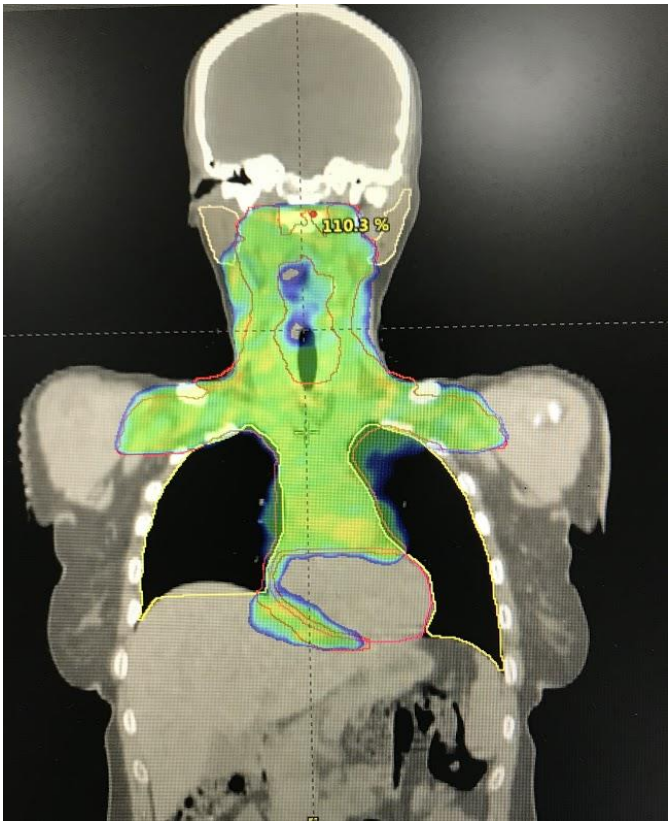

Figure 3.2D Representation of Dose Distribution of Critical Organs

The effectiveness and side effects of radiotherapy (RT) techniques in the treatment of Hodgkin Lymphoma (HL) have been extensively studied in the literature. This study compares the dose distributions of different radiotherapy techniques (B-IMRT and B-VMAT) for the treatment of early-stage HL and evaluates which technique is superior in terms of preserving normal tissues.

The literature includes studies comparing the dose distributions of radiotherapy techniques used in the treatment of HL. For example, Fiandra et al. compared 3D-conformal radiotherapy with different IMRT solutions and showed that IMRT techniques are superior in terms of normal tissue preservation [15]. Our study shows similar results; the B-IMRT technique provides better protection, especially in some healthy tissues with larger volumes (oral cavity, parotid, heart). A long-term study by Hodgson et al examined the risk of second malignancy after HL treatment and showed that radiotherapy may increase this risk [16]. Therefore, minimizing the radiation dose to normal tissues is critical in radiotherapy planning. In our study, the B-VMAT technique provided better results in total

lung preservation, indicating the potential to reduce long-term side effects. The study by Ng et al. showed that the combination of radiotherapy and chemotherapy in the treatment of HL may increase the long-term risk of cardiovascular disease [17]. In our study, the lowest cardiac dose was obtained in the B-IMRT plan, which can be considered an important finding in terms of reducing cardiovascular risks.

Conclusion

As seen in the plan, each plan has its own superiority. For example, the B-IMRT technique provides better protection, especially in some larger volume healthy tissues (oral cavity, parotid, heart), as expected. The B-VMAT technique showed the highest conformity index and better protected the total lungs. As a result, it is possible to provide the radiation dose that can reach the target with different radiotherapy treatment plans while avoiding radiation that will get normal tissues by RT planning procedures in early-stage HL. The advantages and disadvantages of each treatment plan should be considered, and the most appropriate treatment for the patient's clinical condition should be selected.

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Conflict of Interests: The authors Auglare that they have no conflict to interests

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