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IMPACT OF INTERMEDIATE DOSE CALCULATION MODULE ON THORACIC ESOPHAGUS CANCER RADIOTHERAPY PLANNING

Canan Koksal[1*], Nazmiye Donmez Kesen[1], Nergiz Dagoglu Sakin[2]

[1]Division of Medical Physics, Istanbul University Oncology Institute, Istanbul, Turkey
[2]Division of Radiation Oncology, Istanbul University Medical Faculty, Istanbul, Turkey

Abstract. *Radiotherapy is the one of the major treatment modality for thoracic esophagus cancer patients. Delivering high radiation dose to the planning target volume (PTV) while protecting the surrounding normal tissues can be achieved by volumetric modulated arc therapy (VMAT) which is the advanced radiotherapy technique. For creating VMAT dose distributions, optimization algorithms and dose calculation algorithms in commercial treatment planning systems (TPS) are used. Especially in cases of tissue heterogeneity, the final calculated dose volume histogram (DVH) differs from optimal DVH acquired via the optimization procedure. The intermediate dose calculation (IDC) module, in the Eclipse treatment planning system, is utilized on optimization of the VMAT plan to solve these differences. The aim of the present study is to investigate the impact of IDC module during the optimization of VMAT for the thoracic esophagus cancer patients. The VMAT plans were generated on Eclipse TPS v15.1 using AAA algorithm without IDC module for ten patients with thoracic esophagus cancer patients. Then, the plans were re-optimized without changing optimization criteria by using same dose calculation algorithm with IDC module. The prescribed dose to PTV was 50.4 Gy/28 fr. The homogeneity index (HI) and the conformity index (CI) of PTV, maximum dose of spinal cord, mean dose of heart, the lung volume of receiving 5 and 20 Gy, were compared between plans created with and without IDC module. The CI of PTV for VMAT plans with and without IDC module were found to be 0.822±0.030 and 0.729±0.039, respectively (p=0.005). The HI of PTV for VMAT plans with and without IDC module were found to be 0.073±0.017 and 0.126±0.022, respectively (p=0.005). The maximum dose of spinal cord (p=0.028) and the mean dose of heart (p=0.047) were found lower in VMAT plans with IDC module. However, there was no significant difference for the volume of the lung receiving 5 (p=0.236) and 20 Gy (p=0.053). In conclusion, applying IDC module on VMAT optimization increases the plan quality in thoracic esophagus cancer patients.*

Keywords: *Thoracic esophagus cancer, intermediate dose calculation module, VMAT*

1. INTRODUCTION

Esophageal cancer (EC) is the eighth most common type of cancer worldwide [1]. Because most patients are diagnosed at an advanced stage when surgery alone cannot accomplish a cure, radiotherapy plays a significant role in the treatment strategy of EC [2].

Thanks to improvements in technology, sophisticated radiotherapy techniques, such as intensity modulated radiation therapy (IMRT), volumetric modulated arc therapy (VMAT) have been developed. These techniques enable to deliver a high radiation dose to the planning target volume (PTV) while protecting the healthy tissues around PTV [3]. VMAT is widely preferred in clinical use due to providing less delivery time compared to IMRT.

VMAT treatment planning uses inverse planning techniques that conduct dose optimization and dose calculation to generate a clinically acceptable treatment plan [4]. First, plan optimization is performed to obtain the closest solution to the desired dose distribution using an iterative algorithm. The iterative algorithm is a simple and fast dose calculation algorithm that provides rapid optimization. After the optimization is finished, the final dose distribution is computed with a more precise dose calculation algorithm [5]. The final calculated dose volume histogram (DVH) and the optimal DVH acquired by the optimization may not identical due optimization convergence errors. The discrepancy between both DVHs is more observable into the heterogeneous medium such as lung. The intermediate dose calculation (IDC) module is utilized on optimization of the initial plan to reduce these differences [6].

When intermediate dose calculation module is applied throughout the optimization, the optimization is repeatedly carried out with the calculated dose distribution to get optimal DVH. Afterwards the optimization is completed; the dose calculation

* canankksal@gmail.com

algorithm is implemented to the plan once more [6]. There are studies on investigating the impact of the intermediate dose calculation module during the IMRT optimization for various cancer types, except esophagus cancer [5], [6]. The aim of the present study is to investigate the impact of IDC module during the optimization of VMAT for the thoracic esophagus cancer patients.

2. Materials and Methods

Computed tomography (CT) images of 10 thoracic esophagus cancer patients treated in Istanbul University Oncology Institute were used for this research. Patients were set up in a supine position on the CT table. Their arms were immobilized above their heads with the help of a wing board. CT images of patients were acquired with a slice thickness of 3 mm using Phillips Brilliance Big Bore CT scanner during free breathing. Then the images of patients were transferred to the Eclipse (version 15.1) treatment planning system (TPS). Target volumes were contoured on the CT dataset of each patient by one radiation oncologist. Organs at risk (OARs) including heart, lungs, and spinal cord were also delineated.

VMAT plans of ten patients with thoracic esophagus cancer were generated using Eclipse TPS v15.1. Two coplanar full-arcs, each with a length of 358°, were used for VMAT planning. All plans were created with 6 MV photon beams from a Varian Trilogy linac equipped with a Millennium 120-leaf MLC. The maximum dose rate was chosen as 600 MU/min. A dose of 5040 cGy in 28 fractions was prescribed to the PTV. The plan optimization was performed with Photon Optimizer (PO v15.1). Final dose calculation was carried out using Analytical Anisotropic Algorithm (AAA). The plan normalization was made such that 95% of the PTV received 100% of the prescribed dose. First, the plan optimization was conducted without intermediate dose calculation (IDC) module for all patients and AAA was applied to the plan for final dose calculation. These plans saved as “original plans”. Then, the original plans were re-optimized with IDC module without changing optimization objectives. Final dose calculation was performed with same dose calculation algorithm. Created plans with IDC module were named “new plans”.

Plans created with and without IDC module were compared in terms of plan conformity, dose homogeneity of PTV, and OARs doses. The CI [7] and HI [8] were calculated using the following formulas, respectively:

$$CI = \frac{TV_{RI}}{TV} \times \frac{TV_{RI}}{V_{RI}} \qquad (1)$$

$$HI = \frac{D_2 - D_{98}}{D_{50}} \qquad (2)$$

where TV_{RI} is target volume covered by reference isodose, TV is target volume and V_{RI} is the volume of the prescribed isodose. D2, D98 and D50 represent the doses received by 2%, 98% and 50% volumes of the PTV, respectively. The ideal value of CI and HI is 1 and 0, respectively. Maximum dose (Dmax) of spinal cord, mean dose (Dmean) of heart, the lung volume of receiving 5 and 20 Gy (V5 and V20), were evaluated. The Wilcoxon signed-rank test was used for statistical analyses (the SPSS version 11.0). Values of $p < 0.05$ were regarded as statistically significant.

3. Results

The CI of PTV for VMAT plans with and without IDC module were found to be 0.822±0.030 and 0.729±0.039, respectively (p=0.005). The HI of PTV for VMAT plans with and without IDC module were found to be 0.073±0.017 and 0.126±0.022, respectively (p=0.005). The CI and HI values for 10 thoracic esophagus cancer patients are shown in Figure 1 and Figure 2, respectively. The representative DVH of VMAT plans with and without IDC module is shown in Figure 3.

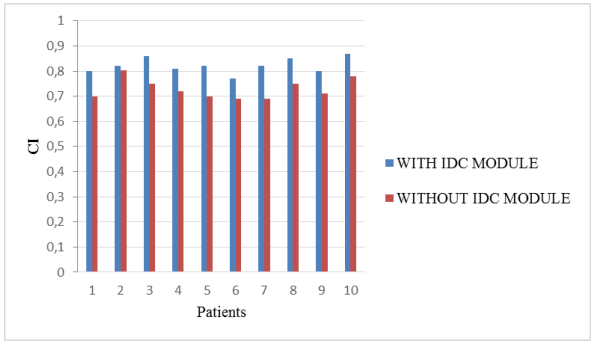

Figure 1. The CI values for 10 patients

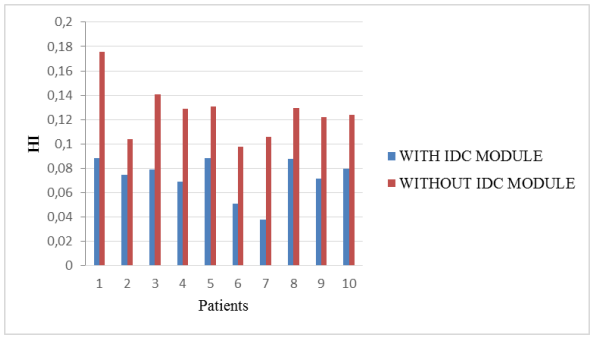

Figure 2. The HI values for 10 patients

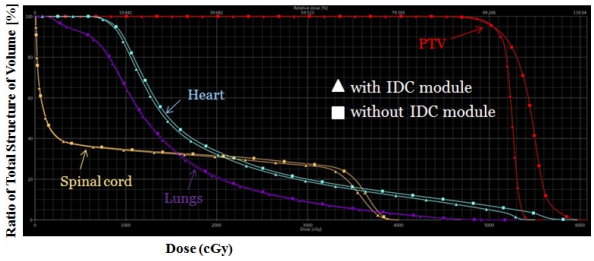

Figure 3. Representative DVH of plans with (Δ) and without (□) IDC module

The maximum dose of spinal cord (p=0.028) and the mean dose of heart (p=0.047) were found lower in VMAT plans with IDC module. However, there was no significant difference for the volume of the lung receiving 5 (p=0.236) and 20 Gy (p=0.053). Dose values of OARs for VMAT plans with and without IDC are shown in Table 1.

Table 1. Dose values of OARs for plans with and without IDC

Patients	Lungs V20 (%)		Lungs V5 (%)		Heart Dmean (cGy)		Spinal cord Dmax (cGy)	
	With IDC module	Without IDC module	With IDC module	Without IDC module	With IDC module	Without IDC module	With IDC module	Without IDC module
1	20	21	92	92	1984	2071	4013	3996
2	6	5	68	67	2039	2026	3465	3545
3	18	20	84	83	2027	1942	4198	4423
4	4	5	70	70	2006	2058	3725	3758
5	25	27	86	86	2504	2622	4105	4256
6	9	9	80	82	1632	1674	3898	3797
7	5	5	66	70	1154	1217	3235	3426
8	22	23	100	100	2440	2578	3674	3779
9	9	10	91	92	1708	1770	3823	3956
10	10	10	84	85	2407	2477	4334	4400
Mean	12.8	13.5	82.1	82.7	1990.1	2043.5	3847.0	3933.6
SD	7.7	8.4	11.2	10.8	415.2	436.4	337.1	341.1

4. Discussion

Radiotherapy is the one of the main treatment method for thoracic esophagus cancer patients. With advanced radiotherapy techniques such as VMAT, in which inverse planning techniques are used, highly conformal dose distributions are obtained, while normal tissues are protected at the maximum extent. Inverse planning is based on the use of optimization algorithms to achieve the objectives of delivering a high dose to the planning target volume (PTV) while diminishing dose to normal organs [9].

Preparing a VMAT treatment plan consists of two steps: plan optimization and final dose calculation. First, the optimization, uses a simplified algorithm, is completed; the final dose calculation is performed with a more accurate dose calculation algorithm. The optimized DVH and the final calculated DVH are different, especially in heterogeneous media. The intermediate dose calculation (IDC) module during optimization was added to Eclipse TPS to obtain better agreement between the final calculated DVH and optimized DVH [5], [6].

This research evaluated the dosimetric impact of IDC module applied to VMAT technique for thoracic esophagus cancer patients using Eclipse v15.1. Using IDC module during optimization of VMAT significantly improved the dose conformity and homogeneity in PTV. There were no significant differences in delivered doses to OARs, except spinal cord Dmax between the original and new plans. Akbaş et al [10] examined the dosimetric impact of IDC module on heterogeneous region radiotherapy planning. They prepared the IMRT plans using AAA with and without IDC for 12 maxillary sinus cancer patients. In their study, the CI values were 1.142 and 1.055; the HI values were 0.090 and 0.067 for IMRT plans without and with IDC, respectively. They reported that the utilizing IDC module throughout optimization improves the plan quality in head and neck cancer IMRT. Park et al [6] investigated the dosimetric effect of IDC module for 30 cases, including brain, head and neck, prostate, and lung IMRT. They concluded that the application of IDC module in IMRT plans provides better target conformity in PTV surrounded by heterogeneous tissues. Li et al [5] analyzed the impact of IDC during optimization on 11 lung IMRT plans. As a result of the study, the better CI and HI values were found in the plans with IDC, compared to the plans without IDC. In addition, they reported that spinal cord Dmax in plans with IDC was significantly lower than in the plans without IDC.

5. Conclusion

In conclusion, applying IDC module during VMAT optimization increases the plan quality in thoracic esophagus cancer patients. Therefore, utilizing the IDC module throughout VMAT optimization for thoracic esophagus cancer patients has become a standard practice in planning process in our institute.

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