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(Research Article)

Determination of the dose calculations accuracy of 3D-CRT treatment planning

Riadul Islam Chowdhury [1, *] and M Jahangir Alam [2]

[1] *Department of CSE, Pundra University of Science & Technology, Bogura, Bangladesh.*
[2] *Department of Radiotherapy, Ahsania Mission Cancer and General Hospital, Dhaka, Bangladesh.*

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Abstract

One of the important treatment modality for preventing cancer is radiotherapy. The objectives of radiotherapy are to deliver the recommended dosage to the tumor while preserving as much of the surrounding healthy tissues and the organs at risk (OARs). The aim of this study was to calculate the exact dose to the tumor and less dose to the OARs by modern LINAC based 3D-CRT techniques. In order to ascertain such delivery, computerised treatment planning systems (TPS) were used for calculating the necessary dose distribution based on anatomical arrangements of organs in the body, which in turn are depended on CT simulation of individual patient and the basic dosage parameters of the LINAC. The quality assurance (QA) tests had to be conducted for determining whether the intended radiation dosage would provide the patient with the appropriate dose distribution. In this present work, elaborate dose calculations of 20 different cancer patients with 6 MV and 15 MV photon beams and 6 MeV electron beam were performed. The laboratory assesments were carried out at Ahsania Mission Cancer and General Hospital, Uttara, Dhaka.

Keywords: 3D-CRT; OAR; QA; LINAC; TPS; CT simulation

1. Introduction

Cancer is a group of diseases characterized by uncontrolled growth and spread of abnormal cells. High-energy X-rays or other particles are used in treatment purposes to kill cancer cells. It can be administered internally or externally. Internal radiation, also known as brachytherapy, involves injecting radioactive material into the body. On the other hand, external radiotherapy uses a suitable device called a linear accelerator (or LINAC) to direct high-energy X-ray or electron beam into the affected area [1].

A precise technique is required to treat tumors with radiation. The aim of radiotherapy treatment planning is to obtain an optimal balance between delivering a high dose to target volume and a low dose to the organs at risk (OARs). The plan is critically estimated in order to prevent any complications that may arise from the dose to the nearby normal organs. Despite some evident limitations of 3D-CRT technique, it is still widely used to treat cancers. Some more advanced 3D-CRT treatment planning techniques have been developed to improve dose distribution to planning target volumes (PTVs) and OARs [2]. The accurate 3D mapping of a tumor's location is made by 3D-CRT's sophisticated computer software and advanced treatment equipment. The patient is fitted with a plastic mold or cast to keep the body part still during treatment. The radiation beams are matched (conform) to the shape of the target and delivered to the target from several directions. In 3D-CRT beam direction generally limited to1-4 directions [3]. Precise beam focusing can reduce radiation damage to normal cells and increase higher radiation dose to the target to raise treatment success.

The aims of the present work were to study the treatment planning system and the calculations of dose for 3D-CRT technique in LINAC based modern radiotherapy. The present work was carried out at Ahsania Mission Cancer and General Hospital, Uttara, Dhaka.

*Corresponding author: Riadul Islam Chowdhury

2. Material and Methods

For this investigation, twenty cancer patients were chosen. A multi-energetic linear accelerator (Elekta Synergy Platform) and Monaco (Monte Carlo dose calculation algorithm) treatment planning system were utilized. At first, tumor type, size and stage were determined by diagnosis. Target volume and organs at risk were optimized through CT simulation and contouring. The prescribed dose was then divided along different directions so that the target volume received the maximum dose and the surrounding OARs obtained limited dose.

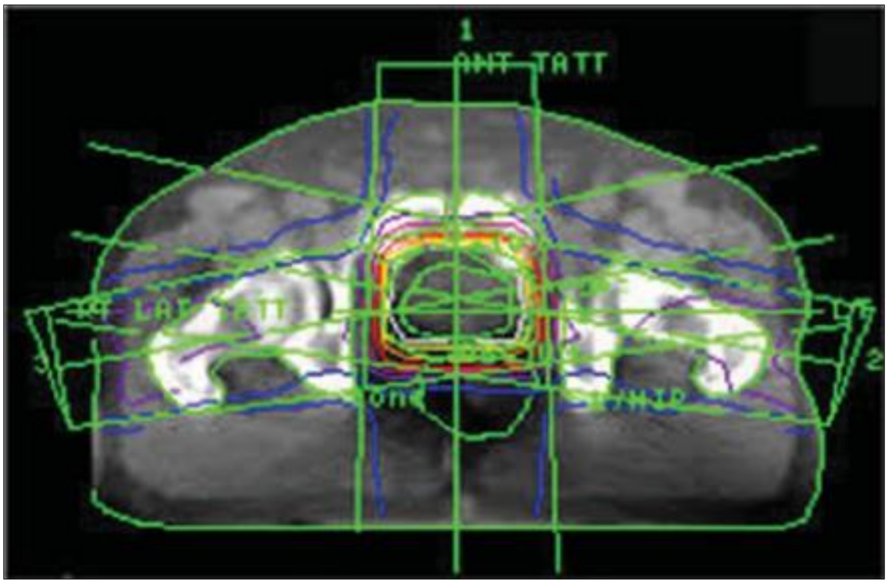

Figure 1 3D-CRT technique having beam fragmentation from various Directions

In this technique (3D-CRT), the target volume and OARs were viewed in three dimensions. The irradiated volume was adjusted to the shape of the tumor by means of irregular beams of uniform intensity that were directed in different directions based on the shape of the tumor. Due to this conformance, radiation exposure to the surrounding healthy tissue was reduced and higher doses could be safely delivered to the tumor [4]. The primary planning objectives were to reduce the dose to the OARs and maintain a homogenous dose to the targets as possible. The effectiveness of each strategy was assessed by analyzing a set of DVH parameters for every plan [5].

3. Results and Discussion

In the present work, elaborate dose calculations of 20 different cancer patients with 6 MV and 15 MV photon beams and 6 MeV electron beam were performed. Generally, 6 MV photon beam were used to treat Brain, Head and Neck (Toncil, Layrnx, Thyroid) cancers and 15 MV photon beam were used to treat the cancers in Oesophagus, Lung, Gall Bladder, Cervix, Rectum, etc. 6 MeV electron beam, on the other hand, was used in the case of Breast cancer. However, beam energy may vary with the location and the stage of cancer. The doses were prescribed according to the stages of cancers.

Dose volume histogram (DVH) contains vital information about the accuracy of plans. From the DVH of each plans, we can know whethere or not the target volume gets the optimum dose and the OARs get dose under the tolerance dose level. The DVH observed for the studied patients in 3D-CRT treatment protocol are depicted in Figures-2 to Figure-21, and the corresponding dose measurements for each patient are presented in Tables-1 to Table-20.

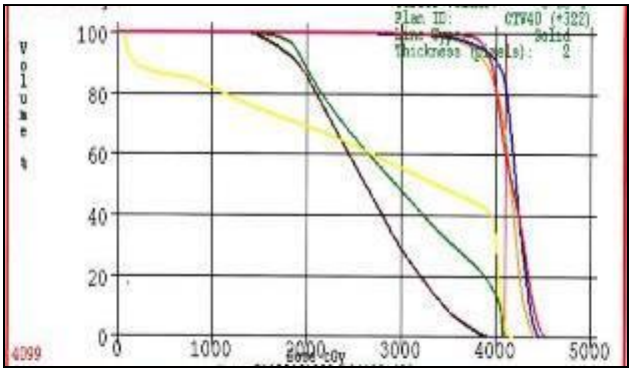

Figure 2 DVH of patient no.1 (Tonsil)

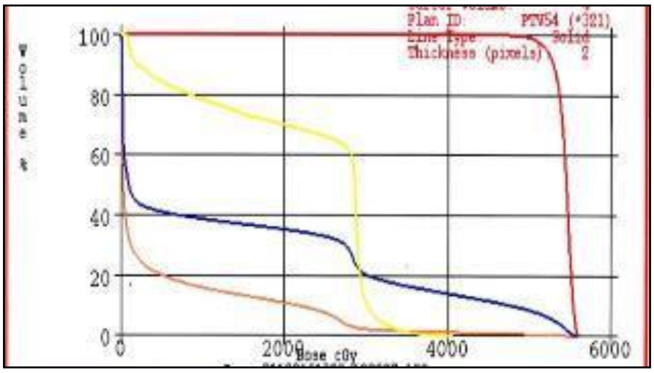

Figure 3 DVH of patient no.2 (Oesophagus)

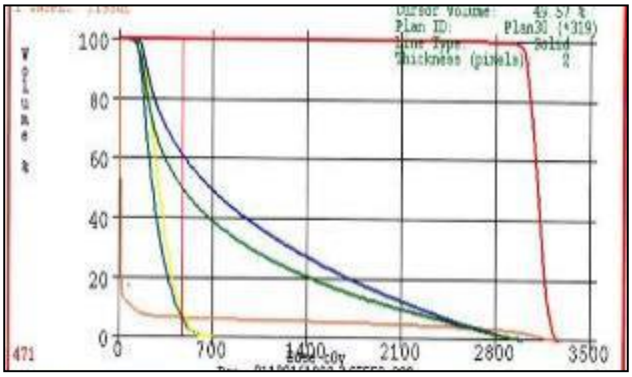

Figure 4 DVH of patient no.3 (Brain)

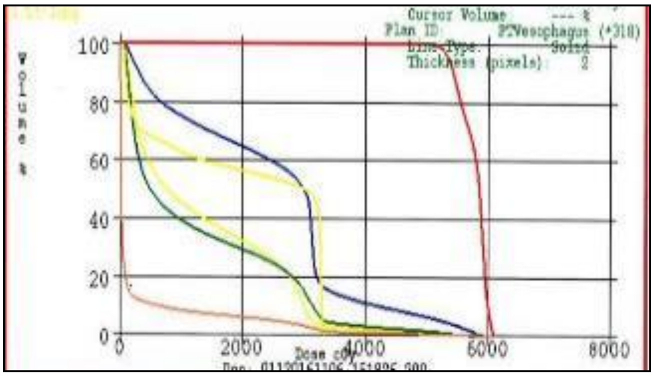

Figure 5 DVH of patient no.4 (Oesophagus)

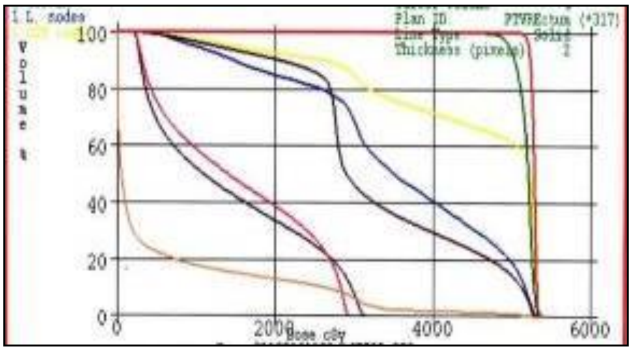

Figure 6 DVH of patient no.5 (Rectum)

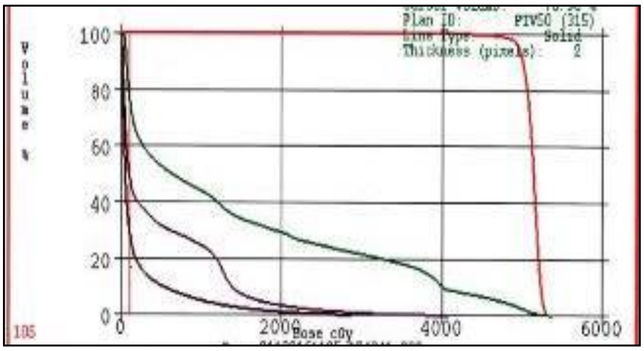

Figure 7 DVH of patient no.6 (Gall Bladder)

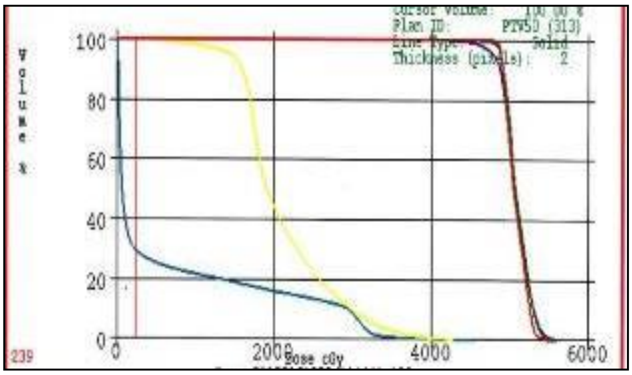

Figure 8 DVH of patient no.7 (Lung)

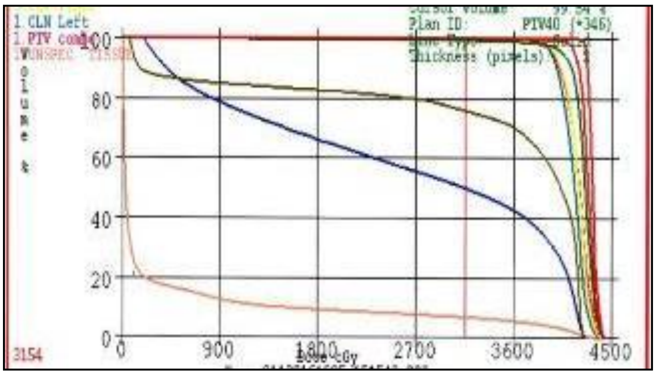

Figure 9 DVH of patient no.8 (Larynx)

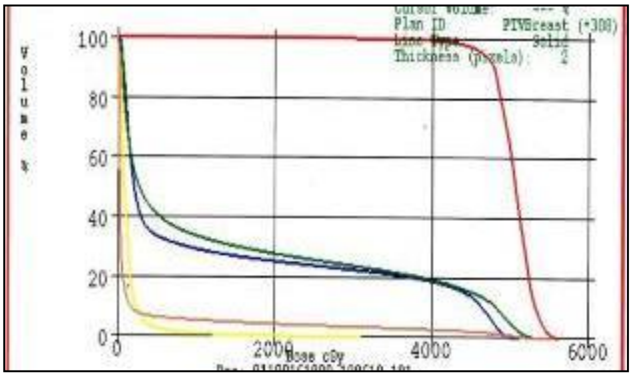

Figure 10 DVH of patient no.9 (Breast)

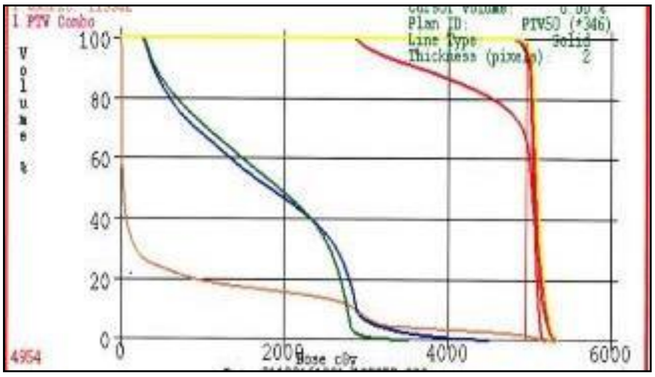

Figure 11 DVH of patient no.10 (Rectum)

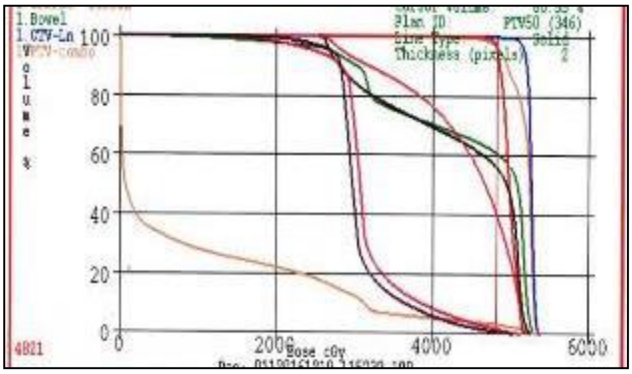

Figure 12 DVH of patient no.11 (Cervix)

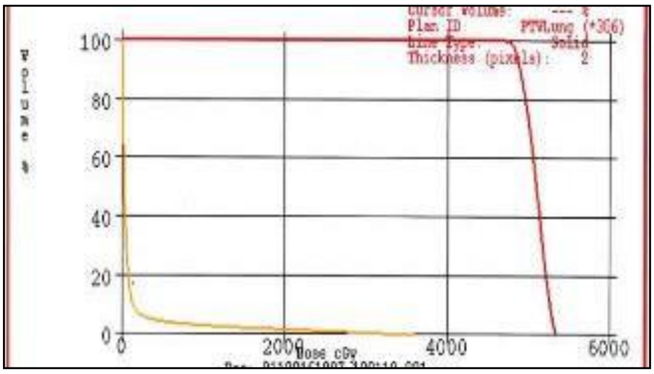

Figure 13 DVH of patient no.12 (Lung)

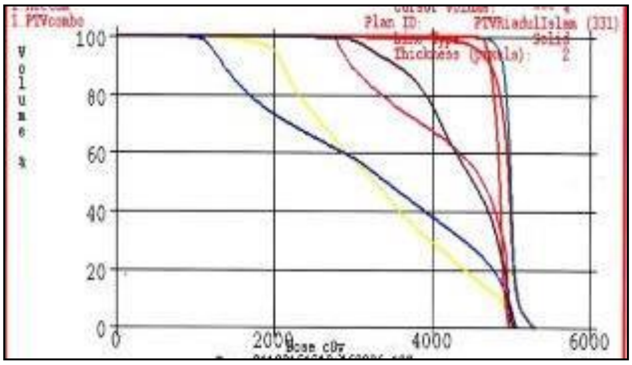

Figure 14 DVH of patient no.13 (Cervix)

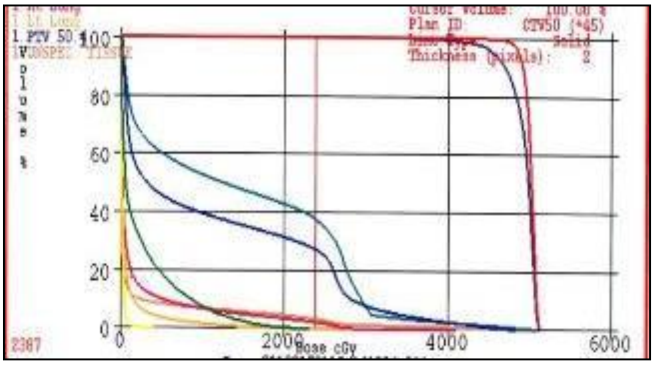

Figure 15 DVH of patient no.14 (Oesophagus)

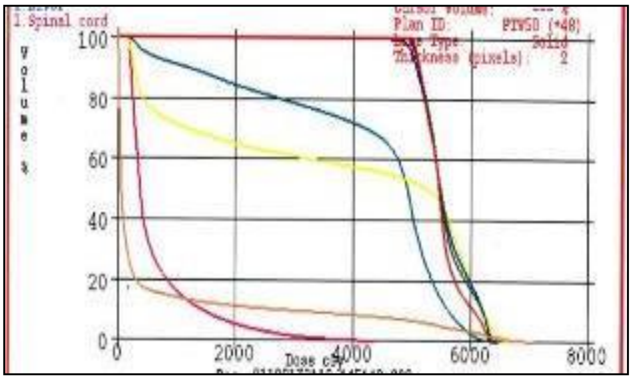

Figure 16 DVH of patient no.15 (Lung)

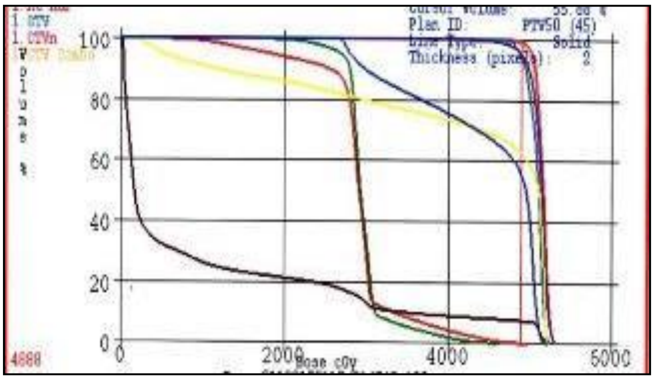

Figure 17 DVH of patient no.16 (Cervix)

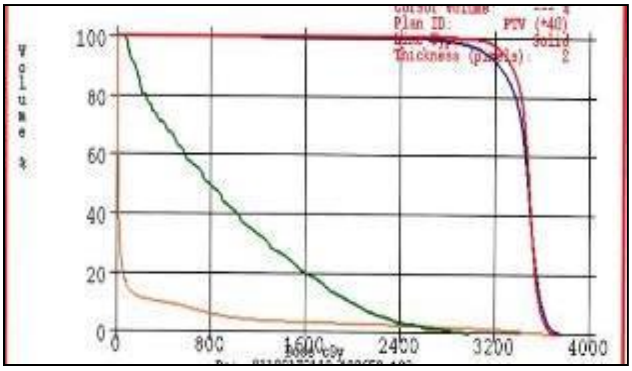

Figure 18 DVH of patient no.17 (Thyroid)

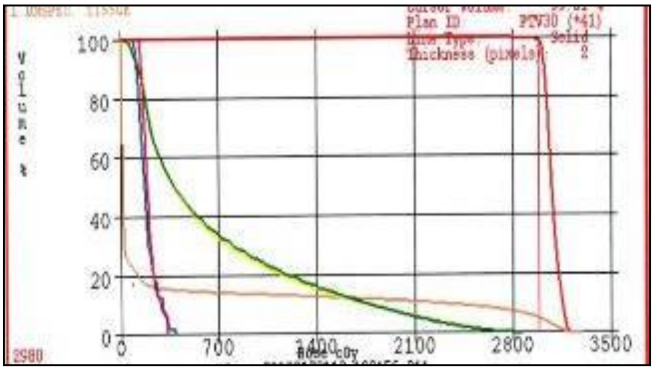

Figure 19 DVH of patient no.18 (Brain)

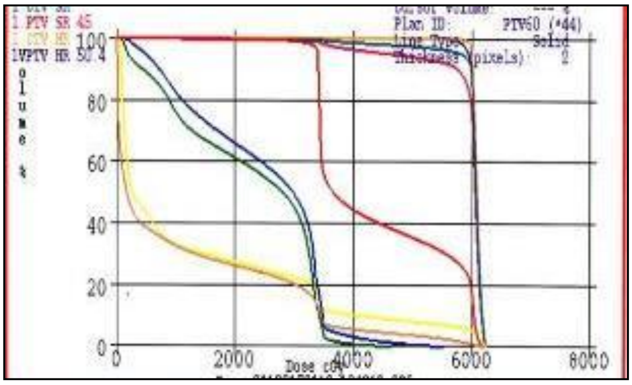

Figure 20 DVH of patient no.19 (Rectum)

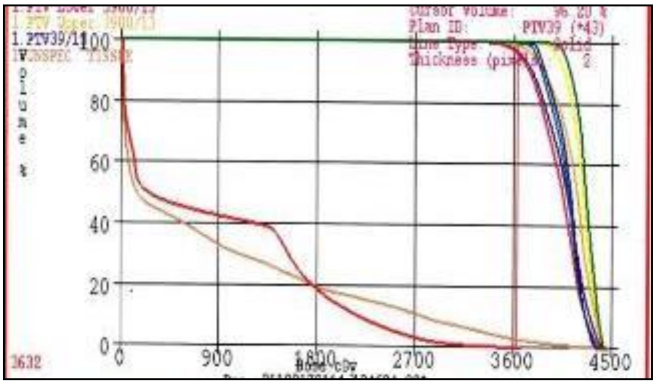

Figure 21 DVH of patient no.20 (Lung)

Table 1 Doses measurement for the patient no. 1 (Tonsil)

Structure	Dose		
	Goal (Gy)	Plan	measured
PTV	40.00	95%-107%	102.9%
CLN left	40.00	95%-107%	102.89%
CLN right	40.00	95%-107%	99.6%
Spinal cord	45.00	50Gy at < 1% V	41.36Gy
Parotid left	25.00	25Gy at < 50% V	29.38Gy
Parotid right	25.00	25Gy at < 50% V	26.2Gy

Table 2 Doses measurement for the patient no. 2 (Oesophagus)

Structure	Dose		
	Goal (Gy)	Plan	Measured
CTV	54.00	95%-107%	102.33%
Spinal cord	45.00	50Gy at< 1% V	34.01Gy
Heart	40.00	50Gy at< 33% V	21.8Gy

Table 3 Doses measurement for the patient no. 3 (Brain)

Structure	Dose		
	Goal (Gy)	Plan	Measured
PTV	30.00	95%-107%	106.67%
Eye right	10.00	45Gy Max	29.86Gy
Eye left	10.00	45Gy Max	30.03Gy
Lens left	5.00	7Gy(0.03) Max	6.67Gy
Lens right	5.00	7Gy(0.03) Max	6.61Gy

Table 4 Doses measurement for the patient no. 4 (Oesophagus)

Structure	Dose		
	Goal (Gy)	Plan	measured
CTV	54.00	95%-107%	104.28%
Spinal cord	45.00	50Gy at< 1% V	32.5Gy
Right lung	37.00	20Gy at < 35% V	12.5Gy
Left lung	37.00	20Gy at< 35% V	12.5Gy
Heart	40.00	50Gy at< 33% V	11.1Gy

Table 5 Doses measurement for the patient no. 5 (Rectum)

Structure	Dose		
	Goal (Gy)	Plan	measured
CTV	50.40	95%-107%	109.01%
L. nodes	50.40	95%-107%	21.14%
CTV combo	50.40	95%-107%	33.56%
Bladder	45.00	70Gy at< 20% V	47.08Gy
Right HOF	30.00	40Gy at < 40% V	18.98Gy
Left HOF	30.00	40Gy at< 40% V	15.94Gy
Cervix	50.00	50Gy at< 50% V	51.64Gy

Table 6 Doses measurement for the patient no. 6 (Gall Bladder)

Structure	Dose		
	Goal (Gy)	Plan	measured
PTV	50.00	95%-107%	105.26%
Left kidney	35.00	20Gy at< 75% V	0.12Gy
Right kidney	35.00	20Gy at< 75% V	0.45Gy
Liver	35.00	35Gy at< 50% V	5.6Gy

Table 7 Doses measurement for the patient no. 7 (Lung)

Structure	Dose		
	Goal (Gy)	Plan	measured
GTV	50.00	95%-107%	102.74%
CTV	50.00	95%-107%	102.73%
PTV	50.00	95%-107%	100.21%
Spinal cord	45.00	50Gy at < 1% V	40.2Gy
Heart	40.00	60Gy at< 33% V	1.8Gy

Table 8 Doses measurement for the patient no. 8 (Larynx)

Structure	Dose		
	Goal (Gy)	Plan	Measured
GTV	40.00	95%-107%	112.12%
CTV	40.00	95%-107%	109.34%
PTV	40.00	95%-107%	106.82%
CLN right	40.00	95%-107%	104.82%
CLN left	40.00	95%-107%	103.82%
PTV combo	40.00	95%-107%	104.31%
Spinal cord	45.00	50Gy at< 1% V	42.32Gy
Thyroid	25.00	45Gy at< 50% V	31.54Gy

Table 9 Doses measurement for the patient no. 9 (Breast)

Structure	Dose		
	Goal (Gy)	Plan	Measured
PTV	50.00	95%-107%	98.21%
Right lung	37.00	20Gy at< 35% V	8.85Gy
Liver	25.00	35Gy at< 50% V	2.2Gy
Heart & GV	40.00	60Gy at< 33% V	1.5Gy

Table 10 Doses measurement for the patient no. 10 (Rectum)

Structure	Dose		
	Goal (Gy)	Plan	Measured
PTV	50.00	95%-107%	104.29%
PTV- CLN	50.00	95%-107%	106.31%
PTV combo	50.00	95%-107%	105.26%

HOF right	25.00	40Gy at< 40% V	23.8Gy
HOF left	25.00	40Gy at< 40% V	23.8Gy
Bladder	30.00	70Gy at < 20% V	50.6Gy

Table 11 Doses measurement for the patient no. 11 (Cervix)

Structure	Dose		
	Goal (Gy)	**Plan**	**Measured**
CTV-T	50.00	95%-107%	96.36%
CTV-CLN	50.00	95%-107%	109.47%
PTV combo	50.00	95%-107%	102.63%
Right HOF	25.00	35Gy at< 50% V	29.62Gy
Left HOF	25.00	35Gy at< 50% V	30.75Gy
Rectum	50.00	50Gy at< 50% V	47.1Gy
Bladder	50.00	70Gy at< 20% V	51.25Gy
Bowel	25.00	48Gy Max	53.24Gy

Table 12 Doses measurement for the patient ID: 12 (Lung)

Structure	Dose		
	Goal (Gy)	**Plan**	**Measured**
PTV	50.00	95%-107%	101.68%
Heart	25.00	60Gy at< 33% V	0.63Gy

Table 13 Doses measurement for the patient no. 13 (Cervix)

Structure	Dose		
	Goal (Gy)	**Plan**	**Measured**
PTV	50.00	95%-107%	98.96%
Pelvic nodes	50.00	95%-107%	102.11%
PTV combo	50.00	95%-107%	96.84%
U Bladder	50.00	70Gy < 20% V	49.38Gy
HOF right	25.00	35Gy < 50% V	33.87Gy
HOF left	25.00	35Gy < 50% V	32.55Gy
Rectum	50.00	50Gy < 50% V	46.38Gy

Table 14 Doses measurement for the patient no. 14 (Oesophagus)

Structure	Dose		
	Goal (Gy)	Plan	Measured
CTV	50.00	95%-107%	102.29%
PTV	50.00	95%-107%	96.1%
Spinal cord	45.00	50Gy at< 1% V	11.29Gy
Left kidney	23.00	20Gy at< 75% V	0.54Gy
Right kidney	23.00	20Gy at< 75% V	0.01Gy
Liver	25.00	35Gy at< 50% V	11.8Gy
Right lung	20.00	20Gy at< 35% V	0.38Gy
Left lung	20.00	20Gy at< 35% V	0.26Gy

Table 15 Doses measurement for the patient no. 15 (Lung)

Structure	Dose		
	Goal (Gy)	Plan	Measured
GTV	50.00	95%-107%	107.15%
CTV	50.00	95%-107%	106.32%
PTV	50.00	95%-107%	105.16%
Heart	25.00	60Gy at< 33% V	57.42Gy
Liver	25.00	35Gy at <50% V	49.11Gy
Spinal cord	45.00	50Gy at< 1% V	31.87Gy

Table 16 Doses measurement for the patient no. 16 (Cervix)

Structure	Dose		
	Goal (Gy)	Plan	Measured
GTV	50.00	95%-107%	102.91%
CTV	50.00	95%-107%	105.81%
CTV combo	50.00	95%-107%	105.01%
PTV combo	50.00	95%-107%	102.91%
Bladder	60.00	70Gy at< 20% V	50.41Gy
Rectum	50.00	50Gy at< 50% V	51.03Gy
Bowel bag	25.00	48Gy Max	52.17Gy
HOF left	25.00	35Gy at< 50% V	29.24Gy
HOF right	25.00	35Gy at< 50% V	29.11Gy

Table 17 Doses measurement for the patient no. 17 (Thyroid)

Structure	Dose		
	Goal (Gy)	Plan	Measured
CTV	30.00	95%-107%	115.01%
PTV	30.00	95%-107%	109.47%
Spinal cord	20.00	50Gy at < 1% V	26.2Gy

Table 18 Doses measurement for the patient no. 18 (Brain)

Structure	Dose		
	Goal (Gy)	Plan	Measured
PTV	30.00	95%-107%	105.97%
Right lens	5.00	7Gy(0.03) Max	3.16Gy
Left lens	5.00	7Gy(0.03) Max	3.68Gy
Right eye	25.00	45Gy Max	28.62Gy
Left eye	25.00	45Gy Max	28.67Gy

Table 19 Doses measurement for the patient no. 19 (Rectum)

Structure	Dose		
	Goal (Gy)	Plan	Measured
CTV HR	60.00	95%-107%	105.26%
CTV SR	60.00	95%-107%	95.04%
PTV HR	60.00	95%-107%	95.91%
PTV SR	60.00	95%-107%	83.53%
Bladder	60.00	40Gy at< 40% V	43.04Gy
HOF right	35.00	40Gy at< 40% V	28.35Gy
HOF left	35.00	40Gy at< 40% V	29.11Gy
Bowel bag	25.00	40Gy at< 100cc	31.13Gy

Table 20 Doses measurement for the patient no. 20 (Lung)

Structure	Dose		
	Goal (Gy)	Plan	Measured
GTV upper	39.00	95%-107%	110.09%
GTV lower	39.00	95%-107%	103.89%
CTV upper	39.00	95%-107%	108.53%
CTV lower	39.00	95%-107%	102.59%

PTV upper	39.00	95%-107%	102.59%
PTV lower	39.00	95%-107%	99.33%
PTV 39 /13	39.00	95%-107%	99.49%
Spinal cord	45.00	50Gy at< 1% V	28.92Gy

The goal of treatment planning was to deliver doses to the targer volumes within 95%-107% of the prescribed doses in 95% of target volumes and kept the doses of OARs below their tolerance limits [6, 7]. But in certain cases for Cervix cancer, it was found that the doses of some OARs (like Rectum, Bowel bag) exceeded their tolerance limits. Since Cervix, Rectum and Bowel bag are very close to one another, it were impossible to get a better dose coverage (95%-107%) in target volumes and kept the doses of OARs below their tolerance limits. In case of patient (Rectum)no. 5, the L.node (CLN) and CTV- combo did not get the expectable dose coverages (95%-107%) in planning. In this case, if we would want a better dose coverage in L.node (CLN) and CTV-combo, then the dose of Cervix exceeded much higher than the tolerance level. Thus, Cervix was badly affected. In cases of patient (layrnx)no. 8 and patient (Thyroid) no. 17, the target coverage doses were much higher than expectable limit. Since this two cases were pallitive case, the aims were to reduce the patient's pain immediately.

4. Conclusion

In radiotherapy treatment procedure quality assurance is essential part for preventing cancer with safe, effective and care. An improper radiation dose will cause to patient more harm than benefit. In order to assure the quality treatment, an individual treatment plan is made for each patient and each tumor volume. Based on clinical considerations and practical limitations, it is almost universally accepted now that the accuracy in the dose delivery to the dose specification target volume should be within 95%-107% of prescribed dose in 95% of target volume and the OARs get doses below the limits of tolerance doses of each case. However, in some critical situations (when the target volume is very small and required high dose), the delivered dose may permeable up to 111% in 95% of target volume of the prescribed dose. In our present study we find that the target volume received 95%-107% of prescribed dose in 95% of its volume and the OARs get doses below the limits of tolerance doses except some critical conditions.

Compliance with ethical standards

Acknowledgement

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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