



## A Study of the Effect of Using Modulated Intensity Radiotherapy Compared to Three Dimension Conformal Radiotherapy on Urinary Bladder Tumors



Rasha S. Shams El Dine<sup>(1)#</sup>, Ahmed Abdel Latif<sup>(2)</sup>, Kamel M. Nasra<sup>(1)</sup>, Dina M. Sallama<sup>(2)</sup>

<sup>(1)</sup>Medical Biophysics Department, Medical Research Institute, Alexandria University, Alexandria, Egypt; <sup>(2)</sup>Medical Oncology Department, Mostafa Kamel Hospital, Alexandria, Egypt.

**D**OSIMETRIC comparison and evaluation of planning target volumes (PTV) coverage and organs at risk sparing using step and shoot (IMRT) and 3D CRT techniques for bladder cancer radiotherapy were performed to evaluate the dosimetric parameters of the step and shoot (IMRT) technique, and to compare them to that of the 3DCRT technique, and then to find whether the use of IMRT technique reduces homogeneity index or not. Data from 50 patients with bladder cancer, planned by IMRT and 3 DCRT were obtained. The prescribed dose for IMRT procedure and 3 DCRT was 64 Gy. Moreover, the target coverage was achieved with 95% of the prescribed dose to 95% of the PTV in 3 DCRT and 95% of the prescribed dose to 98% of the PTV in the IMRT plans. A total of fifty IMRT and 3DCRT plans were performed for evaluation of dosimetric parameters (for each patient both treatment plans, step and shoot IMRT (6 MV energy), and 3DCRT 10 MV energy). This integral dose was calculated as the mean dose times the volume. The mean integral doses (ID) received by all the dosimetrically measured volumes and both the rectum, right and left femoral heads and small bowel were greater for 3DCRT than for IMRT shown in Dose- Volume Histogram (DVH).

**Keywords:** Advances in radiotherapy, Intensity modulated radiotherapy, Conformal radiotherapy, Dose optimization.

### Introduction

Cancer is a major public health worldwide problem and is the second leading cause of death in the United States (Siegel et al., 2022). Any body tissue may be affected, and it may take on various shapes depending on the location of the body.

A benign or a malignant tumor might result from the cells' fast proliferation. Benign tumor is a mass of cells that do not metastasize to other parts of the body and therefore, it is rarely life threatening. In most cases, the prognosis with benign tumors is very good but benign tumors can be serious if they cause pressure effect on vital structures such as blood vessels and nerves. therefore, sometimes they may require treatment and other times they

do not (Waugh & Grant, 2006; Strayer et al., 2014). Malignant tumors, on the other hand, can invade other organs and spread and become life threatening.

Many new types of treatment are now being used or investigated in bladder cancer. namely surgery, intravesical therapy, radiotherapy, targeted therapy, Gene therapy.

Radiotherapy aims to give the prescribed dose to the tumor and to protect as much as possible the organs at risk and the surrounding healthy tissues. Multimodality treatment with radiotherapy, chemotherapy and surgery are available treatments of different kinds of tumors. Intensity modulated radiation therapy (IMRT) is an advanced technique of high precision

#Corresponding author e-mail: [rasha\\_shams17@yahoo.com](mailto:rasha_shams17@yahoo.com)

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radiotherapy that uses computer controlled linear accelerator to deliver precise radiation doses to a malignant tumor or specific areas within the tumor. IMRT allows for the radiation dose to conform more precisely to the three-dimensional (3-D) shape of the tumor by modulating or controlling the intensity of the radiation beam in multiple small volumes. In addition, it allows higher radiation doses to be focused to regions within the tumor while minimizing the dose to the surrounding normal critical structures (Chui et al., 2001).

Radiotherapy starts with scanning of the patients in CT, delineating areas of interest, creating the treatment plans and sending all the data to the machine through a functional system. An important part of this chain is the plan. of system being able to create 3D CRT and IMRT plans. Conventionally, the three-dimensional conformal radiation therapy (3D CRT) treatment planning is manually optimized (Langer & Leong, 1987). This means that the treatment planner chooses all beams parameters, such as the number of beams, beam directions, shapes, weights etc., and the computer calculates the resulting dose distribution (Ezzell, 1996).

The purpose of the present study is to compare the three-dimensional conformal radiation therapy (3D CRT) and the intensity modulated radiation therapy (IMRT) treatment planning techniques for the treatment of bladder cancer, and to evaluate its efficacy in meeting multiple normal tissue constraints with maximizing tumor coverage.

## **Materials And Methods**

Fifty patients of both sexes confirmed with histological bladder tumors from a hospital in Alexandria city (in Oncology Center of Armed Forces Hospital) I nage range (40 -70 years) were recruited in the current study from January 2020 to February 2022.

The present study guarantees the privacy of any personal information regarding the patients data according to the protocol serial number E/C.S/N.T76/2021 in Medical Research Institute, Alexandria University.

*Each patient was subjected to the following:*

Patient set-up (Preparation, Localization & Immobilization), each patient was asked to empty

their bladder and empty rectum, and then each patient is in supine position was immobilized with pelvis board (Pro STEP ABS), Spiral CT with 3-mm slice from 3 cm below the umbilicus to mid shift of femur.

### *Simulation in CT room*

All patient underwent multi slice computed tomography, each patient was placed on a flat table top with a multi slice diagnostic CT scan (Siemens Somatom scope) (Skrzynski & Ślusarczyk-Kacprzyk, 2016), and each patient was fixed by using Pro STEP ABS.

### *Importing and contouring*

The images received from the CT scanner were transferred to the treatment planning system

(TPS). The acquisition and contour of the planning target volumes (PTV) and the critical volumes of organs at risk (OARs) were performed according to the Radiation Therapy Oncology Group (RTOG). The organs at risk, in this work, included rectum, Rt femur, Lt femur and small bowel which were delineated by radiation oncologist on the CT slices using contouring workstation.

### *Designing the treatment plans*

All the treatment plans were created by a medical physicist as follows:

All of the selected patient's plans were done in two group for both three-dimensional conformal radiotherapy and intensity modulated radiotherapy techniques. For group one 50 plans using of 6 MV & 10MV photon energy were conducted.

The prescribed dose of PTV was 64Gy in 32 fraction for two techniques (3D and IMRT), dose per fraction were from 180 to 200 cGy, plans were done in two phases, then analysis of the dose distribution of the 3D and IMRT designs that was calculated as a result is shown in DVH. The PTV was compared according to the homogeneity (HI) and the dose volume histogram (DVH) data.

For the organs at risk (OARs) i.e. Rectum, Lt femur, Rt femur, Small bowel:

- The mean and minimum doses, the V40 and V50% received by the rectum.

- The maximum, minimum, mean doses, the V50% received by the of Lt and Rt femur.
- The V45% received by the small bowel.
- The plans of three -dimensional conformal radiotherapy dose of 64Gy in 32 fraction was calculated, dose per fraction is 200 cGy, 3D Planes were done in two phases with energy 10Mev.
- In intensity modulated radiotherapy dose of dose of 64Gy in 32 fraction dose per fraction is 200 cGy, IMRT Planes were done in two phases with energy 6Mev
- A comparison was carried out, two phases Three Dimension Conformal Radiotherapy (3D) and

Intensity Modulated Radiotherapy (IMRT) is shown in the Fig. 1.

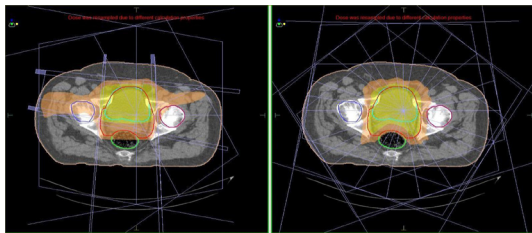


Fig. 1. Transverse slices 3D and IMRT

#### Dose volume histogram (DVH)

Dose volumetric analysis was done by Monaco DVHs sum plans for all phases in both 3D conformal radiotherapy and intensity modulated radiotherapy. The maximum and mean dose for sum plans for PTV, and organs at risk (Rectum, Small bowel, Lt and Rt femur) were calculated from DVH. The last step was exporting the optimal plans to the (mosaic) software.

#### Treatment planning machine

The medical linear Accelerator (Elekta), was used to deliver the prescribed dose.

#### Statistical analysis of data

In the current study, statistical analysis of data was carried out using IBM SPSS 20 software.

### Results

#### Comparison between IMRT and 3D

##### The planning target volume (PTV)

In the present study, the mean dose in the case

of treatment using IMRT is higher than 3D and it was found to be statistically significant at Median (IQR) with range (6420.6 – 6483.1) and (6354.2 – 6452.0), respectively, as shown in Fig. 2.

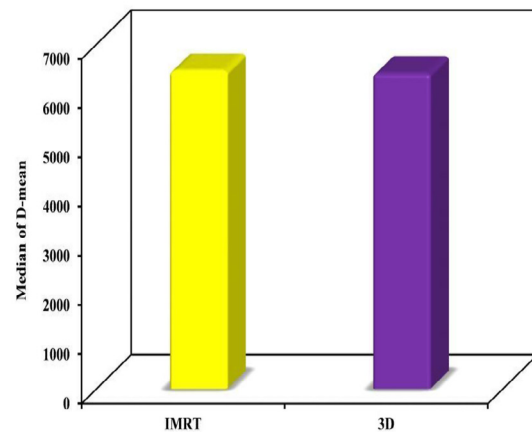


Fig. 2. Mean doses received in the different treatment planning

#### Homogeneity index (HI) of the PTV

In this study, the homogeneity of treatment using IMRT is more than 3D because the value of HI (IMRT) approaching zero and it is statistically significant as shown in Fig. 3 that median (IQR) was in range (0.03 – 0.04) and (0.12 – 0.14), respectively.

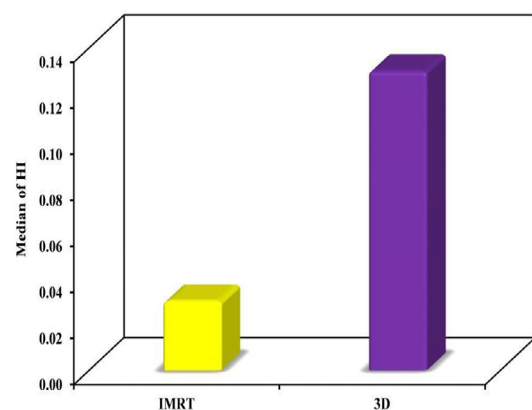
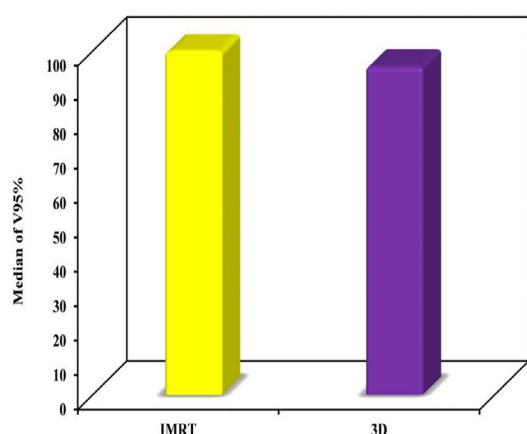


Fig. 3. Comparison between HI in the different treatment planning

#### V95 (Volume of the PTV covered by 95% of the received dose)

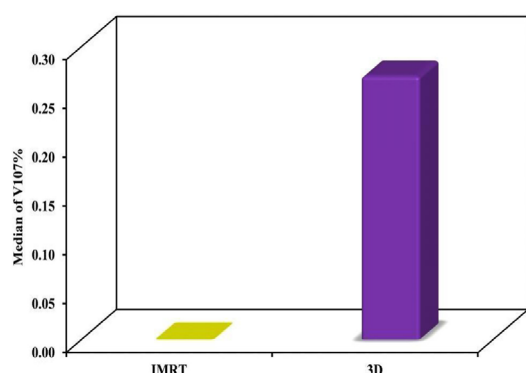
In the present study, The volume of the PTV covered by 95% of the received dose in the case of treatment using IMRT is higher than 3D and it is statistically significant that Median (IQR) with range (100.0-100.0) and (95.1-95.6), respectively, as shown in Fig.4



**Fig. 4. Volumes % covered by 95% of the dose in the different treatment planning**

*V107 (Volume of the PTV covered by 107% of the prescribed dose)*

In the current study, The volume of the PTV covered by 107% of the received dose in the case of treatment using IMRT is lower than 3D and it was found to be statistically significant that Median (IQR) with range (0.0-0.0) and (0.0-1.1), respectively, as shown in Fig. 5.



**Fig. 5. Volumes % covered by 107% of the dose in the different treatment planning**

#### *Organs at risk (OARs)*

The organs at risk considered in this study are as follows:

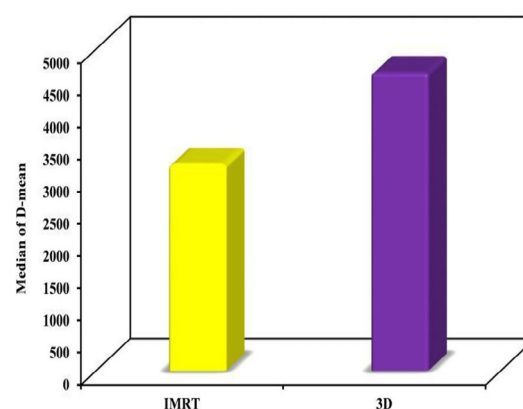
Rectum, Both femoral heads, small bowel. volumes of the organs at risk are as delineated from the CT scans.

#### *The rectum*

##### *Mean dose (cGy) received by the rectum:*

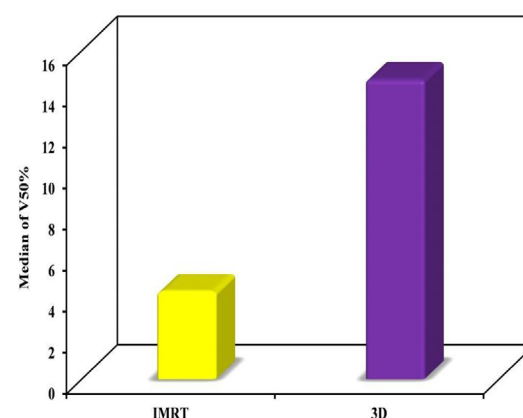
In this study, the mean dose (cGy) received by the rectum in the case of treatment using IMRT is lower than 3D and it was found to be statistically

significant as shown in Fig. 6 that Median (IQR) with range (3131.9 – 3342.2) and (4178.2 – 4763.1), respectively.



**Fig. 6. Mean doses to the rectum**

*V50% (Volume % of the rectum covered by 50% of the received dose):* In this study, the volume % of the rectum covered by 50% of the received dose in the case of treatment using IMRT is lower than 3D and it was found to be statistically significant as shown in Fig. 7 that Median (IQR) with range (2.4 – 13.4) and (5.0 – 29.2), respectively.



**Fig. 7. V50% of the rectum of 3D and IMRT in treatment planning comparison**

#### *The right femur*

*V50% (Volume % of the right femur covered by 50% of the received dose):* In this study, the volume % of the right femur covered by 50% of the received dose in the case of treatment using IMRT is lower than 3D and it was found to be statistically significant as shown in Fig. 8 that Median (IQR) with range (0.0-0.20) and (0.60-4.5), respectively.

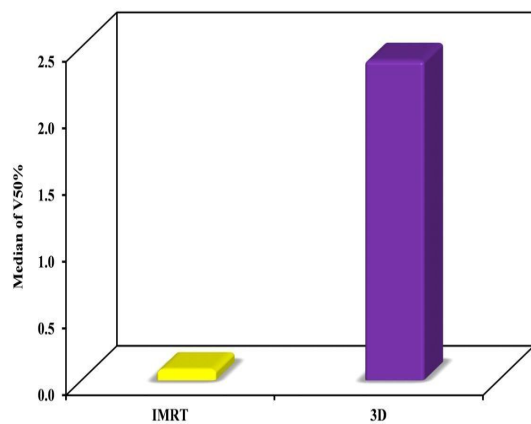


Fig. 8. V50% of right femur of 3D and IMRT in treatment planning comparison

#### Left femur

*V50% (Volume % of the left femur covered by 50% of the received dose):* In this study, the volume % of the left femur covered by 50% of the received dose in the case of treatment using IMRT is lower than 3D and it was found to be statistically significant as shown in Fig. 9 that Median (IQR) with range (0.03-0.35) and (0.80-4.3), respectively.

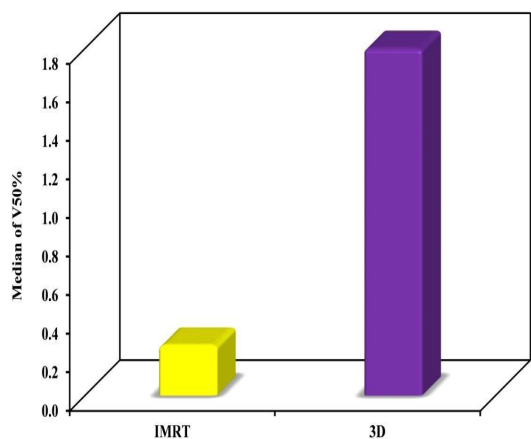


Fig. 9. V50% of left femur 3D and IMRT in treatment planning comparison

#### Small bowel

*V45% (volume % of the small bowel covered by 45% of the received dose):* In this study, the volume % of the small bowel covered by 45% of the received dose in the case of treatment using IMRT is lower than 3D and it was found to be statistically significant as shown in Fig. 10 that Median (IQR) with range (49.68–110.55) and (97.32–217.05), respectively.

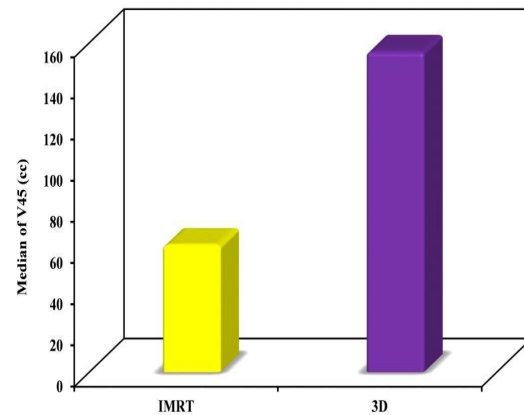


Fig. 10. V45% of small bowel of 3D and IMRT in treatment planning comparison

### Discussion

The purpose of the present study is to compare the 3D conformal and IMRT Radiotherapy techniques, the first plan was performed with the use of Traditional technique (IMRT) with energy (6 MeV). The other plan employed the 3D conformal technique with energy (10 MeV). This work shows that IMRT approach is dosimetrically better than 3D-CRT by sparing significant quantities of the rectum and colon while retaining adequate the coverage of target tumor. In comparison to 3D-CRT, IMRT also preserves the rectum at 50 Gy and higher doses.

The unaffected bladder is next to the primary target, but these data show how versatile IMRT is important in preserving tissues nearby. Overall, the robust capacity of IMRT to protect the rectum, bowel, and both femoral heads from substantial volumes of high-dose radiation calls for consideration in clinical studies for bladder preservation. This result conformed to the results RTOG-8903 and are described in the Supplement (Shipley et al., 1998). RTOG-8903 constraints were also used for organs at risk, including posterior rectum wall constrained to maximum dose of < 50 Gy, but femoral heads were constrained to maximum dose of < 50 Gy. 100% of the gross tumor volume was required to have a minimum coverage at 95% of the prescription. Constraints were evaluated by creating plan sums of the primary and boost treatment for both the IMRT and 3D-CRT plans.

The comparison between the three conformal radiation plans, is considerably greater for IMRT plans ( $p < 0.001$ ) (Vieillot et al., 2010).



In accordance to Menzel (2014) the dose parameters in the **HI**- equation can be read out from volume histogram representing the cumulative dosage in equation. The lower the HI- value (**closer to zero**), a more uniform dosage distribution in the assessed volume is found

The dose parameters in the **HI**- equation can be read out from volume histogram representing the cumulative dosage in equation. The lower the HI- value (**closer to zero**), a more uniform dosage distribution in the assessed volume is found.

$$HI = \frac{D2\% - D98\%}{D50\%}$$

The homogeneity index (HI) is an indication of how homogeneous the dose distribution is within a certain volume.

In this study, the mean dose (cGy) received by the rectum in the case of treatment by IMRT is lower than 3D and it is statistically significant in the obtained results, also the percentage of the rectum volume covered by 50% of the received dose in the case of treatment using IMRT is lower than 3D. The overall dosage distribution to the rectum is much improved compared to 3D-CRT. The possibility of rectal toxicity also seems to be significantly decreased with IMRT (Gulliford et al., 2010).

In accordance to Rimmer et al. (2008) the techniques used in the present work sustained the safety of the normal tissues, since the increase in the radiation dose to bladder tumor is limited by the radiation toxicity effects on these tissues, particularly the rectum the major advantage of IMRT is the ability to decrease the dose to critical structures, which in turn lowers the radiation toxicity effects (Ashman et al., 2005; Freedman et al., 2006).

IMRT plans produced statistically significant lower doses to the left and right femoral heads (Menhel et al., 2006). The percentage volume of the right femur covered by 50% of the received dose in the case of treatment using IMRT is lower than 3D, it is statistically significant in our results.

## Conclusions

The present study represents a good vision about the advantages and disadvantages of two treatment methods for bladder tumors.

IMRT technique is low time consuming for QC and more comfortable for the patient, and it is the best solution for keeping the doses to organ at risk in the permitted level.

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