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Comparative dosimetry of forward and inverse treatment planning for Intensity- Modulated Radiotherapy of prostate cancer

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Abstract: Purpose: *This study compared the dosimetric outcomes and treatment efficiency between forward (F-IMRT) and inverse intensity modulated radiotherapy treatment technique (I-IMRT) for localized prostate cancer.*

Materials and methods: *Twenty patients with localized prostate carcinoma were re-planned on Xio treatment planning system (TPS) for forward and inverse intensity modulated radiotherapy (F-IMRT and I-IMRT). Analyses were performed on comparing the dose volume histograms (DVHs) for Planning target volume (PTV) and the relevant organ at risk (OARs). Target coverage was evaluated with parameters including (Dmean) the mean target dose ,(Dmax) the maximum target dose, (D50%), (D98%), (D2%),(D5%) and (D95%), the doses that covered 50,98,2,5 and 95 % of the volume of the PTV respectively. Also, (V95%) the volume of the target received 95% of prescribed dose (PD) and (V≤110%) the target volume received less than or equal 110% of PD. Target dose distribution and conformality was evaluated with the homogeneity indices (HI) , Conformity Index (CI) and uniformity indices(UI).Treatment efficiency was assessed using total number of monitor units (MUs), total number of segments, integral dose, planning and treatment time. Normal tissue avoidance of OARs was evaluated with using (D30) the dose received by 30% volume for rectum and bladder ,(V70), (V65), (V60) and(V50); volume received at least an absorbed dose 70, 65,60 and 50 Gy respectively. Irradiated body volume (IBV) at 10 Gy (V10), and 20 Gy (V20) were calculated. Also, (IBV36)and (IBV90) volume received 50and 90 % of PD were calculated. Finally the integral dose was calculated .*

Results:

The mean PTV D95% were 68.76±0.28 Gy, 68.92±0.5Gy for F- IMRT and I- IMRT respectively (p= 0.01), D98 %was significantly higher for I-IMRT (68.40±7.3 Gy) plans compared to F-IMRT (68.10±7.1 Gy).

Target dose distribution was homogeneous in F-IMRT plans; however, I-IMRT plans had significantly higher CI (p = 0.02). The mean volume values for rectum and bladder (V70 and V65) were similar and the difference was not statistically significant in both IMRT plans. The mean volume for both femoral heads V50 was smaller in I-IMRT than for F-IMRT planning (p = 0.005).The integral dose was statistically significant in I-IMRT compared to F-IMRT p=0.001.

Conclusion: *I-IMRT has achieved better PTV coverage, CI and offered greater degree of OARs sparing while F-IMRT has better HI and improved the treatment efficiency due to small number of MUs and shorter treatment time. IMRT planning increases the IBV at 10Gy or less but decreases the IBV at 20 Gy. Further research is required to evaluate the dose escalation between F-IMRT and I-IMRT.*

Keywords: *Treatment planning system, Intensity-modulated radiotherapy, forward planning; Inverse planning, dose volume histogram.*

I. Introduction

Radiotherapy is one of cancer treatment modality where ionizing radiation is used to kill the cancer cells [1].
It is aimed to deliver maximum dose to the tumor while minimizing the dose to the surrounding unspecified normal tissues [2] . Before the time of Intensity modulated radiotherapy (IMRT) the conventional high energy photon treatment was used. The introduction of the Computerized Tomographic (CT) in the 1980s and Magnetic Resonance Imaging (MRI) in 1990s has given the radiation oncology a reliable three dimensional (3D) overview of the patient anatomy where the soft tissues and tumors can be clearly outlined. Thus the need to deliver conformal treatment fields became obvious and feasible. Three dimensions conformal radiotherapy (3DCRT) is a change from traditional that uses target and normal tissues identified on serial transverse CT images, field shape based on beam's eye view(BEV) projections, volumetric dose calculations, and volumetric plan evaluation tools such as (DVHs) AAPM report 82, 2003[3] . DVHs display how much radiation is being

delivered to a specific volume of tissue and provide a quantitative evaluation of target coverage as well as dose to normal tissues.

IMRT planning is an extension of 3DCRT that uses ionizing radiation beam intensities and determined by various TPS based on optimization techniques [4]. The success of IMRT planning in different tumor sites is dependent on the accuracy of tumor delineation through different imaging modality [5].

Two treatment planning modality are generally applied for step and shoot IMRT, the first method is an extension of three dimension conformal therapy (3-DCRT) and is defined as forward planning (F-IMRT).

It's a very simplified form of IMRT which employ a few beams each with few segments S Webb, 2003[6] . The planner tried a variety of configurations of beams, wedges and more than one segment (1-3)is used from each beam direction . These segment shapes are adjusted manually after that, the dose weights of the segments are optimized in trial and error by the planner using a computer algorithm until a suitable homogenous dose match is found to the desired dose prescription. The clinical implementation using the F- IMRT planning is relatively easy, because it is closely related to conventional planning. The clinical implementation of IMRT using forward planning is relatively easy, because it is closely related to conventional planning.

The other technique is Intensity Modulated Radiation Therapy (IMRT) which we denote as inverse planning . It's a fixed delivery technique contain a set of intensity modulated beams enters the patient from multiple directions, which the multi-leaf collimator(MLC) allowed to move in between the segments when the beam is off (Step and shoot). The concept of inverse planning IMRT is that, dose distributions are inversely determined, meaning that the treatment planner must specify the dose distribution that is desired.

The method for calculating the required intensity fluence from each beam segment is done by inverse treatment planning with high computer system using an iterative process to calculate doses with algorithms, starting with the desired result(optimization of fluence map) and then working backwards to generate an optimal way to reach the final goal(desired dose distribution).

Most I-IMRT planning computer systems allow a specification of dose-volume constraints and or dose limits S Webb, 2003[6]. Inverse planning is far less related to conventional radiotherapy because the segment shapes are not defined manually ; However, there are complex clinical situations, which require the use of many beam directions and segments; though, in these cases, inverse planning may be the more efficient strategy. In I-IMRT, the number of MUs delivered has increased , reduced the hot spot dose[7] ,increase the integral dose to normal tissues[8-9] and these has increases the risk of secondary malignancy cancer [10] compared to 3DCRT. In addition the prolonged treatment time of I-IMRT may affect the treatment accuracy due to increasing the chances of internal organ movement owing to volume changes (rectum and bladder) , and patient respiration over time [11] . The medical physicist should verify the actual dose delivered to the patient before I-IMRT treatment. AAPM TG119 [12] guide line are available on how to verify IMRT plans. The quality assurance (QA), time involved in planning and delivery are a logical extension of the experience obtained with conformal radiotherapy. Until The International Commission on Radiation Units and Measurements (ICRU) 83[13] Report was released in 2010 for IMRT only and introducing some different concepts and plan evaluation parameters , ICRU 50 [14] and ICRU 62 [15] Reports were widely used as an international reference for the prescribing, recording, and reporting of photon beam radiotherapy, including 3DCRT and IMRT.

The aim of the present study is to compare dosimetric quantitative and qualitative in forward-planning (field-in-field 3D conformal radiation therapy) and inverse-planning IMRT techniques regarding Physical DVH treatment parameters (Target +OAR) and dosimetric parameters as target dose distribution, coverage volume , normal tissue avoidance, Irradiated body volume (IBV),mean and maximum dose, Homogeneity Index (HI), Conformal number , Conformity Index (CI),Uniformity index(UI) , Over dose Index (ODI) ,Mu, delivery time integral dose and treatment efficiency.

II. Materials and Methods

Twenty patients with localized prostate cancer were CT scanned (General Electric (GE) in supine position. All images obtained with 2.5 mm slice thickness. The PTV and OARs delineation was performed by the radiation oncologist. Two plans F-IMRT and I-IMRT (PD =72Gy /36 fraction) made on XIO TPS (CMS; Elekta, version 4.4). All I-IMRT plans were consisted , seven coplanar fields, with 0°, 51°, 100°, 151°, 202°, 253° and 304° gantry angles ;while, in F-IMRT 5 fields with 0°, 51°, 90°, 270° and 315° gantry angle .

All treatments were delivered by ELEKTA precise (6MV) .

Data collection and plan evaluation

The plans were evaluated qualitatively by comparing, the dose distribution through the patient volume (cut-by-cut) and quantitatively with the use of DVHs . The maximum dose, mean dose and a set of values (Dx%) the percentage dose received by the x% volume of the target volume and (Vx %) the percentage volume irradiated by x% of the PD ,were obtained for the OARs. To achieve the target coverage and normal tissue sparing the following parameters were used.

HI and CI indexes

Dose homogeneity and dose conformity are independent specifications for evaluating plan quality.

Dose homogeneity characterizes the uniformity of dose distribution within the target volume[16] and was defined as the difference between the maximum and minimum dose normalized to the median dose[7].

$$HI = (D\ 2\% - D\ 98\%) / D50\%$$

Where D2 (maximum), D98 (minimum) and D50 (the median dose to 50%of target volume) represent the doses received by 2, 98 and 50 %volumes of PTV respectively, and HI = Zero is ideal value.

Dose conformity specifies the degree which the high dose region conforms to the target volume [16] and it used for comparison the degree of conformity between plans and was calculated in term of the tumor volume enclosed by 95% isodose line to the PTV volume (V95% / VPTV), and CI=1 is ideal, Therapy and Oncology Group RTOG [17-19] .

Uniformity (UI) and Over dose (OD) Indexes

The dose UI was defined as UI = D5 / D95, Where D5 and D95 are the dose delivered to 5% and 95% of PTV volume, respectively, [20-21].

The ODI was defined as PTV covered by 105% isodose line to PTV volume ($V105_{\%}$ / V_{PTV}).

OARs

The degree of organ sparing was compared using DVHs for all patients with F-IMRT and I-IMRT plans.

The guideline for OARs evaluation were described in QUANTEC Group report by Marks, 2010[22] table (1).

No plan was accepted with hot spot along the rectal wall and bladder to reduce the toxicity risk.

Table (1) Dose constraints to OARs.

Structure	Constrains
Bladder	V70≤ 25% V65≤ 50%
Rectum	V50<50% V60<35% V65<25% V70<15%
Right and left femoral head	V50<10%

Healthy tissues

To find the lower dose to normal unspecified tissue, (IBV10 and IBV20) the normal tissue volume receiving radiation dose more than 10 Gy and 20 Gy[23-24] respectively were calculated. To estimate the dose outside PTV, (IBV36 and IBV90) the normal tissue volume received 50% and 90% of PD respectively were calculated .

To evaluate the dose to the healthy tissues, the concept of integral dose (ID) was used.

Integral dose is defined as the total energy absorbed by the body, multiplied by volume and computed based on the average organ density, averaged organ dose, and volume.

ID is defined as Integral dose = D .ρ.V (Gy.Kg), Where D, ρ and V are averaged organ dose, averaged organ density and volume, respectively [23]. In this study the integral dose is simplicity calculated as:

Integral Dose =Average Dose × Volume (unspecified tissue) (Gy.cc)

ID is defined as Integral dose = D .ρ.V (Gy.Kg), Where D, ρ and V are averaged organ dose, averaged organ density and volume, respectively [23]. In this study the integral dose is simplicity calculated as:

Integral Dose=Average Dose × Volume (Gy.cc**)**

Treatment efficiency

To achieve the treatment efficiency, the mean average segments number, mean MUs, and mean average treatment time were assessed. Both techniques underwent a "dummy run", to simulate the treatment time of a real patient. The treatment time included the time for planning, radiation delivery, in addition to the time required for QA plan verification.

Statistical analysis

Data were analyzed using SPSS win statistical package version 22. Numerical data were summarized as means and standard deviations (SD) . The Wilcoxon's matched-pairs test was used to determine statistical differences between volumes and doses in F-IMRT vs I-IMRT plans. The dose–volume parameters of target

volumes and OARs were also measured and compared. Probability (p-value) equal or less than 0.05 is considered significant.

III. Results

Both I-IMRT and F-IMRT techniques had good result regarding PTV coverage, while I-IMRT had shown a slightly sharper dose gradient than the F-IMRT plans. Figure (1) showed the isodose distribution of the F-IMRT and I-IMRT techniques in transverse CT section.

Target coverage, dose Conformity and dose Homogeneity index

Tables (2- 3) summarized the dosimetric results of the PTV. The planning objective in both techniques were achieved nearly the same result; however ,the differences were statistically not significant in term of Dmax (75.1±1.53 ,76.3±1.58Gy), D mean (71.48±0.72,71.98±0.78Gy), D50%(71.82± 0.87,72.2± 0.80 Gy) , D5% (74.33±1.42 ,73.71±1.16Gy) , V≤110 (2.95±2.03.1.99±2.83 %), ODI(0.1±0.03 , 0.13±0.02 %) and UI(1.08±0.46, 1.06±0.26 Gy) in F-IMR and I-IMRT respectively .

I-IMRT showed a slightly considerably difference in PTV dose coverage with V95% , D98% , D95, D2 and the differences were statistically significant compared to F-IMRT table (2).

F-IMRT had better acceptable dose homogeneity (0.097±0.054 Gy) compared to I-IMRT (0.095±0.17 Gy) and the differences was statistically significant table (3). The isodose distribution shown a bit better conformity to the PTV in I-IMRT(0.964± 0.011) compared with F-IMRT (0.961±0.010) plans and the differences was statistical significant (p=0.02). I- IMRT reduced the hotspots volume by 4% compared to F-IMRT table (2); however, the difference was statistically not ssignificant.

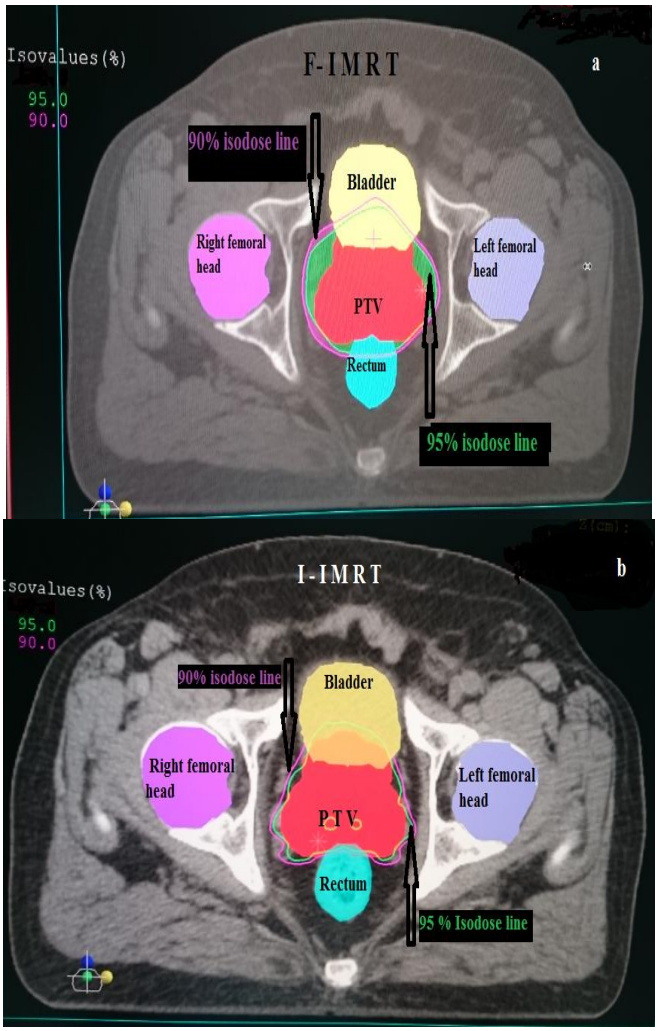

Figure 1 the isodose distribution in the transverse CT section (a) F-IMRT and (b) I-IMRT plans.

Organ at risk (OARs)

Table (4) and figure 2(b-e) summarize the dosimetric result of OARs.

Both techniques achieved organ sparing according to QUANTIC [22] guide constraint ,table (1).
The DVHs analysis for rectum and both femoral heads showed that I-IMRT were better than F-IMRT technique while in bladder both techniques had similar result; however, these differences were statistically not significant. The mean dose for rectum (D30%) was (56.36±9.36, 47.14± 9.96Gy) for F-IMRT and I-IMRT respectively, and the differences were statistically significant table(4) . D30% for bladder was (10.16± 18.62, 10.90±20.04 Gy) with F-IMRT and I-IMRT respectively; however, the differences were statistically not significant. Regarding the rectum and bladder volumes received 70, 65, 60, 50 Gy, there was a small difference between both techniques; however, the differences were statically not significant table (4).
The average mean doses for right femoral head were (30.39 ±6.43, 25.12 ±5.07Gy) for F-IMRT and I-IMRT respectively ;however, the difference were statistically not significant while, the average mean dose (V50) were (2.99±4.4, 0.24±0.86%) for F-IMRT and I-IMRT respectively and (p=0.003) .
The average mean dose for left femoral head were (30.71 ±5.19, 24.77 ±6.38Gy) for F-IMRT and I-IMRT respectively ;however, the differences were statically not significant while, the mean dose (V50) were (3.03 ± 4.25 , 0.14 ± 0.32%) for F-IMRT and I-IMRT respectively,(p=0.06) table (4) .

Table (2) D_{max} (Gy), D_{mean} (Gy), $D_{95\%}$ (%), $D_{98\%}$ (%),$D_{2\%}$, $D_{5\%}$ (%),(%) , $V_{\leq 110\%}$ (%)plans, where D_{max} : maximum dose to, $D_{mean:}$ mean dose, D_{min} : minimum dose for PTV in F-IMRT and I-IMRT.

Parameter	D_{max} (Gy)		D_{mean} (Gy)		$D_{50\%}$ (Gy)		$D_{98\%}$ (Gy)	
	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT
Mean ± SD	75.1±1.53	76.3±1.58	71.48±0.72	71.98±0.78	71.87± 0.53	72.21±0.8	67.19±0.62	67.75±0.95
P-Value	0.06		0.08		0.12		0.04*	
Parameter	$D_{2\%}$ (Gy)		$D_{5\%}$ (Gy)		$V_{95\%}$ (%)		$V_{\leq 110\%}$ (%)	
	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT
Mean ± SD	74.23±1.27	74.61±1.46	74.33±1.42	73.71±1.16	97.04±1.002	97.64±1.09	2.95±2.03	1.99± 2.83
P-Value	0.021*		0.19		0.04*		0.1	
Parameter	D_{min} (Gy)		D95% (Gy)		V90% (%)			
	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT		
Mean ± SD	58.35±3.9	60.2±2.25	68.76±0.28	68.99±0.54	99.23±4.9	99.49±5.1		
P-Value	0.03*		0.01*		≤0.001*			

*P-values < 0.05.

Table (3) the homogeneity index (HI), conformity number (CI), monitor units (MU), number of segments, uniformity index (UI), over dose index, planning time and treatment time in F-IMRT and I-IMRT plans.

Parameter	HI		CI		UI		ODI	
	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT
Mean ± SD	0.097±0.054	0.095±0.17	0.961±0.010	0.964± 0.011	1.08±0.017	1.06±0.29	0.10±0.03	0.13±0.02
P-Value	0.008*		0.02*		0.232		0. 1	
Parameter	MUs		Number of segments		Planning time		Treatment time	
	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT	F-IMRT	I-IMRT
Mean ± SD	665.64±57.44	719.6 ±103.5	5.6±1.71	91.38±9.06	40±9.5	65±13.4	22.5±7.7	38±9
P-Value	0.04*		≤ 0.001*		0.012*		≤ 0.001*	

*P-values < 0.05.

Table (4). The dose–volume parameters for the different OARs for F-IMRT and I-IMRT plans. Where D_{mean}: mean dose to organ

OARs	DVH parameter	F-IMRT	I-IMRT	P -Value
Rectum	D_{mean} (Gy)	42.58±7.59	40.58±5.61	0.3
	D 30%(Gy)	56.36±9.36	47.14± 9.96	0.05*
	V_{50Gy} (%)	37.15±12.27	29.74±8.28	0.08
	V_{60Gy} (%)	26.7±9.8	17.9±6.47	0.1
	V_{65Gy} (%)	20.54±8.59	11.87±5.1	0.1
	V_{70Gy} (%)	9.02±7.38	4.82±3.2	0.2
Bladder	D_{mean} (Gy)	40.30±9.5	40.30±6.21	0.5
	D 30%(Gy)	10.16±18.62	10.90±20.04	0.2
	$V65_{Gy}$ (%)	22.56±8.78	18.37±5.22	0.2
	V_{70Gy} (%)	11.01±6.47	10.74±4.5	0.07
RT head of femur	D_{mean} (Gy)	30.39 ±6.43	25.12±5.07	0.06
	V_{50Gy} (%)	2.99±4.4	0.24±0.86	0.003*
LT head of femur	D_{mean} (Gy)	30.71±5.19	24.77±6.38	0.06
	V_{50Gy} (%)	3.03 ± 4.25	0.14 ± 0.32	0.005*

*P-values < 0.05.

Table (5) Dosimetric parameters for the normal healthy tissue represented as mean and standard deviation (SD).

DVH Parameters	F- IMRT (Mean ± SD)	I- IMRT(Mean ± SD)	P-Value
D mean (cGy)	412.4±139.57	480.25±167.28	≤0.001*
IrV10 (%)	16.3 ±5.82	19.37 ±6.85	0.04*
IrV20 (%)	10.19 ±3.78	13.48 ±4.97	≤0.001*
IrV36 (%)	5.65 ±2.4	6.37 ±2.97	0.003*
IrV90 (%)	0.27 ±1.13	0.01 ±0.019	≤0.001*
Integral dose(cGy)	687.59±425	800.72±608	0.001*

*P-values < 0.05.

Treatment MUs, MLC segment, Integral dose for normal healthy tissue, treatment time and time efficiency

Table(3) showed that, the average planning time 65 ±13.4 minutes (range 40–75 minutes) was longer in I-IMRT compared to F-IMRT 40 ±9.5 minutes (range 30–65 minutes) and the difference was statistically significant. The mean delivery treatment time of I- IMRT (38 ±9 min) was longer than F-IMRT (22.5 ±7.7 min) and the difference was statistically significant.

The average number of segment was (5.6±1.71, 91.38±7.06) for F-IMRT and I-IMRT respectively, table (2), and this was statistically significant ($p \leq 0.001$). I-IMRT increased the number of MUs (719.6 ±103.5 MUs) compared to F-IMRT (665.64± 57.44MUs) . I-IMRT increased the number of segment by factor15 compared to F-IMRT .The larger number of MUs in I-IMRT could lead to higher integral, dose table (5) and this was statistically significant (p=0.04). I-IMRT reduced the hot spot by factor 4% owing to beam modulation during plan optimization.

Regarding unspecified normal tissue , the mean average volume was smaller with F-IMRT compared to I-IMRT table (5) in lower radiation dose region (IBV10, IBV20) and, the differences were statistically significant. The mean irradiated volume received 20Gy was smaller than 10 Gy .

In middle radiation dose region (IBV36), F-IMRT was smaller, with bigger normal tissue volume received 50% of prescribed dose compared to I-IMRT and the difference was statistically significant table(5).

In higher dose region (IBV90), the treated normal tissue volume was higher in F-IMRT compared to I-IMRT and the difference was statistically significant table (5).

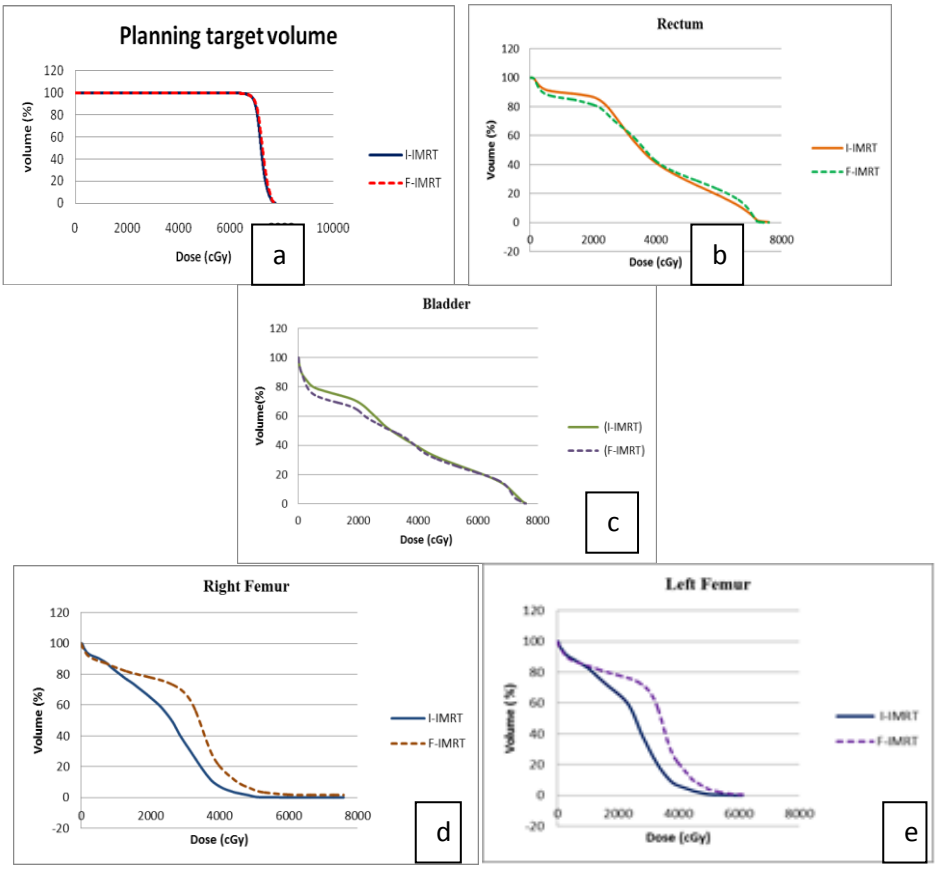

Figure 2(a-e) Mean DVH for (a) PTV, (b) Rectum, (c) Bladder, (d) RT femur and (e) LT femur.

IV. Discussion

Target coverage, dose conformity and dose homogeneity index

The employment of newer and complex technologies for the treatment of tumors improve target coverage while keeping normal tissue doses under known thresholds to avoid the complications ;however, conventional forward technique is used in some cases as pelvis and lungs which have not small PTV margins and dose delivered in one or two phases according to the plan complexity . Also, it is used in some head and neck cases with certain beam arrangement and the high dose delivered in phases to save OARs.

it was observed, both techniques rendered similar and nearly equivalent target dose volume distributions that was able to reach our planning goals and reduce the dose spillage to the healthy tissues ; however, the results showed that I-IMRT achieved better target dose coverage , higher degree of conformality for the concavity PTV and reduced high dose region to the surrounding normal tissue and rectal wall.

I-IMRT optimization provided a uniform dose distribution, and produced greater dose inhomogeneity through steep dose gradients in target volume compared with F-IMRT(P=0.841). The greater dose inhomogeneity was due to ideal optimized I- IMRT plans which, cannot be executed with the use of existing multileaf collimator systems. Also, the isocenter (reference point) was placed anywhere inside the treated volume including those locations that may be near a low-dose region or inside an normal tissue where, it used for positioning the patient in the treatment machine and this was critical for dose delivery [43] . our results were met ICRU 83 guidelines .

According to the RTOG and ICRU 83 guidelines, the CI in I-IMRT has able to conform the dose distribution to the concavity of target volume and achieved improvement with better sparing of critical and uninvolved surrounding structures. Our results were in contrast to the study reported by Fisher [24] and consistent with other studies reported by[25- 26].This contradiction may be due to variation in tumor shape and relevant OARs.

I- IMRT reduced hot dose spots in, due to beam modulation during optimization and our result is consistent with S. Moorthy[7] .

Treatment MUs, MLC segment and Integral dose for normal healthy tissue

F-IMRT has reduced MUs by approximately 7.53% due to small number of beams and segments compared to F-IMRT.

F-IMRT has reduced the number of segment and our result was consistent with J. Luc [27] who reported that, reducing number of segment could limit the degree of intensity modulation and compromise the dose distribution.
The mean delivery time of I-IMRT was longer than F-IMRT owing to the larger number of beams, segments, MUs delivered and the dead time in the gantry rotation from field to field.
F-IMRT has shown to spare more healthy tissue in low dose region at V_{10Gy} and V_{20Gy} compared to I-IMRT. Similar results were showed that the large percentage of healthy tissue received 10-20Gy of radiation with 3DCRT [25- 26, 28]. I-IMRT had statistically significant reduction in the volume of healthy tissue irradiated in the medium dose region (IrV36).I-IMRT has achieved better sparing to normal healthy tissue in high dose region and showed greater dose spillage outside PTV.
F-IMRT has reduced the integral dose by 14% compared with I-IMRT, our result were consistent with Bland, et al. and Pirzkall, et al. [8-9] and in contrast to Shirani, et al. [26].
Aoyama, et al. reported that a larger number of MUs would result in a higher integral dose [29]; however,
Leire, et al. [25] reported that, the integral dose does not depend on the number of MUs only [29], but also, depends on the target volumes and shapes.

OARs sparing
Both techniques achieved QUANTEC guide lines [22] and other studies[8] which recommended that, the relative volume received 70 Gy (V70) for rectum was less than 20% of total rectal volume and, (V70) for the bladder [12] was less than 35%.
I-IMRT decreased the average volume of OARs received high dose by 3.6% (range 0.27-8.8 %).
Regarding the DVHs, figure2(b-e) ,I-IMRT has spared OARs better in high dose region and have a maximum protection compared to F-IMRT, because in F-IMRT, it should be covered the PTV firstly due to the limitation dose in OARs.
I-IMRT technique was better in reducing the dose in the high-dose region in bladder; however, F-IMRT reduced the dose in the low- and medium-dose regions.
I-IMRT reduced the high doses in rectal wall in all patients compared to F-IMRT.
It was reported that the higher radiation dose delivered to small volume of rectum was the primary cause of late toxicities or late rectal bleeding.
Based on the dosimetric results for the rectum in this study, patients treated with I-IMRT were suffered less rectal complications; however, the relation between toxicity and rectal dose-volume with I-IMRT would be investigated with long-term follow up.
Regarding dose-volume relationship, the study has presented the constraints on localization of the OARs during treatment, as well as the duration of follow-up necessary to determine their toxicity.
Lou, *et al*. [27] compared the dosimetry of 3DCRT and IMRT plans based on dose-volume histograms DVHs for rectum and bladder. The daily variation of rectum and bladder volumes and dose to these structures has been shown to vary considerably for a given patient during the whole course of the treatment. The DVHs for rectum and bladder were varied between institutions [20] because volumes of these structures on planning CT varied between patients. These variation were independent among institutions , due to the differences in the institution's planning criteria and techniques. It was observed that F-IMRT spared rectum and bladder better in low dose region compared I-IMRT. Although the difficulties in determining the relation between bladder dose-volume and toxicity, QUANTEC guide lines recommended that no more than 35% and 50% of the bladder volume (bladder + wallcontents) receive a dose greater than 70 and 65 Gy, and this recommendation was based on the treatment outcome of patients treated with 3-DCRT. our result were met these constraint.
IMRT were achieved smaller volume (V50) in both femoral heads than F-IMRT due to beam arrangement in optimization and a choice of treatment technique was a significant predictor for femoral head necrosis.

Treatment planning time and treatment efficiency
The average treatment planning time in I-IMRT (automated segments) has required 65 min which was work loaded for the planner due to, computational time for optimization process and planning algorithms .The planning time would be shortened as the planner had more experience .
The mean treatment time of I-IMRT was longer due to the number of beams, dead time in the gantry rotation from field to field ,number of segments and the larger number of MUs delivered.
F-IMRT had an advantage in shorting the treatment time, it was usefully not only in reduction the chance of the intra-fractional motion of patients, but also decreased the internal organ motion and also, reduction the time that the patients required to maintain a full bladder. Another advantage it was necessary for work loaded radiotherapy centers and thus decrease the patient waiting list.

F-IMRT has reduced MUs by approximately 7.53% due to small number of beams and segments compared to F-IMRT ,and our result was consistent with J. Luc [27] who reported that, reducing number of segment could limit the degree of intensity modulation and compromise the dose distribution.

The mean delivery time of I-IMRT was longer than F-IMRT owing to the larger number of beams, segments , MUs delivered and the dead time in the gantry rotation from field to field.

F-IMRT has shown to spare more healthy tissue in low dose region at V10Gy and V20Gy compared to I-IMRT. Similar results showed that the large percentage of healthy tissue received 10-20Gy of radiation with 3DCRT [25-26, 28]. I-IMRT had statistically significant reduction in the volume of healthy tissue irradiated in the medium dose region (IBV36).I-IMRT has achieved better sparing to normal healthy tissue in high dose region and showed greater dose spillage outside PTV.

F-IMRT has reduced the integral dose by 14% compared with I-IMRT, our result were consistent with Bland, et al. and Pirzkall, et al. [8-9] and in contrast to Shirani, et al. [26].

Aoyama, et al . reported that a larger number of MUs would result in a higher integral dose[29]; however,

Leire ,et al.[25] reported that, the integral dose does not depend on the number of MUs only[29] , but also, depends on the target volumes and shapes.

The higher number of MUs in I-IMRT had the effect in increasing the risk of a secondary malignancy due to an increase in amount of radiation transmitted, scatter and leakage through multi-leaf collimator (MLC). This result was consistent with other study [27, 29, 30-31]. Kry, et al.[32] reported that I-IMRT may be increased the 10-year incidence of second malignancies from 1% in patients treated with 3DCRT to 1.75% in patients treated with IMRT.

V. Conclusion

I-IMRT is a better technique compared to F-IMRT but it need some margins to improve and optimize the dose distributions resulting an improvement PTV coverage

I-IMRT has achieved better CI and PTV coverage. It also has the ability to preserve more OARs at the expense of decreasing target homogeneity, increases the delivered integral dose resulting in, increasing the risk of secondary malignancy. Besides, it also achieved reduction in the volume of normal healthy tissue receiving high dose (IBV90).

On the other hand, F- IMRT has provided better conformality dose distribution, decreased the number of MUs. It also, irradiated smaller volume of normal healthy tissue in the low to medium dose region and delivered lower integral doses.

F-IMRT has smaller number of MUs and thus shortens the treatment time was delivered than I-IMRT which was more comfortable for the patient and useful in decreasing the machine work load in busy department.

In order to achieve similar results of I-IMRT in term of target coverage and dose homogeneity distribution, mixed energies (6 and 15 MV) are needed.

To choose between the two techniques it is necessary to see the patients' characteristics case by case. when the radiation oncologist prescribed a total dose to PTV $\leq$ 72 Gy, it is useful to choose the conventional forward technique, while in cases of high dose to PTV ($\geq$74 Gy) further dosimetric study is required to evaluate dose escalation , clinical benefits and treatment efficiency.

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