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The Impact of Number of Beams in IMRT of Cancer Prostate

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Abstract:
Purpose: The aim of this study is to judge the effect of number of IMRT beams in cancer prostate on different physical and biological evaluation indices and treatment plan quality.
Material and Methods: Seven IMRT plans with different number of beams ranging between five and eleven have been evaluated physically and biologically. Physical evaluation, have been performed by calculating dose homogeneity indices (MHI and HI), target coverage and conformity indices (PITV, TCI, CI, and CN), dose gradient (GI and GM) and an index for overall plan quality factor (QF). Biological evaluation has been performed by calculating TCP, NTCP, and P+.
Results: In IMRT plans with number of beams more than seven, all the physical and biological indices don't vary with the number of beams. In plans with number of beams less than or equal to seven only the values of TCI, PITV, GI, GM and QF are affected by changing the number of beams.
Conclusion: In IMRT, changing the number of beams will affect PITV, TCI, GI, GM, and QF indices and the number of Mus. In IMRT of prostate cancer the optimal number of beams is seven which has a high QF and low number of Mus.

Keywords: *Radiotherapy, prostate, IMRT, physical evaluation, biological evaluation*

1. Introduction

Prostate cancer is the predominant type of cancer in men. It is the sixth most common worldwide and, accounting for about 10% of all cancer cases[1].

To achieve the greatest local control with minimal toxicity is the primary objective in the treatment of clinically localized prostate cancer. Dose escalation, first recognized with conventional techniques [2-5], has been shown to increase local control using three-dimensional conformal radiotherapy (3D-CRT). Subsequently, objective functions for determining normal tissue complication risk have been defined with computed tomography based treatment planning. With dose well established as a strong determinant of biochemical control intensity modulated radiation therapy (IMRT) has been the next step in the search of greater conformity to enable further dose escalation and sparing of healthy tissues. Preliminary results with IMRT propose that the gains in disease control and toxicity reduction may be significant. A benefit in disease control has been demonstrated in several sequential dose escalation studies of 3D-CRT and IMRT [5-10]. To be effective, however, the implementation of IMRT requires perfect targeting of the prostate and the selection of appropriate treatment parameters. The most important treatment parameters in IMRT are the number of beams and their directions.

The issue of selecting the number and direction of beams in intensity-modulated radiation therapy (IMRT) has been considered by several investigators and has been the topic of debate as early as in 1995[11]. One may debate that even today, after many more papers have been published on this subject, the results are not entirely convincing, and not practically useful overall. In fact, in today's clinical practice, the number and direction of beams often has to be found by trial and error.

In a theoretical study by Bortfeld[12], he reported that the required number of beams depends directly on the complexity of the fluency (intensity) profiles that can be delivered within the physical and technical constraints of the treatment machine. In realistic cases, in which the variability of the lateral dose profile is restricted in several ways, the necessary number of beams range in 10 to 20. The consequence of delivering the beams with a 'leaf sweep' technique during continuous rotation of the gantry, as in VMAT, is also

derived in an analytical form. The flounce variability depends, in turn, on the complexity of the dose prescription and is therefore case dependent. However, even the most complex cases do not benefit from an arbitrarily high number of beams. This is so because there is also a physical limit on the achievable amount of fluency (or rather dose) modulation, which is due to the scattering dose.
In another study by Hunt and Burman [13], the number of beams may be less critical than for 3DCRT as long as basic concepts are applied. The ability to modulate the beam intensity within a field can partially compensate for a relatively poor choice of beam directions. Since the complexity of treatment often increases as more fields are used, In the presence of significant target concavities, five to nine uniformly spaced, non-coaxial or, if beneficial, non-coplanar fields, often yield clinically acceptable dose distributions.
Chung et al [14] recommended an IMRT plan with seven relatively equally spaced coplanar beams (0^{o}, 50^{o}, 100^{o}, 150^{o}, 210^{o}, 260^{o} and 310^{o}) to achieve better target coverage that achieved by irregularly spaced beams.

1.1. Aim of the Work
The aim of this work is to study the effect of changing the number of beams in IMRT of cancer prostate on different physical and biological evaluation indices and treatment plan quality.

2. Material and Methods

2.1. Cases and Plans
In this study we used de-identified CT data sets from 18 patients that had been previously treated at Oncology Department, Ain Shams University Hospitals with 3DCRT to the prostate only.
Dose distributions were generated retrospectively for each data set using seven IMRT plans with different number of beams. The number of beams range from 5 beams to 11 beams. The beam angles in all plans were optimized using Eclipse IMRT optimization module supplied with v13.5 of Varian Medical Systems Eclipse planning software on which all plans have been performed. The beam arrangements in the seven plans are shown in figure 1.
A conventional schedule with a daily dose of 2 Gy for a total dose of 76 Gy in 38 fractions over treatment time of 52 days has been used. Dose distribution was normalized and prescribed on planning target volume (PTV) mean dose.

2.2. Physical Evaluation
A treatment plan was considered acceptable and we evaluated it physically and biologically if its dose distribution was able to meet the prescribed prostate planning constrains outlined in table (1).
Several studies have shown that isodose distribution and dose volume histograms (DVHs) analysis are insufficient to rank treatment plans, therefore some other indices have been used to represent target dose conformity and dose homogeneity [15-19]. Recently, in a previous study we have described a procedure to perform a physical and biological evaluation of treatment plans in advanced radiotherapy techniques [20]. That procedure has been applied in this study to evaluate the different IMRT plans. In that procedure, the physical evaluation has been performed by generating three dimension dose distribution and DVHs of the PTV and different organs at risk (OARs). Dose distribution and DVHs have been used to generate the different PTV dose statistics. The generated statistical quantities are; the maximum, minimum, mean, modal and median PTV doses as well as the standard deviation (STD) of the PTV dose distribution. The DVHs of different OARs have been used to estimate the percentage dose (D) of an organ receiving by certain percentage (n) of the volume (Dn). For rectum and bladder D15, D25, D35 and D50, which represent 15%, 25%, 35% and 50% of the OAR volume, were determined. For the two heads of femur, the D25 and D40, which represent 15%, and 40% of the OAR volume, were determined. In addition to that the total number of monitor unit (MUs) applied to deliver the prescribed dose for each treatment plan was summed and recorded.

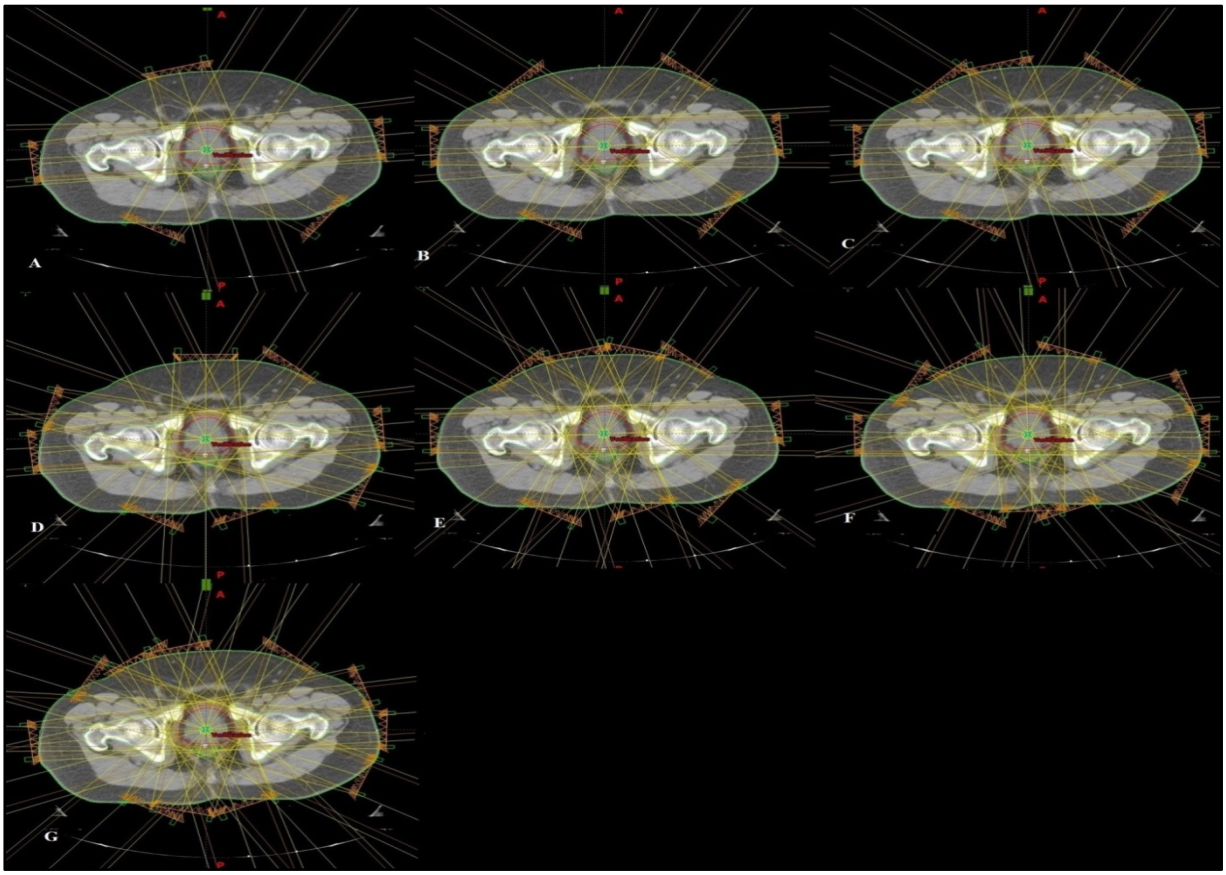

Figure 1: Beam arrangements in differentt IMRT plans

In addition to that dosimetrical analysis and according to the procedure we suggested previously [20], the following dosimetrical indices have been calculated;

Homogeneity Index (HI):HI was described as,

$$HI = \frac{D_{Max}}{D_p} \quad (1)$$

where D_{Max} is PTV maximum dose and D_p is the prescribed dose [21].

Modified Homogeneity Index (MHI): It is expressed as:

$$MHI = \frac{D_1}{D_{99}} \quad (2)$$

Volume/organ at risk (OAR)	Dose constraint
Planning target volume (PTV)	99% of the volume to get ≥ 95% of the prescription Minimum dose > 90% of the prescription Maximum dose <107% of the prescription The maximum dose must be within the PTV
Rectum	<50% of the volume to receive 60 Gy <35% of the volume to receive 65 Gy <25% of the volume to receive 70 Gy <15% of the volume to receive 75 Gy
Bladder	<50% of the volume to receive 65 Gy <35% of the volume to receive 70 Gy <25% of the volume to receive 75 Gy <15% of the volume to receive 80 Gy
Head of femuer	<45% of the volume to receive 40 Gy <25% of the volume to receive 45 Gy <0% of the volume to receive 50 Gy

Table 1: Planning objectives for intensity modulated radiation therapy (IMRT) of the prostate

Target Coverage Index (TCI): It is expressed as [22]:

$$TCI = \frac{V_{tP}}{V_t} \quad (4)$$

where; V_{tp} is the target volume receiving at least the prescription dose, and V_t is the total target volume.
Prescription isodose to target volume (PITV) ratio: PITV is expressed as;

$$PITV = \frac{V_P}{V_t} \quad (5)$$

where V_p is surface volume surrounded by prescription isodose level (inside and outside the PTV), and V_t is the target volume[20, 23].
Conformity Index (CI): It is defined as:

$$\mathrm{CI} = \frac{\mathrm{V_p}}{\mathrm{V_{tp}}} \quad (6)$$

where; Vp is the total volume receiving at least the prescription dose, and Vtp is the target volume receiving at least the prescription dose, [24].
Conformity number (CN): It is defined as;

$$CN = TCI\ X\ CI = \frac{V_{tP}}{V_p}\ X\ \frac{\mathrm{V}_{tp}}{\mathrm{V_t}} \quad (7)$$

where; V_p is the total volume receiving the prescription, V_t is the target volume, and V_{tp} is the target volume covered by the prescription [25].
Gradient index (GI): GI is expressed as:

$$GI = \frac{V_{50}}{V_{100}} \quad (8)$$

where; G_{50} and G_{100} are the volumes covered by 50% and 100% respectively [26].
Gradient Measure (GM): GM is calculated given by Eclipse treatment planning software as the difference between the equivalent sphere radius of 100% and 50% isodoses.
Quality factor (QF): The QF of a plan can be expressed as:

$$QF = [2.718 \exp(-\sum_i^n W_i X_i)] \quad (9)$$

In the above equation, X_i represents all of the PTV indices used for evaluating a plan. The values of the weighting factor (W_i) can be adjusted between 0 and 1 for all relatively weighted indices for a user-defined number of indices (N)[22]. In this study the indices that used in calculating QF are HI, MHI, TCI, PITV, CI, CN, GI and GM. The weighting factor (W_i) that applied in equation (9) for calculating QF is 1/8 for the eight indices.

2.3. Biological Evaluation

According to the procedure we described in a previous study [20], biological evaluation has been performed by calculating both of the tumor control probability (TCP), Normal tissue complication probability (NTCP) and Complication-free tumor control probability (P+) using the Eclipse TPS system

3. Results

3.1. Physical Evaluation

All treatment plans of the three different techniques were able to satisfy all dose-volume constrains prescribed in table (1) for all cases.

3.1.1. Dose Distribution

Figure (2) shows the typical isodose distributions of seven plans applied in this study and described above. The dose distribution of 5, 6, 7, …, and 11 beams IMRT plans are shown in figure (2A), (2B), (2C), …, (2G), respectively.

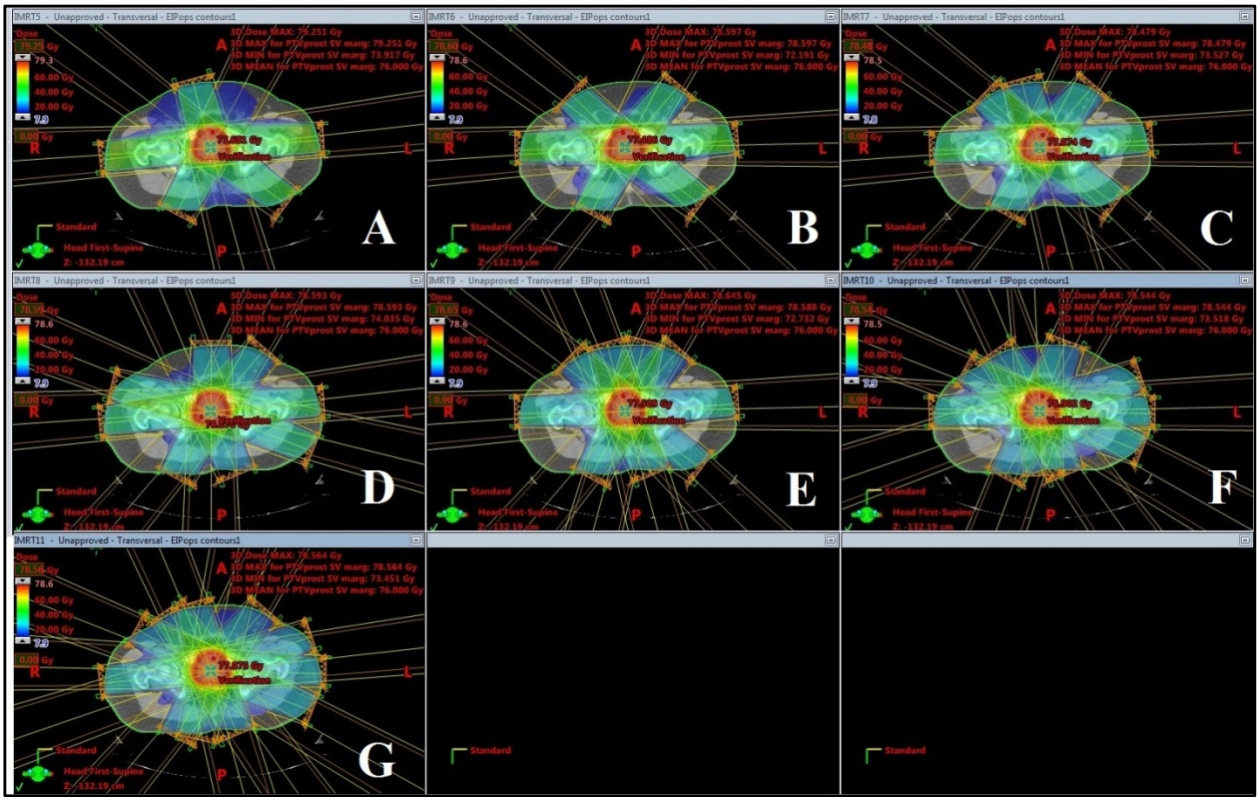

Figure 2: Dose Distribution of all plans

Dose volume histograms (DVHs) for the PTV, rectum, bladder, and heads of femur, for each of the seven plans are presented in Figure (3).

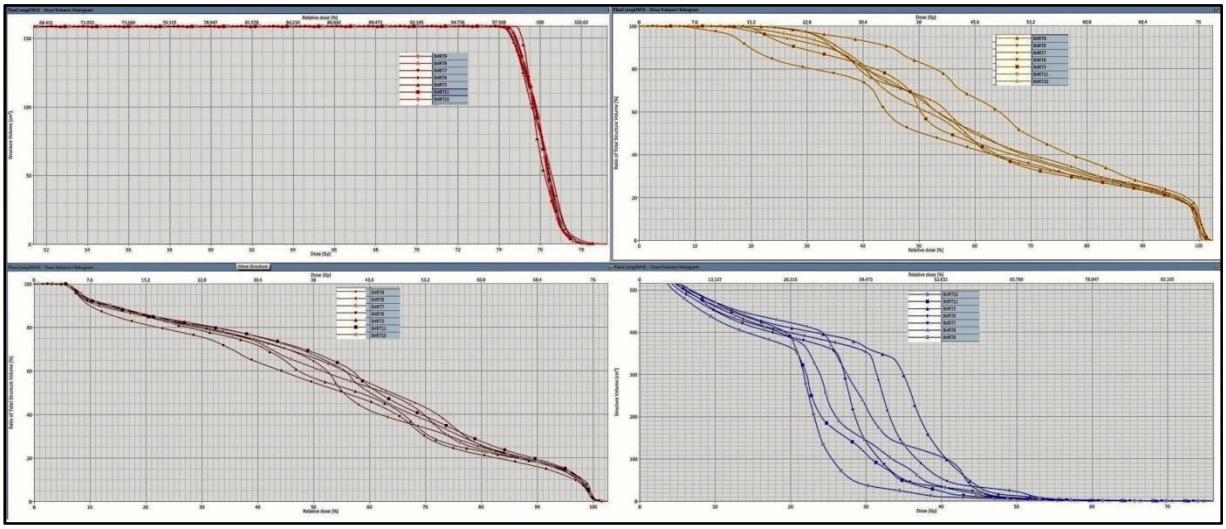

Figure 3: DVHs of PTV, Bladder, Rectum and Heads of femur for the Seven plans

3.1.2. PTV Dose Statistics

As shown in table (2) and Figure (4) the Mean, Mode and medial doses of the seven plans are almost equal.This result indicates that the dose distribution in the PTV has a normal statistical distribution and this lead to conclude that the dose distribution in the PTV is highly homogeneous in all plans. Figure (5) shows the standard deviation (STD) of the PTV dose in all plans. The difference of the STD values in different plans was not significant. It is obvious in figure (5) that the STD doesn't depend on the number of beams. In Figure 6 it is obvious that all plans have very close values of Maximum Dose (Dmax). It is also clear in figure (6) that difference in the minimum dose (Dmin) is minor and doesn't depend on the number of beams. That minor difference was found to statistically insignificant.

Index	IMRT5	IMRT6	IMRT7	IMRT8	IMRT9	IMRT10	IMRT11
Max Dose	104.3±1.49	103.4±1.44	103.3±1.42	103.4±1.45	103.4±1.41	103.3±1.4	103.4±1.41
Min Dose	97.3±2.21	95±2.08	96.7±2.12	97.4±2.31	95.7±2.22	96.7±2.33	96.6±2.39
Mean Dose (Gy)	100	100	100	100	100	100	100
Mode Dose (Gy)	99.4±0.09	101±0.11	100.1±0.11	100.2±0.1	100.3±0.11	100.1±0.1	99.9±0.1
Median Dose (Gy)	99.8±0.07	100±0.07	100.1±0.09	100.1±0.08	100±0.07	100.6±0.09	100±0.08
STD	0.9±0.1	1.2±0.11	1.1±0.1	0.9±0.1	1.1±0.12	1±0.1	1±0.11
HI	1.043±0.019	1.034±0.016	1.033±0.014	1.034±0.16	1.034±1.015	1.033±1.013	1.034±1.14
MHI	1.044±0.01	1.048±0.013	1.046±0.011	1.042±0.09	1.048±0.013	1.042±0.01	1.043±0.011
CI	1.094± 0.12	1.089± 0.12	1.099±0.13	1.036± 0.11	1.16±1.15	1.11±0.14	1.104±0.13
CN	0.369±0.039	0.452±0.045	0.482±0.049	0.52±0.049	0.434±0.044	0.518±0.051	0.445±0.046
TCI	0.404±0.013	0.492±0.015	0.53±0.017	0.538±0.018	0.503±0.016	0.523±0.016	0.491±0.014
PITV	0.442±0.065	0.536±0.069	0.582±0.077	0.557±0.073	0.583±0.078	0.529±0.0767	0.542±0.071
GI	2.478±0.069	2.03±0.06	1.887±0.051	1.858±0.049	1.988±0.059	1.91±0.051	2.036±0.061
GM	4.28±0.92	3.43±0.81	3.02±0.73	3.17±0.75	3.01±0.71	2.9±0.68	2.85±0.63
MU	655±81	682±85	692±89	699±96	688±95	702±99	710±102
QF	0.731±0.79	0.821±0.08	0.864±0.081	0.851±0.081	0.861±0.079	0.882±0.082	0.884±0.083

Table 2: Physical Evaluation Indices averaged over 18 patients for different techniques

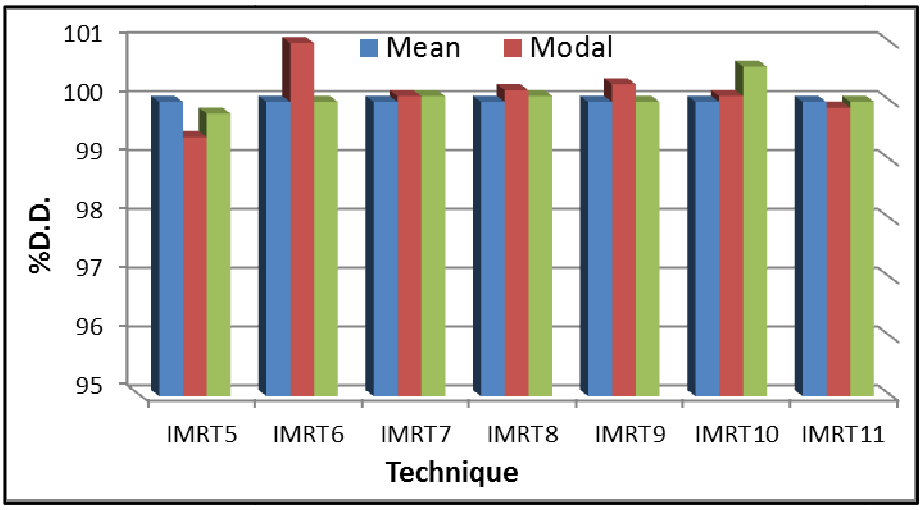

Figure 4: Dose Statistics of PTV indicating mean dose, modal dose, and median dose

3.1.3. Homogeneity Indices

Figure 7 shows both HI and MHI of all plans. We can see that both HI and MHI can lead to the same conclusion regarding PTV dose homogeneity. It is obvious that all plans have homogeneity indices close to 1 i.e. they have good dose homogeneity. It is noticeable in Figure (7) that the values of HI and MHI, and accordingly the PTV dose homogeneity, don't depend on the number of beams. The results obtained in figure (7) harmonizes with the results shown in figures 5 and 6 that in IMRT the number of beams don't affect the PTV dose homogeneity.

3.1.4. Target Coverage Index (TCI) and PITV

Figure (8) displays the calculated TCI and PITV for all plans. It is apparent that, the number of beams has no effect on both TCI and PITV values in plans with number of beams equal to or more than seven. In plans having number of beams less than seven, the number of beams have a minor effect on both of TCI and PITV values.

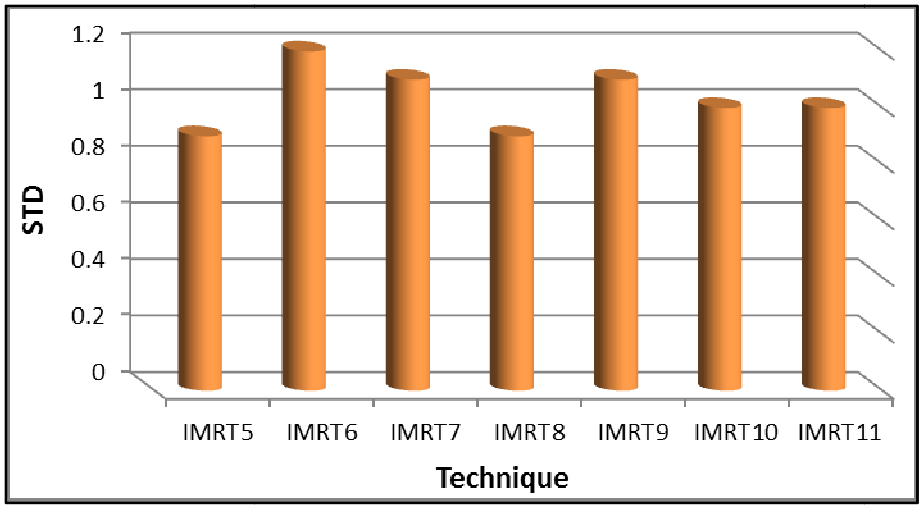

Figure 5: The STD values of the PTV dose distribution in the seven plans

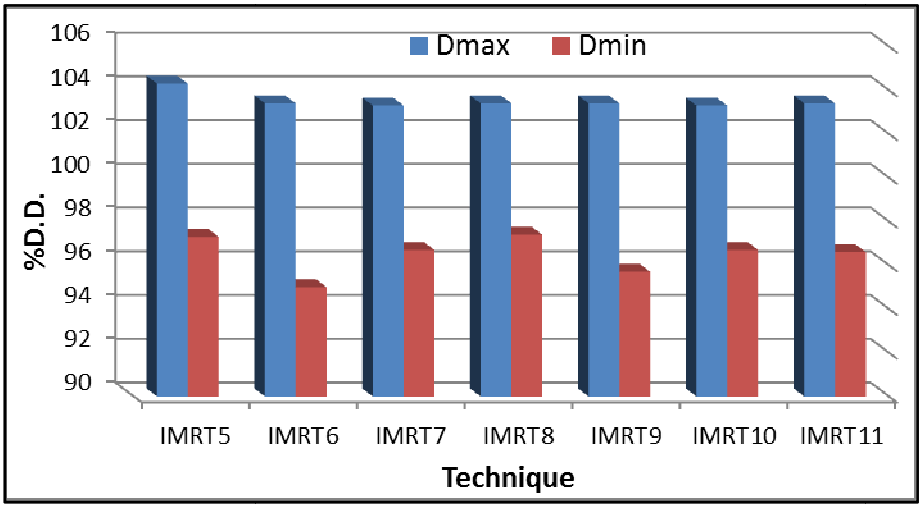

Figure 6: Maximum and minimum PTV doses of the seven plans

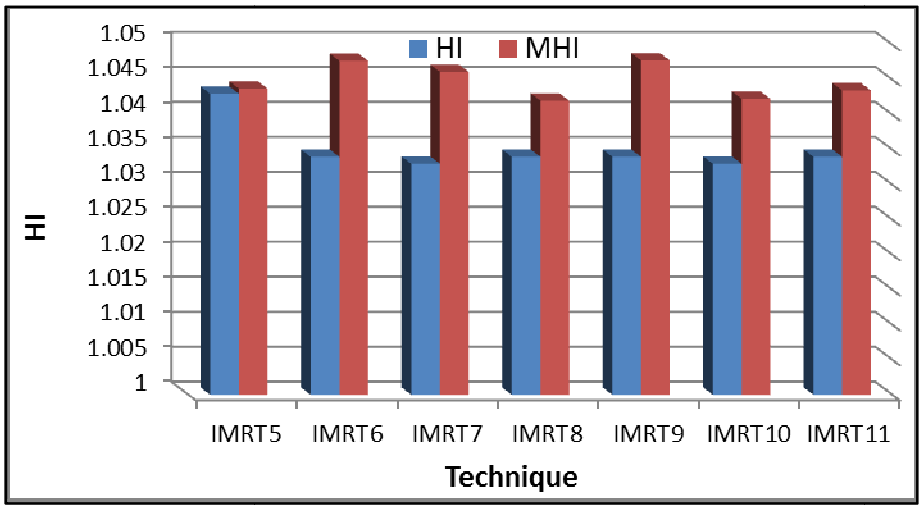

Figure 7: Dose Homogeneity Index (HI) in comparison with Modified Homogeneity Index (MHI) for different techniques

3.1.5. Dose Conformity

Figure 9 shows the CI and CN values of different plans. It is clear that, the values of CI in all IMRT plans are almost similar. The values of CN in all plans are almost equal except in five beams plan which has a lower CN value but with no significant statistical difference in comparison with the other plans.

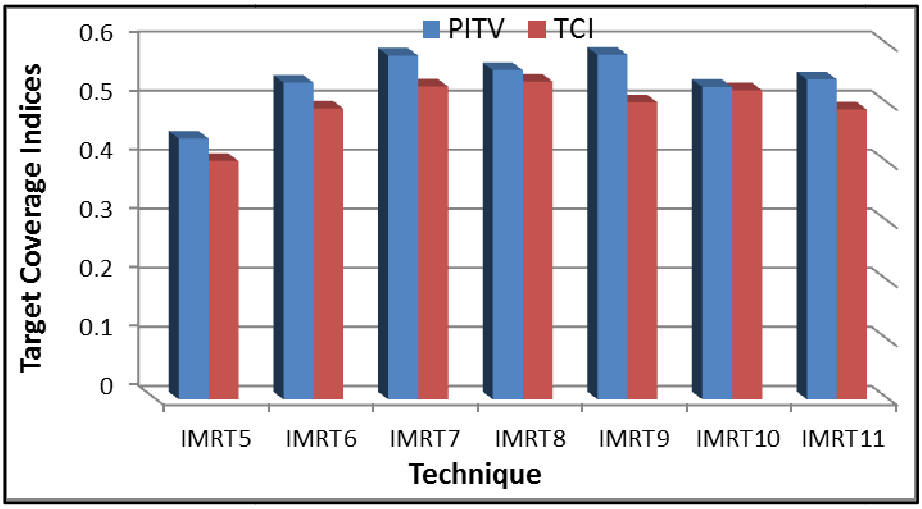

Figure 8: Target Coverage expressed in terms of TCI in comparison with PITV for all plans

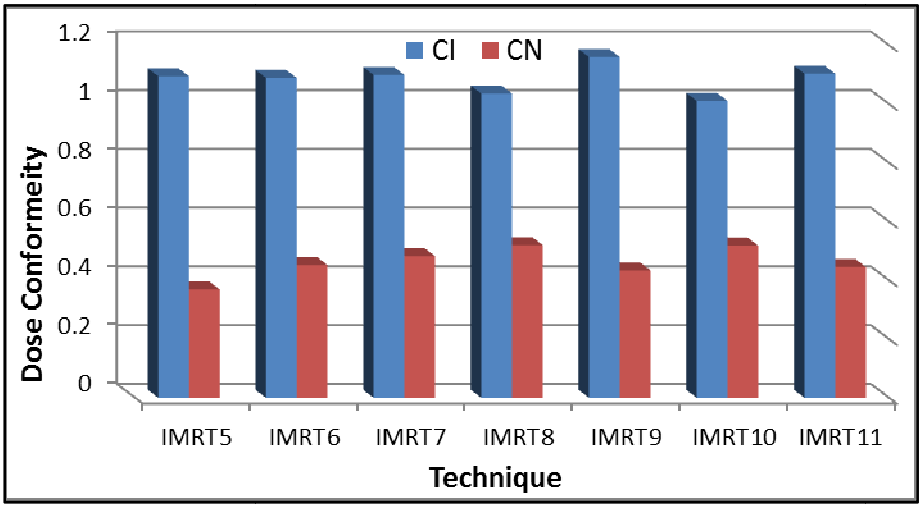

Figure 9: Dose conformity expressed in terms of conformity index (CI) in comparison with conformity number (CN) for all techniques

3.1.6. Dose Gradient

Figure 10 shows the values of GI of different plans. We can notice that the GI values of all plans are very close except in five beams plan which has a higher GI value. This means that in IMRT with number of beams more than five the dose drop outside the PTV is very quick in comparison with IMRT with five beams only.

Figure 11 shows the Gradient measure values of the seven plans. The GM represents the distance of dose drop between PTV and OARs. This means that the higher the GM value is the wider of the distance of dose drop. It is obvious that increasing the number of beams from 5 to 7 decrease the GM value. For plans with seven beams or more the variation of the number of beams doesn't affect the GM value.

3.1.7. Number of MUs

In figure (12) it is obvious that the more the number of beams is the more the total number of monitor units (MUs). The large number of monitor units (MUs) in IMRT technique with large number of beams means that they have high total integral dose and accordingly the high probability of secondary cancer after curative treatment.

3.1.8. Quality Factor (QF)

Figure (13) represents the variation of the QF values with the number of beams. We can point out in figure 13 that the lowest QF value was obtained in IMRT plans with number of beams less than seven. It is also clear that in plans with number of beams equal to or more than seven beams, the values of QF don't vary significantly with the number of beams.

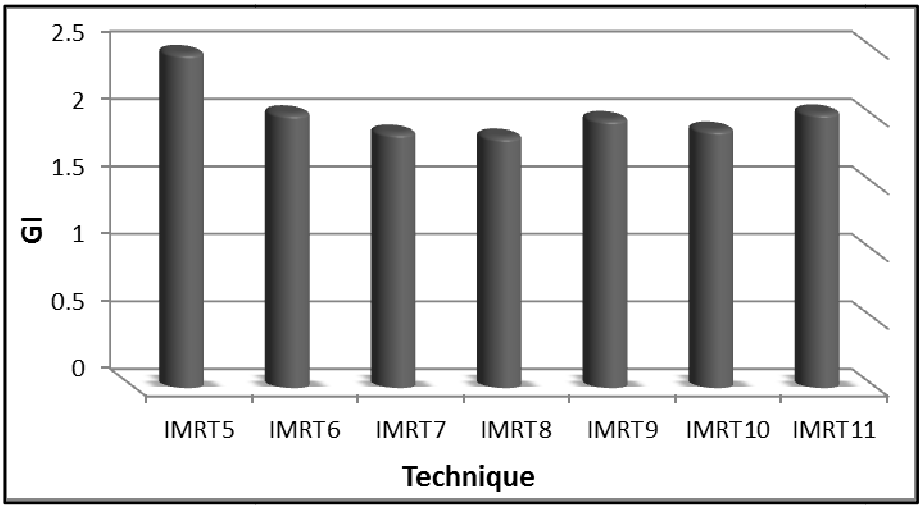

Figure 10: Dose gradient index (GI) for different treatment plans

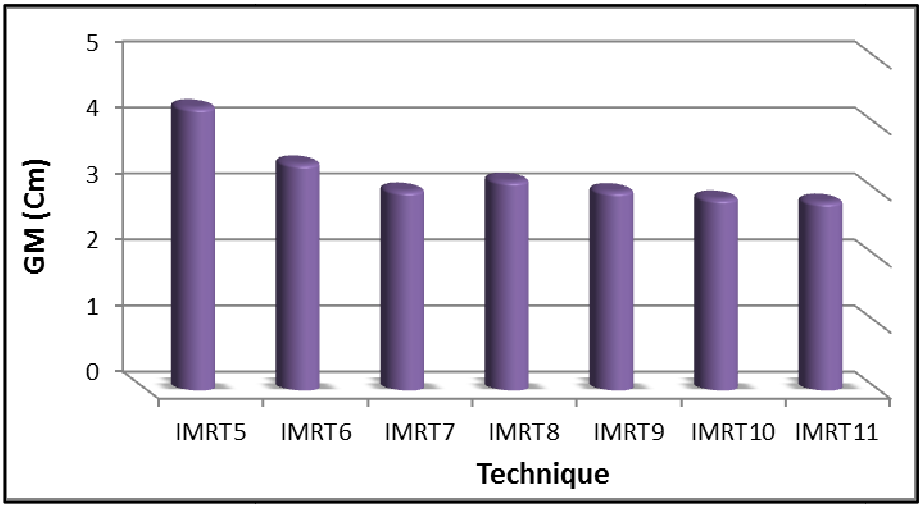

Figure 11: Gradient measure of different plans

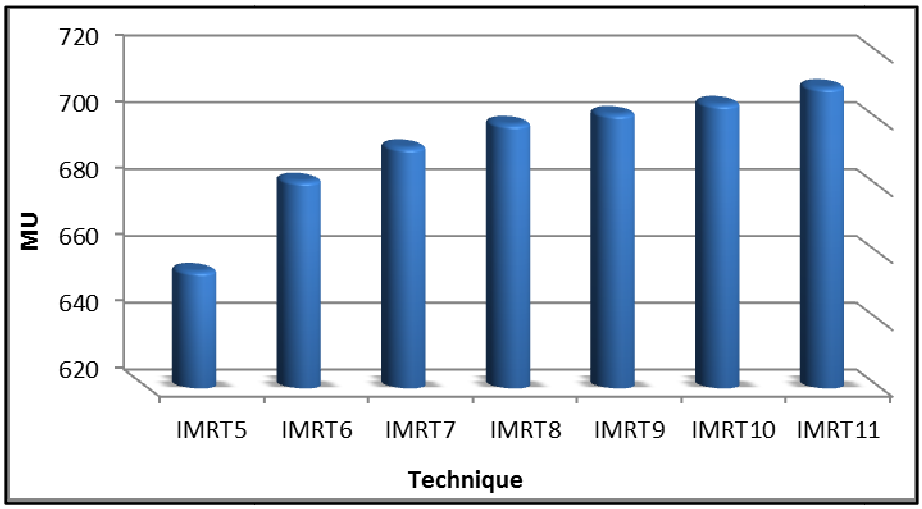

Figure 12: The number of Mus in different treatment plans

3.1.9. Dose to Organs at Risk

Dose delivered to OARs are presented in table 3 and figures 14, 15 and 16. It has been pointed out that the doses delivered to both bladder and rectum doesn't vary significantly with the number of beams. On the other hand the heads of femur doses are lower in plans with number of beams more than seven.

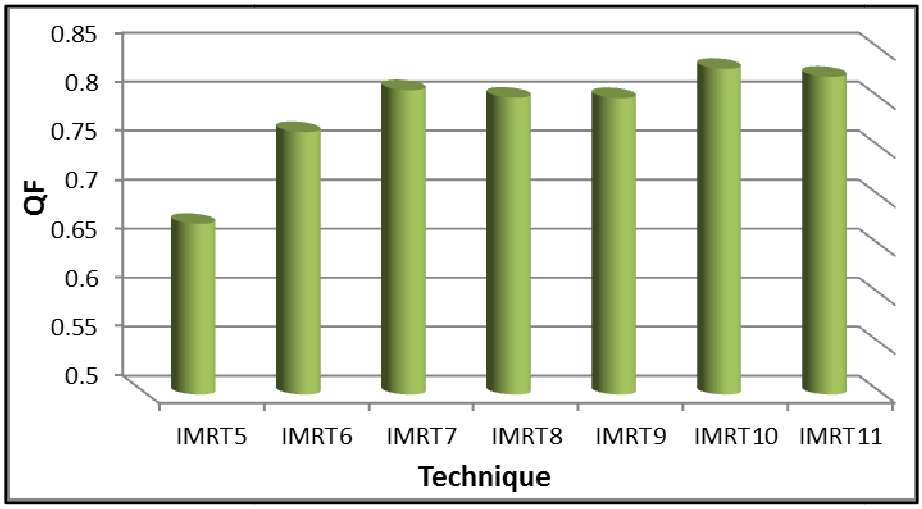

Figure: 13: Treatment plan quality factor (QF) for different plans

Dose to OARs		IMRT						
		IMRT5	IMRT6	IMRT7	IMRT8	IMRT9	IMRT10	IMRT11
Bladder	D15	75.07±1.99	75.15±2.02	74.45±1.81	74.93±1.89	75.75±1.99	74.93±1.97	75.24±2.01
	D25	65.99±5.19	65.85±4.98	68.31±5.12	67.09±5.06	70.37±5.31	67.83±5.012	68.72±5.21
	D35	51.51±8.88	53.88±4.99	58.12±4.98	52.61±4.82	62.56±5.13	55.85±5.01	56.63±5.11
	D50	41.94±4.44	38.38±4.32	45.34±4.61	44.33±4.49	52.35±4.81	43.75±4.02	46.0±4.53
Rectum	D15	71.66±1.73	69.47±1.53	71.47±1.64	71.8±1.57	71.27±1.59	71.95±1.61	72.28±1.69
	D25	57.93±2.45	56.39±2.42	59.57±2.48	60.69±2.51	61.12±2.66	61.47±2.67	62.74±2.7
	D35	51.77±2.64	51.27±2.63	54.51±2.81	51.84±2.61	56.73±2.75	54.84±2.83	55.88±2.95
	D50	44.12±3.18	42.14±2.86	47.59±3.45	42.05±2.96	48.55±3.61	45.63±3.31	46.8±3.52
Femoral Head	D25	38.27±7.91	34.2±7.65	29.51±6.94	32.52±7.13	23.84±5.51	28.83±6.94	22.76±4.51
	D40	36.05±9.12	32.24±8.23	27.79±7.63	29.18±7.91	22.39±6.08	24.73±6.82	26.87±7.41
	Dmax	76±1.12	74.7±0.95	76.1±1.11	75.4±0.97	75.5±1.06	75.6±1.07	75.3±1.03

Table 3: Doses to OAR averaged over 18 patients for different techniques

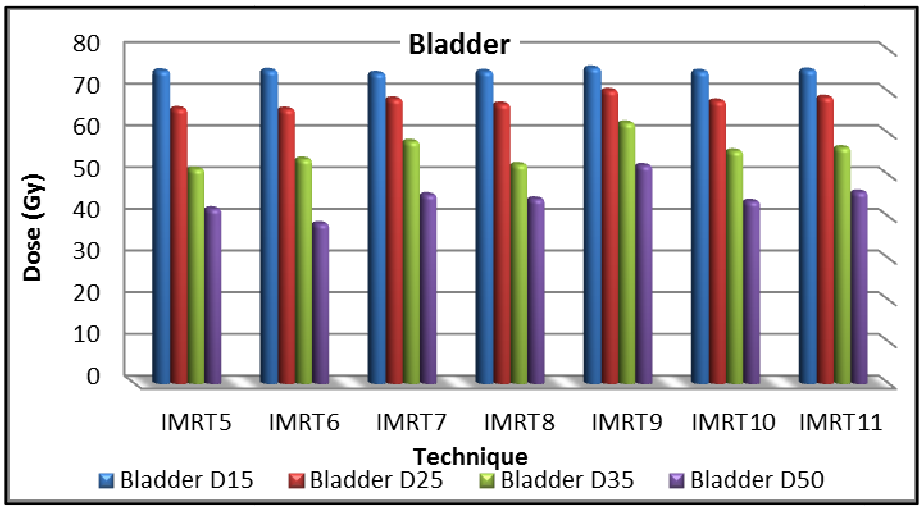

Figure 14: D15, D25, D35, and D50 of Bladder in different plans

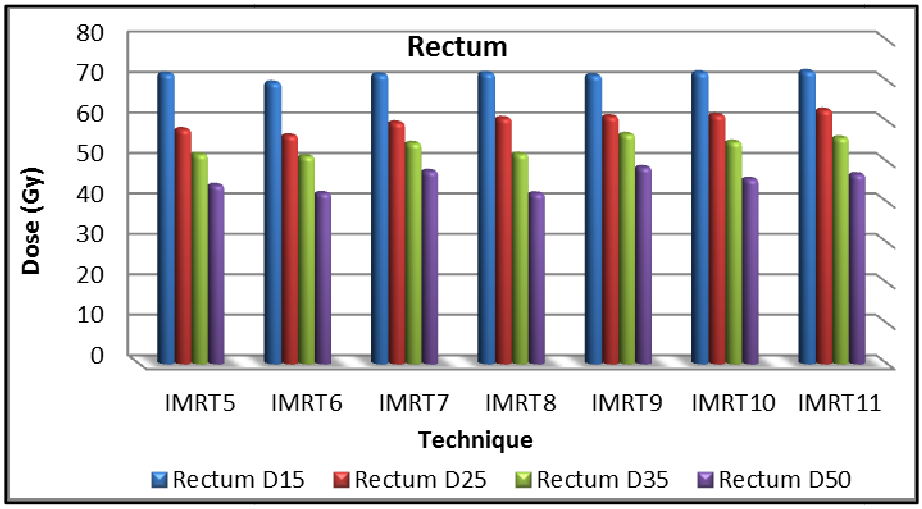

Figure 15: D15, D25, D35, and D50 of rectum in different plans

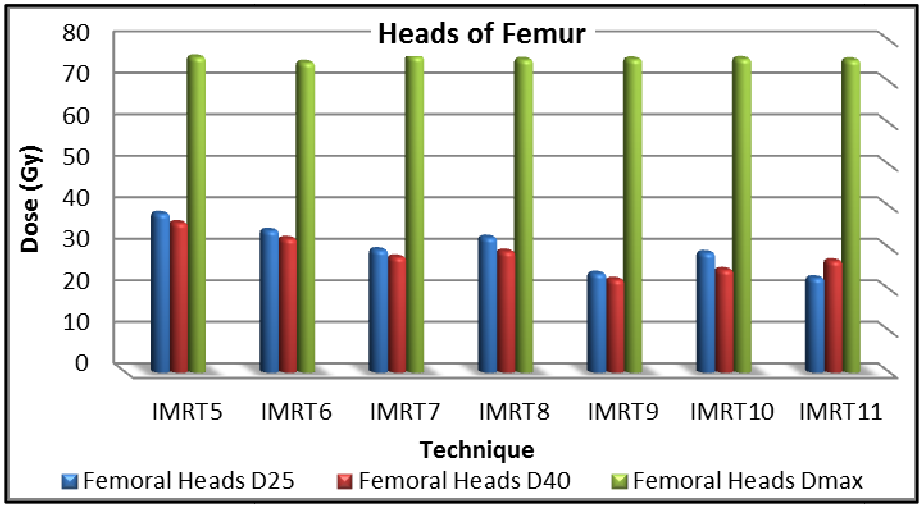

Figure 16: D25, D40, Dmax of heads of femur in different plans

3.2. Biological Evaluation of Treatment Plans

TCP values are illustrated in both figure 17 and table 4. It is obvious that TCP values for all plans are close with no significant difference. The reason of this likeness in the TCP values is the similarity in prescribed dose and dose normalization in all plans.

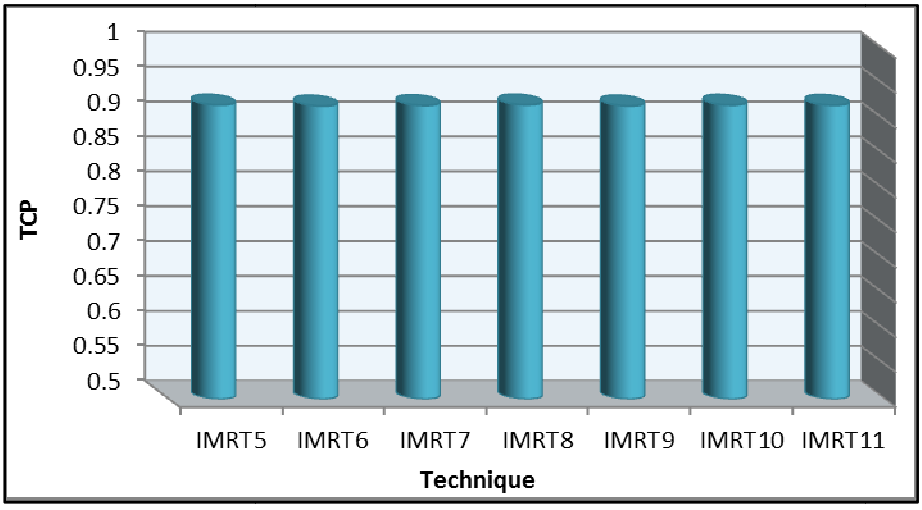

Figure 17: TCP Values of different treatment plans

In figure 18 it is clear that in IMRT plans, there is no certain trend of the NTCP with the number of beams. The highest NTCP value is produced in IMRT9 which has four of the nine beams facing the bladder from the anterior side. The lowest value of bladder NTCP in IMRT plans was produced in IMRT6 which as no beams facing the bladder from the anterior side. This means that the beam direction is more effective in the determining the NTCP value than the number of beams. The NTCP values agree with values of D25, D35, D50 of the bladder (Figure 14).

Probability	IMRT5	IMRT6	IMRT7	IMRT8	IMRT9	IMRT10	IMRT11
TCP	921±0.012	0.920±0.012	0.921±0.013	0.921±0.014	0.92±0.012	0.921±0.013	0.921±0.013
Bladder NTCP	0.0023±0.002	0.0012±0.001	0.0035±0.003	0.0024±0.001	0.0057±0.004	0.0027±0.003	0.0032±0.003
Rectum NTCP	0.072±0.009	0.062±0.006	0.068±.007	0.072±0.009	0.068±0.007	0.073±0.007	0.075±0.008
Femoral heads TCP	0.0023±0.002	0.0012±0.001	0.0015±0.002	0.0017±0.002	0.001±0.001	0.0016±0.002	0.0014±0.001
P+	0.851±0.011	0.861±0.015	0.853±0.009	0.851±0.01	0.852±0.011	0.85±0.012	0.848±0.011

Table 4: TCP, NTC of different OAR's, and PPlus averaged over 18 patients for different techniques

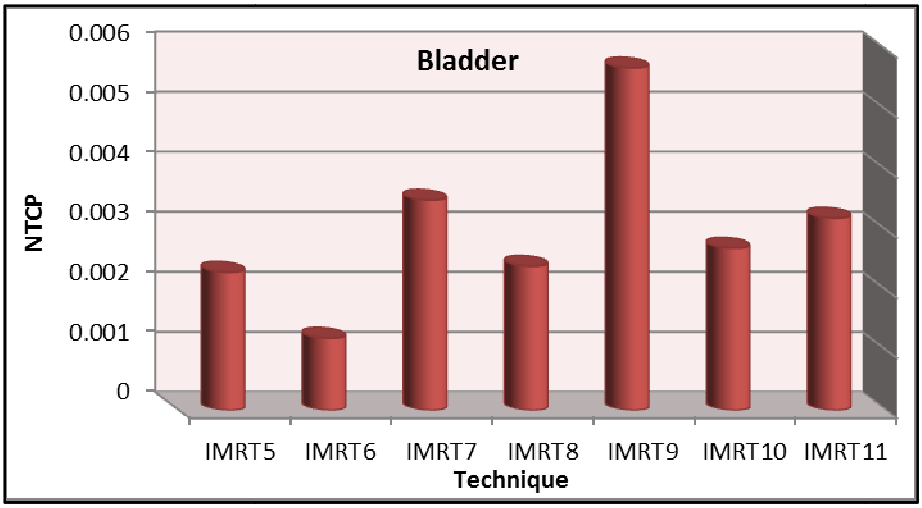

Figure 18: NTCP of the bladder in different plans

Similar results of the independency of NTCP on the number of beams are obtained on Figures 19 and 20 for both of rectum and the heads of femur.

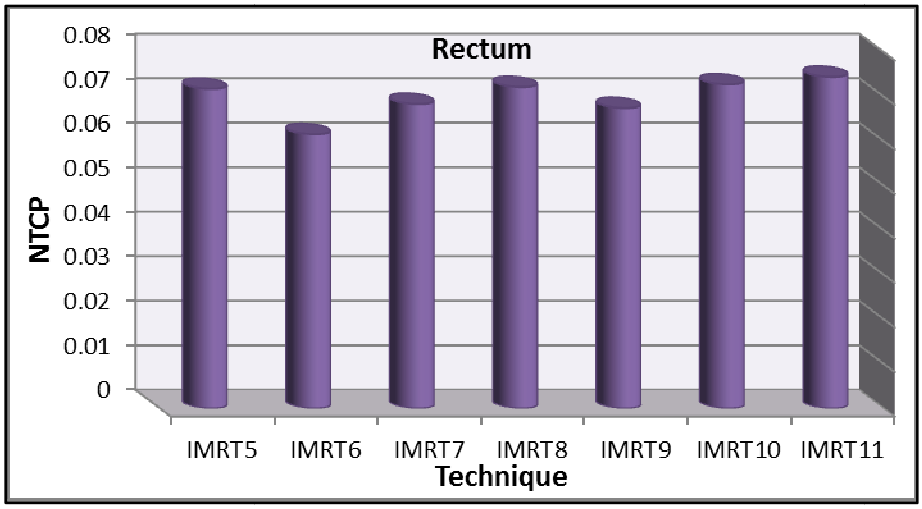

Figure 19: NTCP of the rectum in different plans

The values of P+ for different plans are similar as shown in figure 21. The reason of that is the similarity of the TCP values in the seven plans.

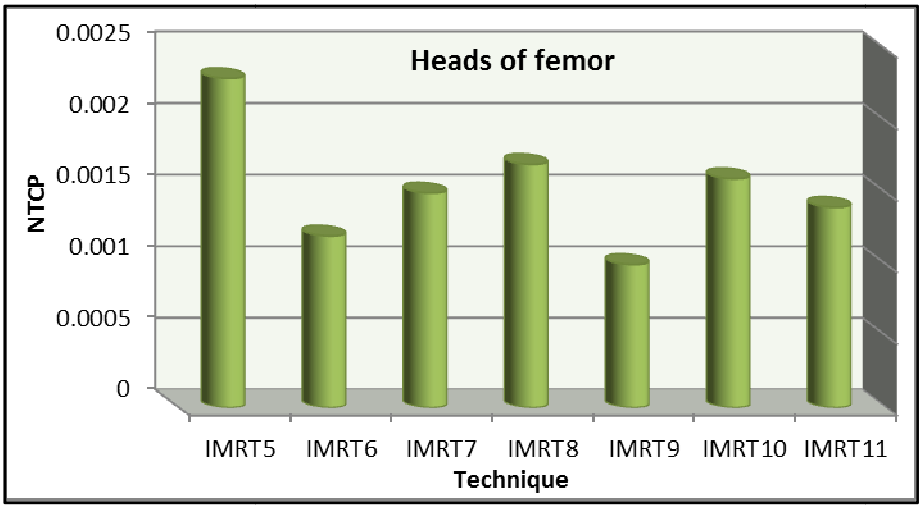

Figure 20: NTCP of the femoral heads in different plans

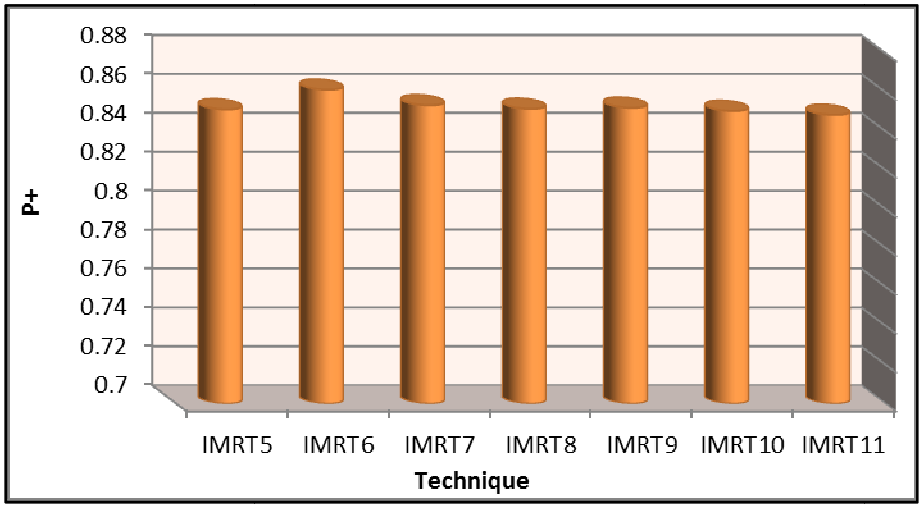

Figure 21: P+ of different treatment plans

4. Discussion

In this study we used de-identified CT data sets from 18 patients that had been previously treated at Oncology Department, Ain Shams University Hospitals with 3DCRT to the prostate only. To determine the optimal number of beams in IMRT of cancer prostate, IMRT treatment planning was performed with different number of beams ranging between 5 and 11. To define the optimal number of beams the outcome of different IMRT treatment plans were evaluated. The physical evaluation of the different plans was implemented by generating dose distributions and DVH's for PTV and OAR's. All plans were able to produce a dose distribution that was adequate for treatment and satisfying all dose-volume constrains. We noticed a very obvious likeness in the dose distribution of the plans (figure 2) and in the DVH's of PTV and OARs (figure 3). This result indicates that dose distribution and DVH's alone are not competent to rank the treatment plans. We pointed out the same conclusion in a recent study compared IMRT with Rapid Arc and 3DCRT [20].In spite of that, DVH's are the most commonly used quantitative results in treatment planning analysis.

Amin et al [20] were suggested a procedure to comprehensively evaluate a certain treatment plan. In that procedure several dosimetrical and biological models were used. We have applied this procedure to perform both of the physical and biological evaluation of different IMRT plans. For physical evaluation dose distribution and DVH's of both PTV and OAR's were generated and from them PTV dose statistics were calculated. The PTV dose statistical quantities were; average, maximum, minimum, median, and modal PTV dose in addition to the standard deviation of the PTV dose. According to that procedure we have calculated HI and MHI for PTV dose homogeneity, PITV, TCI, CI, and CN for target coverage and dose conformity, GI and GM for dose gradient and for overall plan quality QF has been calculated. For radiobiological evaluation we calculated TCP for tumour and NTCP for OAR's, as well as P+ for free complication tumour control. In addition to the physical and biological indices the total number of monitor unit (MUs) applied to deliver the prescribed dose for each treatment plan was summed and took into account in selecting the optimal plan where the lowest number of monitor units (MUs) produces the lowest total integral dose and accordingly the lowest probability of secondary cancer after curative treatment.

Analysis of the PTV dose statistical quantities was almost similar in all plans and indicated that the dose distributions were homogeneous in all plans. The similarity of the statistical quantities of the different IMRT plans shows that they are not adequate in

displaying the priority of one plan over the others. The values of MHI and HI of different IMRT plans indicated similar results of homogeneous dose distribution and similarity of the dose distribution. The results of the PTV dose statistics, as well as the HI and MHI, indicate that; the PTV dose distribution and dose homogeneity don't depend on the number of beams.

PITV, TCI, CI, and CN indices have been used to evaluate target coverage and conformity. All of these indices displayed good PTV coverage and dose conformity in all plans with no significant difference. In spite of that none of these indices allowed us to rank the plans. The PITV and TCI indices values didn't show any dependency on the number of beams for plans having number of beams more than seven. On the other hands, in plans with number of beams equal or less than seven both of PITV and TCI increases with the number of beams. CI and CN indices didn't vary the number of beams.

In this study we have used both of GI and GM to predict the dose gradient. We noticed that the number of beams up to seven beams in IMRT plans will affect both of GI and GM. The variation with the number of beams is clear in GM more than GI. For plans with number of beams more than seven there no effect of varying the number of beams. This study showed also that GM is more sensitive to the variation with the number of beams than GI.

When we used QF in the physical evaluation, it was sensitive to the variation in dose homogeneity, conformity and gradient. The difference in plan quantitative quality was very clear and statistically significant between different plans with plans having number of beams between 5 and 7. Plans with number of beams more than seven have no variation of QF with the number of beams.

The total number of monitor units is an important factor in selecting the optimal treatment plan because the higher the total numbers of monitor units is the higher the probability of secondary cancer after curative treatment. In addition to that increasing the total number of MUs increases the treatment delivery time i.e. less comfortable and less accurate treatment. In this study, as expected, we got a higher total number of MUs and accordingly a higher treatment delivery time and higher probability of secondary cancer in plans with higher number of beams.

In IMRT technique we pointed out that the directions of the beams is more critical in OARs dosimetry than the number of beams. IMRT plans with beams facing any OAR produce a higher dose to that organ regardless the number of beams

In biological evaluation of different treatment plans we have used TCP, NTCP and P+. In this study, TCP values did not give any indication of plan priority over another because TCP values for all plans are close with no significant difference. The reason of this likeness in the TCP values is the similarity in prescribed dose and dose normalization in all plans and the satisfaction of dose-volume constrains. This means that the number of beams doesn't affect the TCP.

Although, the difference of the doses to OARs in different plans was not statistically significant the difference in NTCP was statistically significant. This is very clear in NTCP of Heads of femur. So, it is obvious that the number of beams don't affect the values of NTCP. This means that biological evaluation will clarify the difference in treatment planning outcomes more than physical evaluation.

The difference between NTCP values for IMRT plans were very close, so we needed another biological index to show the difference in biological outcome of the different plans. So P+ has been estimated to get an evidence of the priority of one plan over another. We pointed out the P+ value, which integrated both TCP and NTCP, doesn't vary with the number of beams.

In agreement with Chung et al [14], we pointed out that in IMRT of cancer prostate, seven beams is the optimal number of beams due to its high value of QF and its lower total number of MU's. This result agrees with the optimization of the number of beams performed by Eclipse IMRT optimizer which provides an optimal number of beams equal seven in most of the cases.

5. Conclusion

1. In physical evaluation indices only PITV, TCI, GI, GM, and QF as well as the total number of MU'us are affected by number of beams.
2. The dose of the OAR's is affected by the beams direction more than number of beams.
3. According to this study, in IMRT of prostate cancer the optimal number of beams is seven because it has a high QF value and low total number of Mus.

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