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Evaluation of 3D Conformal Radiotherapy for Prostate Cancer Using Dosimetric Indices

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THE PRESENT study aims to evaluate three dimensional conformal radiation therapy (3DCRT) for patients with prostate cancer. This will be done by the effect of 6 MV and 15 MV photon energies in addition to some of treatment fields using different of conformity indices. For such study 10 patients with prostate cancer are selected. The computed tomography CT slices are taken for each patient and transferred to XiO treatment planning system. Evaluation of treatment plans is performed by conformity indices. The 3DCRT plans are designed using CMS XiO treatment planning system using linear accelerator with multi-leaf collimator (MLC) with two energies 6 and 15 MV. The results of conformity index (CI) show an average value from 1.5± 0.03 to 1.9± 0.06 in 6-Fields with 15 MV and 3-Fields with 6MV, respectively. The results of conformation number (CN) indicate an average value from 0.51± 0.02 to 0.67± 0.02 in 3-Fields with 6MV and 6-Fields with 15MV, respectively. In conclusion, the use of high-energy 15 MV or 6 MV photons achieves the same dose coverage but in case of using 15 MV photon produces better safety for organs at risk and also improves conformity indices of dose to planning target volume (PTV). This occurs when increasing number of fields which improves conformity indices and decrease dose to organs at risk. The conformity index and conformation number give the same dosimetric information after the revision of DVH and dose distributions.

Keywords: Prostate cancer, Conformity index (CI), Conformation number (CN), Computed tomography.

The goal of radiation therapy is to deliver a lethal amount of dose to target volumes while sparing the surrounding tissues. Conformal radiotherapy is introduced to achieve the best adaptation of the shape of a high isodose envelope to the exact shape of the PTV (1). The goal of 3DCRT is to have the prescribed radiation dose distribution shaped like the target volume (2). In the work of *Carrie et al.* (3) they reported that conformal radiotherapy could be the next major revolution in the field of radiotherapy. Dearnaley *et al.* (4) published the first randomized study comparing the incidence of late adverse effects after conventional radiotherapy or conformal radiotherapy which delivered the same total dose. The authors showed a significant reduction of the incidence of proctitis and rectal bleeding with conformal radiotherapy. Giraud *et al.* (5) concluded, that it has already been clearly demonstrated that conformal radiotherapy significantly decreases toxicity to healthy tissues. For deep-seated tumor treatment, particularly for larger target volumes or larger size patients, using high energy photon is more suitable than low energy photon because of its better penetrating power, skin sparing effect, conformity on PTV, and less normal tissue doses. Adverse skin reactions are also a concern for low-energy treatment of deep-seated targets, particularly in large patients [6]. Evaluation of the quality of the treatment plans considers the important process in 3DCRT because an optimal plan for treatment of patient is selected. The conformity index is developed as an extension of section-by-section dosimetric analysis and dose-volume histograms (DVH) and can be defined as an absolute value resulting from the relationship between tumor volume, and the volume delineated by an isodose curve [7]. The use of conformity index could facilitate the choice of treatment and comparisons of various treatment plans for conformal radiotherapy, stereotactic radiotherapy, and brachytherapy [8]. In the present study the conformity index CI_{RTOG} and Conformation number CN are used as tools to evaluate the 3DCRT plans to choice the optimal plan for treatment of prostate cancer.

Materials and Methods

Patient population

In the present study 10 patients are selected with prostate cancer. A computed tomography (CT) in pelvis region in supine position of patients with 3–5mm slices thickness for each patient are acquired according to treatment protocol. All the patients' images sets are chosen such that, there is no much variation in their anatomy. All the patients' Anterior-Posterior (AP) and lateral dimensions are very close. The mean anterior-posterior (AP) separation of these patients is 25.6 cm and the mean lateral separation is 39.5 cm. The planning target volume (PTV) varied from 41.18 to 124.76 cm^3 (Table 1).

TABLE 1. The prescription dose , PTV and patients volumes for all investigated cases.

Patient number	Prescribed Dose (cGy)	PTV Volume cm^3	Patient Volume cm^3
1	6000	41.18	39439.64
2	6000	81.17	11433.56
3	6000	42.77	36000.47
4	6000	42.6	21533.4
5	6000	81.11	62112.71
6	6000	74.69	13205.82
7	6000	124.76	1378748.68
8	6000	57.25	23876.23
9	6000	44.33	14559.46
10	6000	47.17	16235.32

Treatment planning

CT images for patients are then transferred to a radiotherapy planning computer for outlining and target volume (OARs) such as rectum, bladder and femoral heads . In this study beam energies of 6MV and 15MV are used delivered on linear accelerator with multi-leaf collimator (MLC) .The clinical treatment plans of (3DCRT) designed using CMS XiO Treatment Planning System software version 4.3.3 (Fig.1). Dose is calculated by convolution algorithm with a grid size of 2 mm .In this study six treatment plans are done for each patient.Table 2 discripes treatment techniques , gantry angles, beam weighting and wedge angles to determine that the similarity or difference between the plans is due to energy and/or number of fields. Figure 2 shows 3D-view for the treatment techniques. The three following objectives should be verified : 1) target coverage (95% of the prescribed dose covered at least 95% of the PTV while the PTV volume receiving more than 107% of the prescription dose is limited to zero), 2) OAR sparing 3) sparing of healthy tissue .

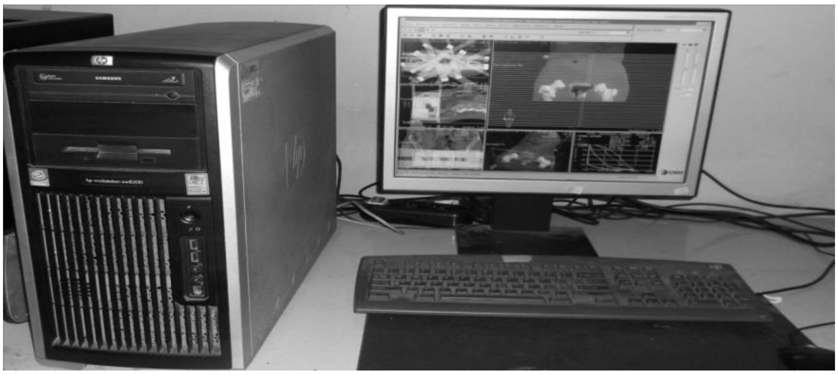

Fig. 1. Treatment planning system(CMS XiO).

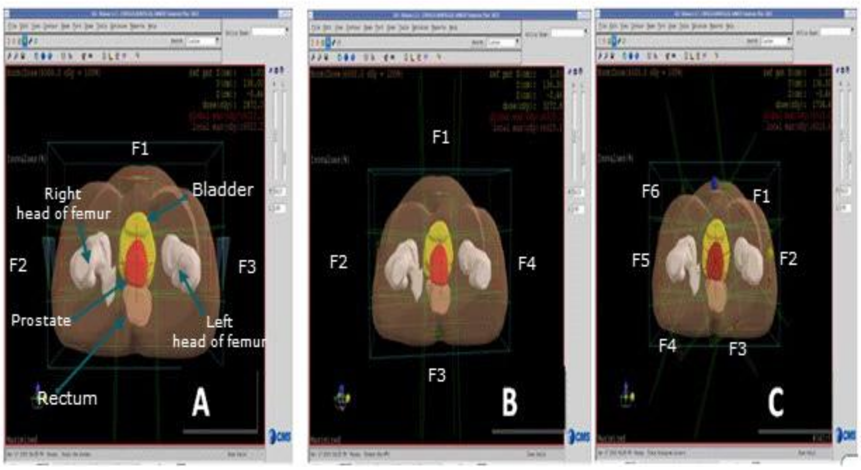

Fig. 2. 3D-view of 3 treatment method by treatment planning system(XIO), (A) 3-Fields anterior and two laterals with wedge(F1,F2 and F3), (B) 4-Fields anterior, posterior and two laterals (F1, F2, F3 and F4)(C) 6-Fields technique(F1, F2, F3, F4, F5 and F6).

TABLE 2. Description of treatment techniques.

Plan	Description	Gantry angles (°)	Weightings (%)	Wedges angles
1	3-Fields	0,90,270	50,25,25	50° Thick to Anterior On lateral fields
2	4-Fields	0,90,180,270	All Equal	N A
3	6-Fields	30,90,162,234,306,270	All Equal	N A

Evaluation of plans

Dose-volumetric analysis of both energies (6MV and 15MV) for 3DCRT plans are performed by both qualitative and quantitative methods. Target coverage was evaluated according to compare maximum dose (**D_{Max}**) , mean dose to **(D_{Mean})** and the percentage of target volume that received 95% of prescribed dose (TV95%) are calculated. Homogeneity of dose within PTV has been evaluated by using homogeneity index (HI) as defined by equation (1);

$$HI = D_{5\%} / D_{95\%} \qquad (1)$$

where $D_{5\%}$ and $D_{95\%}$ are the minimum doses delivered to 5% and 95% of the PTV **[9,10]** . The smaller and closer the value of HI to 1, the better the homogeneity of dose in the PTV.

Conformity of high dose around the target has been evaluated by conformity Index CI_{RTOG} proposed by Radiation Therapy Oncology Group (RTOG) in 1993 **[11,12]** . Conformity Index Equation (2) is defined as the ratio of the prescription isodose volume or the volume of total tissue receiving the reference dose to the target volume.

$$CI_{RTOG} = V_{RI} / TV \qquad (2)$$

where CI_{RTOG}= Conformity Index proposed by Radiation Therapy Oncology Group (RTOG), V_{RI} = The volume of total tissue receiving the reference dose, and TV =target volume

A conformity index equal to 1 corresponds to ideal conformation. If the conformity index is situated between 1 and 2, treatment is considered to comply with the treatment plan **[7]**.

Another evaluation tools described by Van't Riet *et al* . [13] and is defined by the following equation .

$$CN = (TV_{RI} / TV) \times (TV_{RI} / V_{RI}) \qquad (3)$$

where CN = Conformation number, TV_{RI} = Target volume covered by the reference isodose, TV = Target volume and V_{RI} = The volume of total tissue receiving the reference dose and according to ICRU 50 the reference isodose used are isodose 95% of prescription dose[14]

The dose-volume parameters for organ at risk are measured for each plan at 6MV and 15 MV by comparing several physical indices. For rectum and bladder the percentage of irradiated volume that receive at least 50, 40 and 20 Gy ($V_{50Gy\%}$, $V_{40Gy\%}$ and $V_{20Gy\%}$),in addition to (D_{Max}, D_{Mean}) are calculated. For femoral heads .(Rt.head of femur and Lt head of femur) the percentage volumes that receive at least 40, 30, and 20 Gy ($V_{40Gy\%}$, $V_{30Gy\%}$ and $V_{20Gy\%}$) and also maximum and means doses(D_{Max}, D_{Mean}) are calculated.

Statistical analysis

It is performed by using a paired t-test using Microsoft excel 2007 to determine dose-volumetric differences for 6MV vs. 15MV for PTV, CI_{RTOG} and CN. Differences are considered statistically significant at $p \leq 0.05$.

Results and Discussion

Planning target volume dose parameters and homogeneity

The dose distributions Colorwash with Isodose Lines (Fig. 3) for all treatment techniques. The D_{Max} in PTV for all techniques and energies are within the acceptable values and do not exceed 107% of prescription dose (ICRU50.1993)[14]. In case of 6 MV D_{Max} has higher value than 15 MV Plans . For 3-Fields D_{Max} value (average 61.2 ± 0.2, 60.4±0.2 , p = 0.013) for 6 MV and 15 MV, respectively. In case of 4-Fields plans D_{Max} value (average 60.3±0.1, 59.7±0.1, p = 0.29) for 6 MV and 15 MV, respectively. Also D_{Max} in 6-Fields plans value (average 61±0.2, 60.5±0.1, p = 0.025) for 6 MV and 15 MV, respectively .The mean dose(D_{Mean}) in PTV has high values with 6 MV in comparison with 15 MV plans .The mean dose has statistical significances differences between 6MV and 15MV (p= 0.0003,0.004,0.0027) for 3-Fields,4-Fields and 6-Fields respectively .

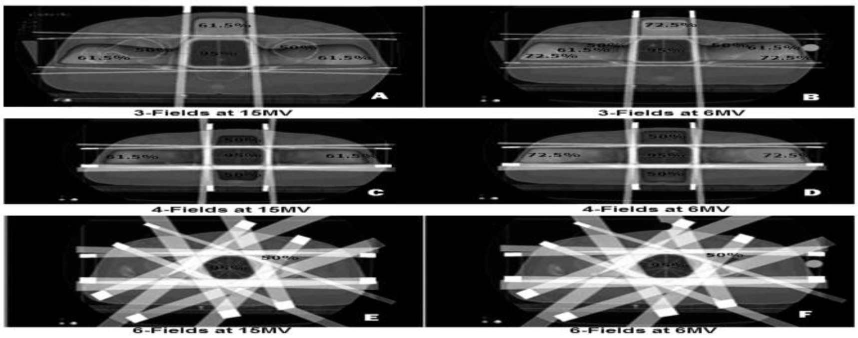

Fig. 3. The dose distributions Colorwash with Isodose Lines in transverse plan CT slices in all treatment techniques form treatment planning system ,95%,72.5%,61.5%and 50% of prescription dose.(A) 3-Fields at 15MV (B) 3-Fields at 6MV(C) 4-Fields at 15MV(D) 4-Fields at 6MV (E)6-Fields at 15MV (F) 6-Fields at 6MV .

The minimum dose (D_{Mim}) in PTV increased with 6 MV than 15 MV (average 55.7±0.3, 56.2±0.3, 56.2±0.3 for 3-Fields,4-Fields and 6-Fields, respectively), in 6 MV, Plans . In case of 15 MV, D_{Min} has average values 55.4 ±0.3, 55.3±0.3, 55.1±0.2 for 3-Fields,4-Fields and 6-Fields, respectively. The percentage of volumes of PTV that received 95% of prescription dose ($TV_{95\ \%}$) has accepted values in all treatment techniques .

The plans with 6 MV has higher values of ($TV_{95\ (\%)}$) than 15MV plans (average 99.3 ±0.2 vs 98.8±0.3 ,p=0.02) in 3-Fields , (average 99.8±0.1 vs 98.8±0.3 ,p=0.004) in 4-Fields and (average 99.8±0.1vs 98.5±0.3 ,p=0.0004) in 6-Fields plans for 6 MV and 15 MV, respectively .The homogeneity index HI has small values in 6 MV than 15 MV in all techniques except in 3-Fields (average 1.05 ±0.01, 1.04±0.01,p=0.05) for 6MV and 15MV plans (Table 3).

TABLE 3. The maximum dose D_{Max} , the mean dose D_{Mean} , the minimum dose D_{Min} , the percentage of volume that received 95% of the prescription dose ($TV_{95\,(\%)}$) and Homogeneity Index HI to PTVs at both energies 6MVand 15MV in all treatment techniques .

Technique	3-Fields		P- Value	4-Fields		p-value	6-Fields		p-value
Beam energy	6MV	15MV		6MV	15MV		6MV	15MV	
D_{Max} Gy (M±SE)	61.2 ± 0.2	60.4± 0.2	0.013	60.3± 0.1	59.7± 0.1	0.29	61± 0.2	60.5± 0.1	0.025
D_{Mean} Gy (M±SE)	59.4 ± 0.1	59± 0.1	0.0003	59.6± 0.1	59.2± 0.1	0.004	59.6± 0.1	59.2± 0.1	0.0027
D_{Mim} Gy (M±SE)	55.7 ± 0.3	55.4± 0.3	0.023	56.2± 0.3	55.3± 0.3	0.05	56.2± 0.3	55.1± 0.2	0.01
$TV_{95\,(\%)}$ (M±SE)	99.3 ± 0.2	98.8± 0.3	0.02	99.8± 0.1	98.8± 0.3	0.004	99.8± 0.1	98.5± 0.3	0.0004
HI (M±SE)	1.05 ± 0.003	1.04± 0.003	0.05	1.03± 0.003	1.04± 0.003	0.05	1.03± 0.003	1.04± 0.001	0.004

(M±SE) = Mean ± Standard error .

The conformity index and the conformation number

The results indicate that 6 MV beam energy increase CI_{RTOG} values than 15 MV. In case of 3-Fields techniques CI_{RTOG} has average value from 1.7 ± 0.03 to 1.9 ± 0.06,*p* = 0.002 for 15MV and 6MV, respectively. Also CI_{RTOG} has average values from 1.6 ± 0.06 to 1.8 ± 0.09, *p*=0.03 in 4-Fields technique and 1.5 ± 0.03 to 1.7 ± 0.06, *p*=0.005 in 6-Fields technique for 15MV and 6MV, respectively . The data indicate that there are statistical significance between (3-Fields and 4-Fields ,*p*=0.02), (3-Fields and 6-Fields , *p*=0.001) at 6 MV plans and without statistical significances between (4-Fields and 6-Fields,p=0.19) at 6MV beam energy. Also in high energy 15MV plans there are significance differences between (3-Fields and 4-Fields ,p=0.03) and (3-Fields and 6-Fields ,*p*=0.003),but no statistical significance between (4-Fields and 6-Fields,p=0.18). The results show that, increase number of fields improve the CI_{RTOG} values .

The general trend of the 15MV beam energy and number of treatment fields improve the conformity index. Table 4 shows CI_{RTOG} in all treatment techniques to all patients and p–value to compare with the different treatment techniques. Figure 4 shows the conformity index in different treatment techniques in all patient which illustrates the better CI_{RTOG} in 6-Fields with 15MV beam energy technique.

TABLE 4 . The conformity index (CI_{RTOG}) for treatment techniques in all patients.

No. Field	3-Fields		4-Fields		6-Fields	
Beam energy MV	**15**	**6**	**15**	**6**	**15**	**6**
Patient No.						
1	1.4	1.8	1.4	1.6	1.6	1.9
2	1.7	1.9	1.3	1.5	1.4	1.5
3	1.5	1.7	1.3	1.3	1.2	1.4
4	1.7	2.0	1.9	2.2	1.5	1.8
5	1.6	1.8	1.5	1.7	1.3	1.5
6	1.6	2.1	1.5	2.0	1.4	1.8
7	1.8	2.2	1.6	2.0	1.6	1.9
8	1.9	2.1	1.7	2.0	1.6	1.8
9	1.8	2.0	1.6	1.8	1.5	1.7
10	1.7	1.9	1.6	1.8	1.6	1.9
Mean ±SE	1.7 ± 0.03	1.9 ± 0.06	1.6 ± 0.06	1.8 ± 0.09	1.5 ± 0.03	1.7 ± 0.06

CI_{RTOG} comparison of treatment plans	P-Value
3-Fields (6MV vs 15MV)	0.002
4-Fields (6MV vs 15 MV)	0.03
6-Fields (6MV vs 15 MV)	0.005
6MV (3-Fields vs 4-Fields)	0.02
6MV (3-Fields vs 6-Fields)	0.001
6MV (4-Fields vs 6-Fields)	0.19
15MV (3-Fields vs 4-Fields)	0.03
15MV (3-Fields vs 6-Fields)	0.003
15MV (4-Fields vs 6-Fields)	0.18

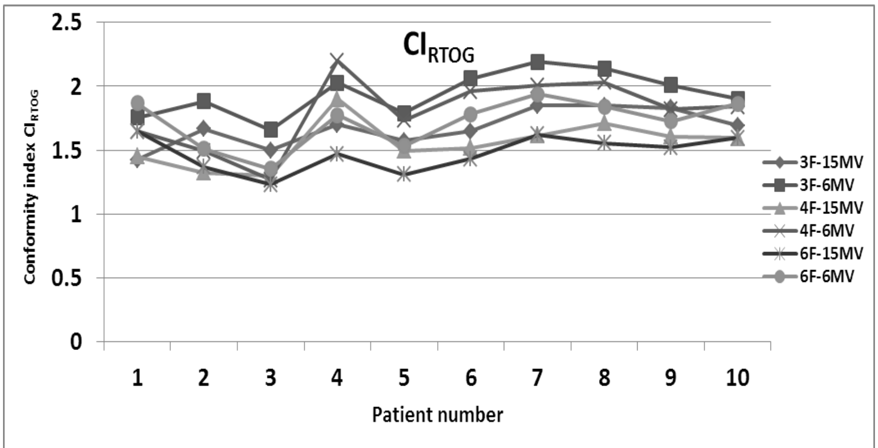

Fig. 4. The conformity index CI_{RTOG} for all treatment techniques .

The present results indicate an enhancement of CN at 15 MV greater than in case of 6 MV by 14%,13% and 14% in 3-Fields, 4-Fields and 6-Fields techniques respectively .Also the results show that increase in number of fields enlarges values of CN. This is due to statistical significance between(3-Fields and 4-Fields , *p*=0.02), (3-Fields and 6-Fields, *p*=0.001) at energy 6 MV and without statistical significances between (4-Fields and 6-Fields, p=0.11) at 6 MV beam energy (Table 5).

TABLE 5. Conformation number CN values in all treatment techniques in all patients.

NO. Field	**3-Fields**		**4-Fields**		**6-Fields**	
Energy MV	**15**	**6**	**15**	**6**	**15**	**6**
Patient No.						
1	0.66	0.56	0.66	0.60	0.59	0.53
2	0.59	0.53	0.73	0.66	0.72	0.66
3	0.65	0.59	0.75	0.77	0.80	0.73
4	0.56	0.48	0.50	0.45	0.64	0.55
5	0.63	0.56	0.66	0.58	0.75	0.65
6	0.60	0.49	0.66	0.51	0.68	0.56
7	0.53	0.45	0.59	0.50	0.61	0.51
8	0.53	0.47	0.56	0.49	0.62	0.54
9	0.53	0.48	0.61	0.55	0.64	0.58
10	0.56	0.51	0.61	0.54	0.61	0.54
Mean ±SE	0.58 ± 0.02	0.51 ± 0.02	0.63 ± 0.02	0.56 ± 0.03	0.67 ± 0.02	0.59 ± 0.02

CN comparison of treatment plans	P-Value
3-Fields (6MV vs 15MV	0.004
4-Fields (6MV vs 15 MV	0.001
6-Fields (6MV vs 15 MV	0.02
6MV (3-Fields vs 4-Fields)	0.02
6MV (3-Fields vs 6-Fields)	0.001
6MV (4-Fields vs 6-Fields)	0.11
15MV (3-Fields vs 4-Fields)	0.02
15MV (3-Fields vs 6-Fields)	0.003
15MV (4-Fields vs 6-Fields)	0.05

Also in high energy 15 MV there are significance differences between (3-Fields and 4-Fields ,p=0.02),(3-Fields and 6-Fields ,*p*=0.003) and (4-Fields and 6-Fields,p=0.05) (Table 5). The general trend the high energy 15 MV and number of treatment fields improve CN values. Figure 5 shows that the CN in different treatment techniques. The results of CI_{RTOG} have average value from 1.5±0.03 to 1.9± 0.06 in 6-Fields with15MV and 3-Fields with 6MV, respectively. Also the conformation number range from 0.51±0.02 to 0.67±0.02 in 3-Fields with 6MV and 6-Fields with 15MV, respectively .The Conformity index and conformation number show a better values in 6-Fields at 15MV. Both indices give the same information after the revision of DVH and dose distributions for PTV.

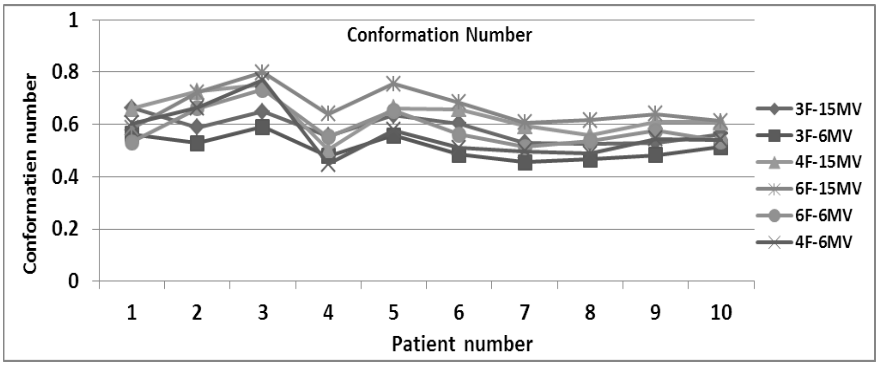

Fig.5. Conformation number CN for all patients with different treatment techniques.

These results are in agreement with that obtained by Petkovska *et al*. **[15] .** The authors calculated the conformity index in 3D Conformal radiation therapy of brain cancer patients using CI_{RTOG} and had its value between 1.2 and 2.04 .They concluded that conformity index is essential parameter for evaluation of treatment but it needs additional dosimetric indices for evaluation as DVH, dose coverage and dose distribution .Also Stanley *et al.* **[16]** showed that the conformity index is sufficient for plan quality evaluation if a revision of the dose-volume histogram or dose distributions can be performed. The conformation number index effectually provides the same dosimetric information as CI_{RTOG} index .

In the study of Ammar *et al.* **[17],**they found that conformity index and conformation number were used to evaluate different stereotactic treatment techniques of brain lesion. They concluded that the conformity index, dose homogeneity and the outfield dose are important aspects of plan quality.

Dose to organs at risk (OAR)

In all treatment techniques 15 MV plans reduces the dosimetic parameters of rectum wall than 6 MV plans. An exception is for 3-Fields method, shows high values at 15 MV than 6 MV plans for D_{max} (average 59.4±0.3 vs 59.2±0.3) and D_{mean}(average 25.15±3 vs 24.72 ±2.9).The percentage of rectum wall volume that receives 50,40, and 20 Gy ($V_{50Gy\%}$, $V_{40Gy\%}$, $V_{20Gy\%}$) at 6 MV plans are larger than at 15 MV plans. The treatment technique of 6-Fields at 15 MV produces reductions in $V_{20Gy\%}$ about 7% in comparison with maximum value in other treatment technique.

For bladder The smaller value of $V_{50Gy\%}$,$V_{40Gy\%}$ and $V_{20Gy\%}$ (average 10.5±2.8, 22.4±5.9 and 46±9), respectively show at 6-Fields at 15MV beam energy plans (Table 6) .The treatment technique 6-Fields at 15 MV provides 18.7% reduction for bladder mean dose D_{Mean} and 31% reduction in $V_{50Gy\%}$.

For femoral heads the values of $V_{40Gy\%}$, $V_{30Gy\%}$,$V_{20Gy\%}$,$D_{Max,}$ and D_{Mean} are decreased at15 MV than 6 MV plans(Table 6). The right femur D_{Mean} decreases at 15 MV than 6 MV by 6%(3-Fields) ,7% (4-Fields) and 5.2% (6-Fields) . Also the left femur D_{Mean} decrease at 15 MV than 6 MV by 6.3%(3-Fields),7%(4-Fields) and 8%(6-Fields) . The smaller value of D_{Mean} is indicated at 6-Fields at 15 MV treatment plans. The treatment technique for right femur 6-Fields at 15 MV produces reductions in values of $V_{30Gy\%}$ about 94.8%.

For left femur at same conditions shows reduction of 87.1% (Table 6) .This reduction in dosimetric parameters represents a benefit for this technique.

TABLE 6. The dosimetric parameters (Mean ± Standard Error) for the different OAR for all patients at both energies (6MV, 15MV).

OAR	DVH parameters	3-Fields		4-Fields		6-Fields	
		6MV	15MV	6MV	15MV	6MV	15MV
Rectum	$D_{Max\ Gy}$	59.2±0.3	59.4±0.3	59.22±0.3	58.8±0.4	59.8±0.3	59.15±0.3
	$D_{Mean\ Gy}$	24.72 ±2.9	25.15±3	26.6±2.8	26.07±2.8	25.9±3	25.22±3
	$V_{50Gy\%}$	9.18±2.4	9.28±2.4	10.23±2.5	9.41±2.4	10.62±2.3	10.08±2.2
	$V_{40Gy\%}$	16.36±3.4	13.05±2.6	20±3.7	18.4±3.7	24.23±4.4	22.6±4
	$V_{20Gy\%}$	60.4±6.8	58.9±6	60.87±5.9	57.5±6.3	57.9±7.2	56.6±7.2
Bladder	$D_{Max\ Gy}$	60.3±0.3	58.6±0.4	59.8±0.3	59.1±0.3	59.8±0.3	58.83±0.4
	$D_{Mean\ Gy}$	23.39±4.9	22.94±4.6	21.66±4.3	21.1±4.2	19.6±4.1	19±4.1
	$V_{50Gy\%}$	15.2±4.7	13.8±4.4	13.4±3.4	12.2±3.2	11.8±3.1	10.5±2.8
	$V_{40Gy\%}$	29.9±7.3	20.6±4.2	24.2±5.7	23.5±5.9	23.5±6	22.4±5.9
	$V_{20Gy\%}$	54.6±8.8	46.6±8.1	51.8±9.2	51.5±9.1	46.9±9	46±9
RT head of femur	$D_{Max\ Gy}$	47.1±0.6	41.9±0.5	44.3±0.6	38.3±0.5	39.1±1.3	38±1.5
	$D_{Mean\ Gy}$	22.16±1.3	20.8±1.2	23.4±1.3	21.6±1.1	17.2±0.9	16.3±0.8
	$V_{40Gy\%}$	9.3±1.8	1.2±0.6	8.5±1.9	0.3±0.2	0.2±0.1	0.1±0.1
	$V_{30Gy\%}$	46.2 ± 2.8	38.1±4.7	49±3.2	44.6±3.1	6.5±1.6	2.5±0.6
	$V_{20Gy\%}$	59±3.2	56.3±3.5	60.5±3.2	59.4±3.2	54±3.4	52±3.1
LT head of femur	$D_{Max\ Gy}$	47.8±0.6	42.4±0.4	44.3±0.7	38.3±0.4	38.5±1.6	36.6±1.5
	$D_{Mean\ Gy}$	22±1.1	20.6±1	22.9±1.3	21.3±1.1	17.2±0.9	15.8±0.8
	$V_{40Gy\%}$	9 ± 1.6	1.7±0.9	8.4±2.2	0.06±0.04	0.19±0.2	0.01±0.01
	$V_{30Gy\%}$	47.3±3.5	43.6±3.4	51±3.5	46.7 ± 3.5	6.9±1.5	6.1±1.6
	$V_{20Gy\%}$	57.6 ± 3.1	51.9±4.4	59.2±10	58±3.2	53.6±3.2	50.6±3.2

In present study the treatment at 15 MV improves the dosimetric parameters of OARs (bladder, rectum and femoral heads).In mean while the use of abeam low energy increases the treatment time increases. Due to elongated time of treatment an intrafractional movements of prostate occurred which lead to uncertainty of treatment Tong *et al.* [18].

Welsh *et al.* [19] stated that because of high-energy photons (*e.g.*, greater than 10 MV) which have dosimetric advantages .This is because of their greater depth of penetration and skin-sparing potential.Such energies are commonly used in 3D conformal radiotherapy.

The results of The present study are in agreement with that obtained by Vaezzadeh *et al.*[20] if increasing beam energy, and number of fields , this will spares organs at risk and improves dose conformity index to PTV .Also Runham *et al.* [21] concluded that the 6-field technique produced a plan with significantly smaller dose to the femoral heads when compared to the 5-field method for 3DCRT of prostate cancer treatment.

Conclusion

- Both values of utilized photon energies 6 and 15 MV gives same tumors control and dose coverage.
- 15 MV photon beam produces better safty for organs at risk and improves conformity indices of dose to PTV.
- Increasing number of fields improves conformity indices and drops dose to organs at risk.
- According to conformity indices results, the 6-Fields at 15 MV is the optimal plan of treatment.
- The Conformity index and conformation number give the same dosimetric information after the revision of DVH and dose distributions.

References

1. **Rosenwald, J.C., Gaboriaud, G. and Pontvert, D.,** Conformal radiotherapy: Principles and classification. *Cancer Radiother.* **3**, 367–377(1999).

2. **Palma, D., Otto, K., Verbakel, W. and Senam Rev, S.,** New developments in arc radiation therapy: A review. *Cancer Treatment Reviews,* **36** (5), 393-399 (2010).

3. **Carrie, C., Ginestet, C., Bey, P., Aletti, P., Haie-Meder, C., Briot, E., Resbeut, M., Coste, G., Chauvel, P. and Brassard, N.,** Conformal radiation therapy. Federation nationale des centres de lutte contre lecancer (FNCLCC)]. *Bull Cancer.* **82**,325–330(1995).

4. **Dearnaley, D.P., Khoo, V.S., Norman, A.R., Meyer, L., Nahum, A., Tait, D., Yarnold, J. and Horwich, A.,** Comparison of radiation side-effects of conformal and conventional radiotherapy in prostate cancer: *A Randomised Trial. Lancet,* **353**,267–272(1999).

5. **Giraud, P., Helfre, S., Lavole, A. and Rosenwald, J.M.,** Non-small-cell bronchial cancers: Improvement of survival probability by conformal radiotherapy. *Cancer Radiother,* **6**,125s–134s(2002).

6. **Chow, J. C., Grigorov, G. N. and Barnett, R. B.,** Study on surface dose generated in prostate intensity-modulated radiation therapy treatment, *Medical Dosimetry,* **31** (4),249-258(2006).

7. **Feuvret, L., Noel, G., Mazerron, J. and Bey, P.,** Conformity index :A Review. *Int. J.Radiation Oncology Bio. Phys.* **64**(2), 333-342(2006).

8. **Nag, S., Bice, W., DeWyngaert, K., Prestidge, B., Stock, R. and Yu, Y.,** The American Brachytherapy Society recommendations for permanent prostate brachytherapy postimplant dosimetric analysis. *Int. J. Radiat. Oncol. Biol. Phys.* **46**, 221–230(2000).

9. **Yoo, S., Wu, Q.J., Lee, W.R. and Yin, F.F.,** Radiotherapy treatment plans with RapidArc for prostate cancer involving seminal vesicles and lymphnodes. *Int J. Radiat Oncol Biol. Phys.* **76**, 935-942(2010).

10. **Wang, X., Zhang, X., Dong, L., Liu, H., Gillin , M., Ahamad, A., Ang, K. and Mohan, R.,** Effectiveness of noncoplanar IMRT planning using a parallelized multiresolution beam angle optimization method for paranasal sinus carcinoma. *Int. J. Radiat. Oncol. Biol. Phys*. **63**, 594-601(2005).

11. **Huchet, A., Caudry, M., Belkacemi, Y., Trouette, R., Vendrely, V., Causse, N., Recaldini, L., Atlan, D. and Maire, J.P.,** Volume-effect and radiotherapy part two: Volume-effect and normal tissue. *Cancer Radiother*, **7,** 353–362 (2003).

12. **Shaw, E., Scott, C., Souhami, L., Dinapoli, R., Kline, R., Loeffler, J. and Farnan, N.,** Single dose radiosurgical treatment of recurrent previously irradiated primary brain tumors and brain metastases: Final report of RTOG protocol 90–05. *Int. J. Radiat. Oncol. Biol. Phys.* **47**(2), 291–298 (2000).

13. **Van't Riet, A., Mak, A.C., Moerland, M.A., Leo, H.E. and Wiebe, V.D.Z.,** A conformation number to quantify the degree of conformality in brachytherapy and external beam irradiation: application to the prostate. *Int. J. Radiat. Oncol. Biol. Phys.* **37**, 731–736(1997).

14. **International Commission on Radiation Units and Measurements (ICRU),** report 50: prescribing, recording, and reporting photon beam therapy.Bethesda: ICRU(1993) .

15. **Petkovska,S., Tolevska,C., Kraleva,S. and Petreska, E.,** Conformity index for brain cancer patients. *Proceedings of the second conference on medical physics and biomedical engineering*, pp 56-58(2010) .

16. **Stanley, J., Breitman, K., Dunscombe, P.P. Spencer, D. and Lau, H.,** Evaluation of stereotactic radiosurgery conformity indices for 170 target volumes in patients with brain metastases. *Journal of Applied Clinical Medical Physics*, **12**(2), 245-253 (2011).

17. **Ammar, H., Eldebawy, E., Maarouf, E., Khalil, W. and Zaghloul, M.S.,** Evaluation of the peripheral dose and the conformity index for three stereotactic radiotherapy techniques: Arcs, Noncoplanar fixed fields and intensity modulation. *International Journal of Cancer Therapy and Oncology*, **2**(4), 1-12 (2014).

18. **Tong, X., Chen, X., Li, J., Xu, Q., Lin, M., Chen, L., Price, R.A. and Ma, C.,** Intrafractional prostate motion during external beam radiotherapy monitored by a real-time target localization system. *Journal of Applied Clinical Medical Physics*, **16**(2), 51-61 (2015).

19. **Welsh, J.S., Mackie, T.R. and Limmer, J.P.,** High-energy photons in IMRT: uncertainties and risks for questionable gain, *Technology in Cancer Research & Treatment*, **6**, 147–49 (2007).

20. **Vaezzadeh, S.A., Allahverdi, M., Nedaie, H.A., Aghili, M. and Esfehani, M.,** Comparison of conventional and 3D conformal treatments using Linac energies for prostate cancer'. *Iran. J. Radiat. Res.***10** (3-4), 145-150(2012).

21. **Runham, J., McDowall, W., Bryant, D. and Martin, J.,** A3D conformal radiation therapy class solution for dose escalated prostate irradiation'. *The Radiographer,* **55** (3), 13–17(2008).

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تقييم العلاج الإشعاعي ثلاثى الابعاد لسرطان البروستاتا بإستخدام مؤشرات قياس الجرعة

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تهدف هذه الدراسة إلى تقييم العلاج الإشعاعي ثلاثي الابعاد للمرضى الذين يعانون من سرطان البروستاتا.وذلك من خلال تأثير طاقاتات الفوتون ٦ و ١٥ ميجافولت بالإضافة إلى بعض حقول العلاج باستخدام مؤشرات مطابقة مختلفة. لهذه الدراسة تم اختيار ١٠ مرضى يعانون من سرطان البروستاتا تم أخذ صور اشعة مقطعية CT لكل مريض ونقلها إلى جهازالتخطيط العلاجىXiO. تم تقييم خطط العلاج باستخدام مؤشرات المطابقة. تم تصميم خطط العلاج الاشعاعى ثلاثى الابعاد باستخدام جهاز التخطيط العلاجى XiOوالمعجل الخطي مزود برأس علاجية متعددة الوريقات (MLC). اظهرت نتائج مؤشر المطابقة (CI) متوسط قيمة من ٠,٠٣ ± ١,٥ إلى ٠,٠٦± ١,٩ عند استخدام ٦ حقول مع ١٥ ميجافولت و ٣ حقول مع ٦ ميجافولت على التوالي ونتائج رقم المطابقة (CN) تشير إلى متوسط قيمة من ٠,٠٢ ±٠,٥١ إلى ٠,٠٢ ± ٠,٦٧ في ٣ حقول مع ٦ ميجافولت و٦ حقول مع ١٥ميجافولت على التوالي. ويوضح البحث أن إستخدام طاقات الفوتون ١٥ ميجافولت أو ٦ ميجافولت يحقق نفس تغطية الجرعة للورم ولكن في حالة استخدام ١٥ ميجافولت تنتج امان أفضل للاعضاء الحرجة، ويحسن أيضا من مؤشرات مطابقة الجرعة إلى حجم هدف التخطيط PTV .كما يحدث هذا عند زيادة عدد الحقول مما يحسن مؤشرات المطابقة ويقلل الجرعة على الاعضاء الحرجة . مؤشر المطابقة وعدد المطابقة تعطي نفس معلومات قياس الجرعة بعد مراجعة العلاقة البيانية بين الجرعة وحجم الانسجة DVH وتوزيعات الجرعة.