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Dosimetric Evaluation of Treatment Plans of 3DCRT & IMRT in Prostate Cancer EBRT

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Abstract

This study aims to compare 3DCRT & IMRT plans for two groups of prostate cancer patients *i.e.* "Prostate Only (PO) group" means the planning target volume includes the prostate & a margin of 1 cm from all sides except 0.6 cm from the posterior side & "Prostate + Seminal Vesicles (PSV) group" means the PTV includes Prostate & Seminal Vesicles surrounded with a margin of 1 cm from all sides except 0.6 cm from the posterior side. Total of 17 patients has been studied. Among them, 9 patients belong to PO group and 8 patients are in PSV group. In this study, 5 beams plan is used for 3DCRT planning while 7 beams plan is used for IMRT planning. This study declares the superiority of IMRT against 3DCRT technique in both PO & PSV groups. The conformity of PTV achieved in IMRT is much more than 3DCRT, while IMRT lags 3DCRT in dose homogeneity to PTV. Also, in IMRT, the OARS are safer than in 3DCRT. 3DCRT planning is done with Prowess Panther and IMRT planning with KonRad.

Subject Areas

Oncology

Keywords

3DCRT, 6MV & 15MV, IMRT, PO, PSV, PTV, OARs

1. Introduction

The prostate is a walnut-size gland located between the rectal wall and pubic symphysis. It surrounds the urethra between bladder neck and urogenital di-

aphragm. The Seminal Vesicles and vas deferens tunnels through prostate and enter into urethra. Morphologically, it is classified into three zones *i.e.* Central Zone, Peripheral Zone and Transition Zone. 75% of prostate cancers originate from the peripheral zone. Prostate cancer is diagnosed by serum examination (PSA level), Physical Examination (DRE), Needle Biopsy and CT/MRI imaging [1].

Radiotherapy is the most commonly used treatment method for the treatment of prostate cancer. The main goal of radiotherapy is to deliver uniform prescribed doses to PTV (Planning Target Volume) and minimum doses to surrounding tissues and Organ At Risks (OARs). The OARs in radiotherapy of prostate cancer are rectum, bladder, femur heads, penile bulb and bowel [2]. Radiotherapy is classified into two major divisions *i.e.* Brachytherapy and External Beam Radiotherapy (EBRT). In brachytherapy, the radioactive sources are inserted into or nearby tumor to deliver the dose while in EBRT, the source is placed outside patient body at a certain distance to deliver the dose to tumor inside patient body. There are three most common techniques being used for EBRT are 2D conventional Radiotherapy, 3-Dimensional Conformal Radiotherapy (3DCRT) and Intensity-Modulated Radiotherapy (IMRT). 2D conventional RT is an old technique based on 2D radiographs. Prostate cancer exhibits a good response to increasing radiation prescribed dose, which demands advancement in technology to improve conformity of dose [3] [4] [5] [6]. The beams are shaped only with collimator jaws, therefore have very limited control on the sparing of OARs while delivering maximum prescribed dose to target volume and hence allow ≤ 70 Gy dose to target volume. 3DCRT and IMRT allow delivering more than 70 Gy to PTV with acceptable doses of OARs. 3DCRT plans are based on 3D images (CT scans) and MLCs (Multi-Leaf Collimators) are used for beam shaping with a help of Beam Eye View (BEV). 3DCRT plans are optimized on a simple approach of forward planning. IMRT plans are also based on CT scans and MLCs are used for beam shaping, but are better for dose conformity to PTV and OARs sparing than 3DCRT because of the additional feature of intensity modulation. The inverse planning technique is used for the optimization of plan.

In this study, the dosimetric comparison of 3DCRT and IMRT plans has been studied for two groups of patients classified on basis of PTV defined. 3DCRT planning was performed after delineating target volumes and OARs by using Prowess Panther. A "5-beam technique" is used for 3DCRT plans on basis of a recommendation of Joshua Runham in his study [7]. For IMRT planning, it is good to have a template plan as a start, which is not optimal for all patients, but likely to produce an acceptable plan. Ezzell *et al.* suggested a standard protocol plan of five fields with rectum and bladder D10 limits set to 60 Gy and target doses of 75.6 Gy to 95% of CTV, leading to a mean prostate dose of 78.8 Gy [8]. IMRT planning was done by KonRad. The prescribed dose to PTV for both PO & PSV groups is 78 Gy. Plans are evaluated with the help of DVHs (Dose Volume Histograms) and clinical indices defined in Saint Anne, Lariboisiere, Tenon (SALT), Radiation Therapy Oncology Group (RTOG) guidelines & ICRU 83 [9].

2. Material & Methods

In this study, 17 patients have been selected from INMOL patient database. These patients were divided into two groups on the basis of PTV defined named as PO group and PSV group. 9 patients belong to the PO group and 8 belong to PSV group. PTV in PO group includes only the prostate along with a margin of 1 cm all around and 0.6 cm from the posterior side while PTV of PSV group includes both Prostate and Seminal Vesicles along with the same margin as was made in PO group. All patients with prostate cancer were instructed to drink water before CT simulation in INMOL. The patients were scanned from L5 to mid of femur with 5 mm CT slice thickness. No patient is treated in this study.

IMRT & 3DCRT planning was done with KonRad & Prowess Panther respectively. Prowess Panther provides the ability to delineate OARs and target volumes. It also provides an option to open MLC manually and automatically. The isocenter was set in the center of PTV for all patients of both groups. The prescribed dose to all the patients in this study is 78 Gy for both IMRT & 3DCRT. To evaluate plan, DVHs of delineated structures are available at the completion of plan. 3DCRT planning of patient was done with fast photon effective algorithm. 5 beams 3DCRT plan was made for both PO and PSV group as shown in Table 1. 3DCRT plans were considered acceptable on the criteria that 95% - 107% of prescribed dose covers PTV and the doses to OARs are less than their tolerance dose constraint limits.

Seven beams plan was made for IMRT planning of both groups shown in Table 2.

Table 1. Template plan of 3DCRT.

Number of Beams	Beam Angles	Beam Energy	Beam Weight (%)
Anterior Beam	0˚	6 MV	75
Left Ant. Lat. Beam	60˚	15 MV	75
Left Lat. Beam	90˚	15MV	100
Right Ant. Lat. Beam	300˚	15 MV	75
Right Lat. Beam	270˚	15 MV	100

Table 2. Template plan of IMRT.

Number of Beams	Beam Angle	Beam Energy	Weight (%)
1st Beam	0˚	6 MV	100
2nd Beam	50˚	6 MV	100
3rd Beam	100˚	6 MV	100
4th Beam	150˚	6 MV	100
5th Beam	220˚	6 MV	100
6th Beam	250˚	6 MV	100
7th Beam	300˚	6 MV	100

KonRad software performed inverse planning IMRT and also leaf sequencing for each beam. The delineated structures are categorized into three organ types *i.e.* Organ Type 1, Organ Type 2 and Organ Type 3. Organ Type 1 was target volumes. Organ Type 2 was OARs. OARs were femur heads, bladder & rectum. Some non-realistic organs *i.e.* organ 70, organ 90, avoidance, bladder-PTV & rectum-PTV were also drawn to help achieve desired goals. The Organ Type 3 was unclassified organs. The energy selected for IMRT planning was 6 MV. For inverse planning, the software needs desired goals *i.e.* maximum and minimum dose goal to target volume and only maximum dose goal to OARs. Values of PTV maximum and PTV minimum were 80 Gy and 78 Gy whereas the maximum dose to bladder, rectum and femur heads were 76 Gy, 76 Gy and 50 Gy. The software also provides a facility to draw DVH points as desired. Inverse planning in IMRT is done by the help of objective function which shows that how close the current dose distribution is to desired dose distribution. "Overlap priority" in KonRad is used to remove the ambiguity in overlap organs according to radiobiological demand. "Penalty value" is used to compel the optimizer to follow the respective dose goal rather than others. IMRT plans were considered acceptable with criteria that at least 98% of PTV covers 95% of prescribed dose and the doses to OARs are less than their tolerance dose constraint limits [10].

After completion of 3DCRT & IMRT planning, the plans were evaluated by clinical indices recommended by RTOG, SALT and ICRU 83. These indices are Conformity Index (CI), Homogeneity Index (HI), Healthy Tissue Over-dosage Factor (HTOF) and tumor Coverage Volume Factor (CVF). These indices are defined as:

$$CI_{RTOG} = \frac{V_{pres}}{PTV}$$

V_{pres} = Volume covered by prescribed dose;

PTV = The target volume;

CI_{RTOG} = The RTOG conformity index ($1 \le CI_{RTOG} \le 2$).

But the value of index cannot decide the rejection of any plan. Another index is also used for comparing plans is called as "Homogeneity Index" [9].

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}}$$

$D_{2\%}$ = The dose to 2% of PTV;

$D_{98\%}$ = The dose to 98% of PTV;

$D_{50\%}$ = The dose to 50% of PTV.

The last factor used often for comparison is "healthy tissue over-dose volume factor (HTOF)" is given by:

$$HTOF = \frac{HTV_{pres}}{LV}$$

HTV_{pres} = Healthy tissue receiving prescribed dose;

LV = Lesion Volume.

Statistically, a Wilcoxon signed-rank test was used for finding the significance of DVH differences for the 3DCRT and IMRT techniques in each group. 95% confidence level (P–value ≤ 0.05) was considered statistically significant.

3. Results

Average value of clinical indices for both RT techniques for PO group is given in Table 3. It is seen that conformity of PTV in IMRT is significantly better than 3DCRT for PO group ($p < 0.05$). The CI value more close to 1 will be considered more conformal. The OARs are also much spare in IMRT than 3DCRT with respect to HTOF ($p < 0.05$). While homogeneity index (HI) is showing that dose homogeneity to PTV is lost in IMRT in comparison to 3DCRT. The Bar plot of these indices is shown in Figure 1.

To compare the dose distribution of PTV in PO group for both RT techniques, Table 4 is given with a DVH values. IMRT plans are acceptable with a criteria given in ICRU report 83 (95% of prescribed dose must cover 98% of PTV) but the average maximum dose to PTV slightly exceeds 110% of prescribed dose thus generating a hot spot. The maximum dose to PTV is 87 Gy and 82.2 Gy in IMRT and 3DCRT respectively. IMRT is seen more sensitive to hot and cold spots with respect to 3DCRT. The mean dose to PTV is significantly greater in 3DCRT than IMRT. The dose to 50% of PTV is same in both 3DCRT and IMRT.

Table 3. Average clinical indices of 3DCRT & IMRT plans of PO group.

Comparison Indices	IMRT ± SD	3DCRT ± SD	P-value
CI	1.36 ± 0.078	1.71 ± 0.169	0.008
HI	0.125 ± 0.088	0.07 ± 0.0093	0.008
HTOF	0.36 ± 0.078	0.71 ± 0.162	0.008

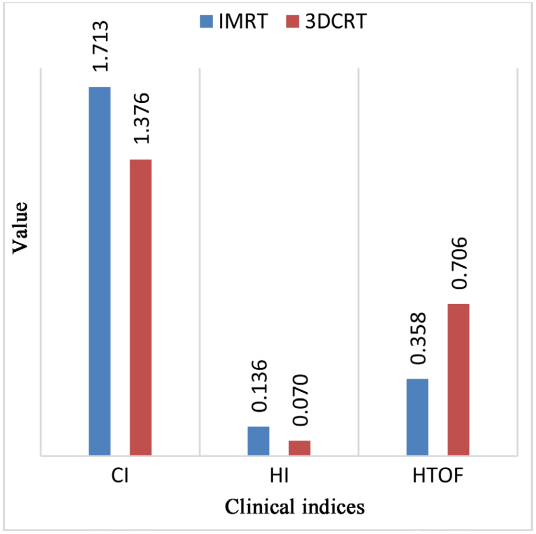

Figure 1. Bar plot of comparison of 3DCRT & IMRT w.r.t clinical indices in PO group.

Comparison of DVH of PTV for PO Group is shown in Figure 2.

The DVH points V25, V40, V60 and V70 for bladder and rectum of PO group are given in Table 5 and Table 6. Graphical representation of DVH of OARs is shown in Figures 3-6. There is no significant difference between DVH point V25 for rectum in IMRT and 3DCRT. For V40 and V60, IMRT has shown a little improvement on 3DCRT while V70% for IMRT is 5.83, significantly less than 12.03 in 3DCRT. In bladder of PO group, IMRT is superior to 3DCRT for all V40, V60 and V70 ($p < 0.05$) except V25. In 3DCRT, the average dose to LFH and RFH

Table 4. Comparison of 3DCRT & IMRT in PTV of PO group.

	IMRT ± SD (Gy)	3DCRT ± SD (Gy)	P-value
Max. Dose	87.06 ± 1.27	82.22 ± 0.97	0.008
Mini. Dose	74.4 ± 0.78	74.61 ± 0.677	0.008
Mean Dose	78.38 ± 0.44	79.36 ± 0.59	0.008
D2	84.28 ± 0.70	81.69 ± 0.81	0.008
D98	74.27 ± 0.38	76.05 ± 0.62	0.008
D50	79.76 ± 0.65	79.63 ± 0.85	0.262

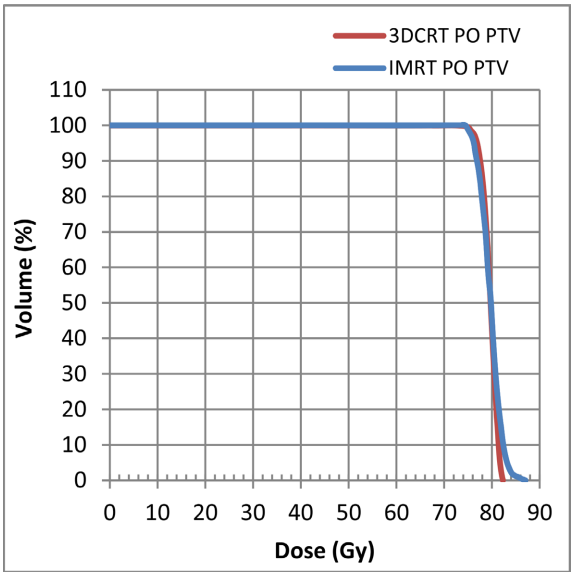

Figure 2. DVH comparison of 3DCRT & IMRT in PTV of PO group.

Table 5. Comparison of 3DCRT & IMRT with respect to (w.r.t) DVH points of rectum PO group.

	IMRT ± SD	3DCRT ± SD	P-value
V25 (%)	39.4 ± 11.17	39.4 ± 14.6	0.477
V40 (%)	24.83 ± 6.8	23.97 ± 8.97	0.593
V60 (%)	12.22 ± 3.12	15.44 ± 7.43	0.214
V70 (%)	5.83 ± 1.85	12.03 ± 6.49	0.008

Table 6. Comparison of 3DCRT & IMRT w.r.t DVH points of bladder of PO group.

	IMRT ± SD	3DCRT ± SD	P-value
V25 (%)	37.16 ± 13.44	44.94 ± 21.45	0.086
V40 (%)	25.57 ± 9.69	34.30 ± 15.96	0.021
V60 (%)	14.38 ± 5.22	23.78 ± 12.18	0.021
V70 (%)	9.27 ± 4.39	17.48 ± 8.20	0.028

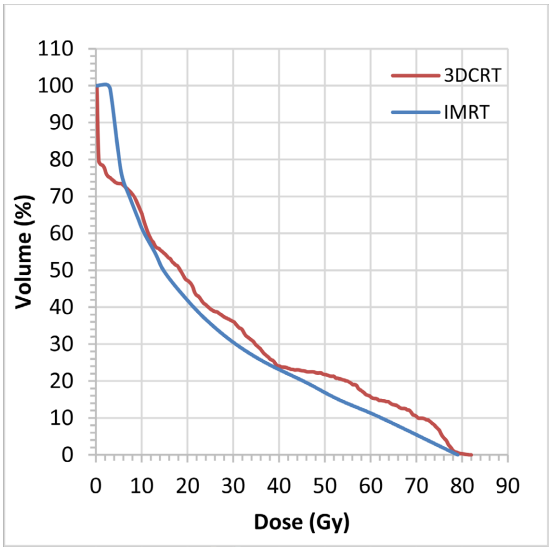

Figure 3. DVH comparison of 3DCRT & IMRT in rectum of PO group.

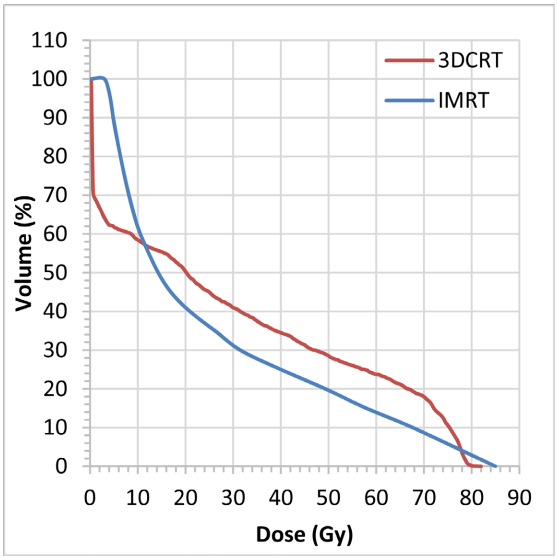

Figure 4. DVH comparison of 3DCRT & IMRT in bladder of PO group.

is same, 33.2 Gy, and larger in comparison to 15.7 Gy and 20.44 Gy deposited by IMRT respectively.

In PSV group, the bar plot for comparison of dose distribution with the help of clinical indices is shown in **Figure 7**. Like in PO group, the Conformity of

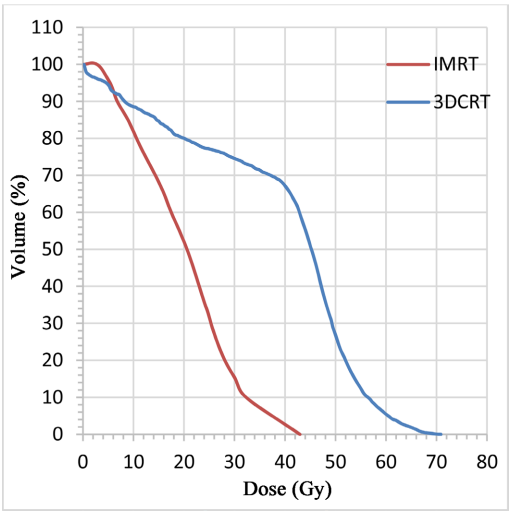

Figure 5. DVH comparison of 3DCRT & IMRT in LFH of PO group.

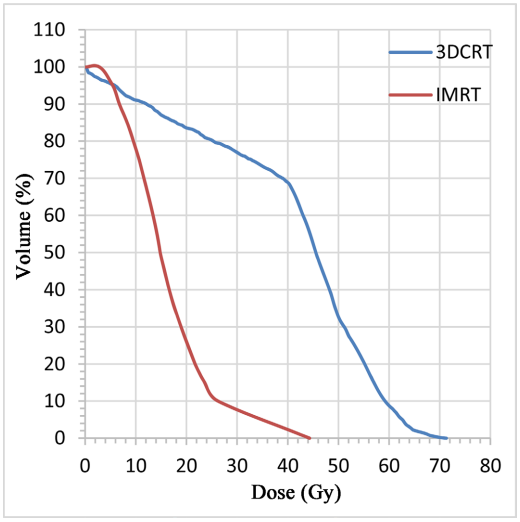

Figure 6. DVH comparison of 3DCRT and IMRT in RFH of PO group.

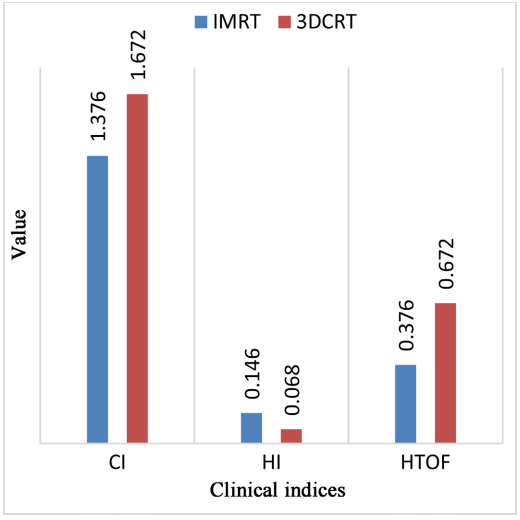

Figure 7. Bar plot comarison of 3DCRT & IMRT w.r.t clinical indices in PSV group.

PTV in IMRT (1.37) is better than the conformity in 3DCRT (1.67). Similarly, dose homogeneity in PTV is more with 3DCRT than IMRT. The healthy tissue receiving prescribed dose (HTOF) is 0.375 in IMRT in comparison to 0.671 in 3DCRT, means Healthy tissue receiving 95% prescribed dose is less in IMRT than 3DCRT. Tabulated value of indices is given in Table 7.

The DVH comparison of IMRT and 3DCRT for PTV of PSV group is shown in Figure 8 and Table 8. IMRT plans are acceptable regarding to guidelines of ICRU report 83. The dose receiving 98% of volume (D98%) is 95% of prescribed dose (74 Gy) in IMRT and 75.98 Gy in 3DCRT. The mean dose to PTV is higher in 3DCRT *i.e.* 79.42 Gy than IMRT *i.e.* 77.78 Gy. The dose heterogeneity is

Table 7. Average clinical indices for 3DCRT & IMRT plans of PSV group.

Comparison Indices	IMRT	3DCRT	P-value
CI	1.37 ± 0.06	1.67 ± 0.118	0.012
HI	0.132 ± 0.118	0.07 ± 0.097	0.012
HTOF	0.376 ± 0.602	0.67 ± 0.118	0.012

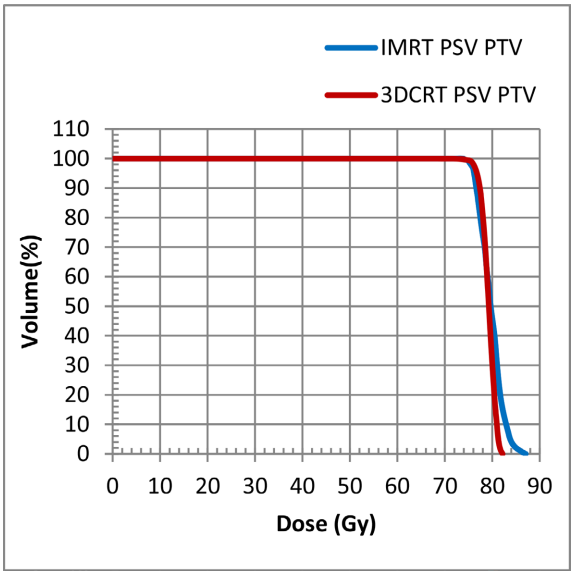

Figure 8. DVH comparison of 3DCRT & IMRT in PTV of PSV group.

Table 8. Comparison of 3DCRT & IMRT w.r.t DVH points in PTV of PSV group.

	IMRT ± SD (Gy)	3DCRT ± SD (Gy)	P-value
Max. Dose	87.26 ± 0.55	82.08 ± 1.21	0.012
Mini. Dose	73.7 ± 0.81	74.56 ± 0.71	0.012
Mean Dose	77.78 ± 1.81	79.42 ± 0.59	0.036
D2	84.77 ± 1.01	81.55 ± 0.95	0.012
D98	74.2 ± 0.21	75.98 ± 0.95	0.012
D50	79.61 ± 0.56	79.30 ± 1.45	0.624

prominent in IMRT again. The average maximum dose to PTV slightly exceeds 110% of prescribed dose. The sharp dose rise at the center and sharp dose fall at the periphery of PTV is more in IMRT than 3DCRT. The advantage noticed in 3DCRT over IMRT in both group of patients is its smooth dose distribution in PTV.

The DVH comparison of 3DCRT and IMRT in sparing OARs of PSV group is shown in Figures 9-12. In this group, the DVH points V25 & V40 of rectum show no significant difference between IMRT and 3DCRT while V60, V70 in rectum for IMRT is 18.12%, 8.75%which are significantly smaller in comparison to 28.86%, 18.77%, in 3DCRT. In bladder, the results of V25, V40 and V70 for IMRT have no statistical difference to 3DCRT. The bladder volume receiving 60 Gy in IMRT is less than that of 3DCRT. In IMRT, the average doses of LFH and

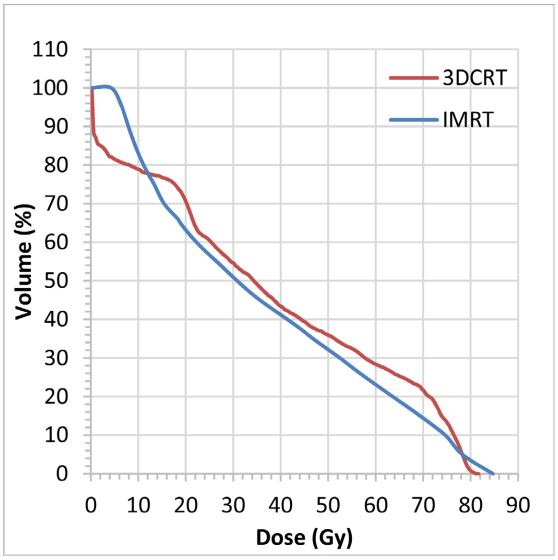

Figure 9. DVH comparison of 3DCRT & IMRT in Rectum of PSV group.

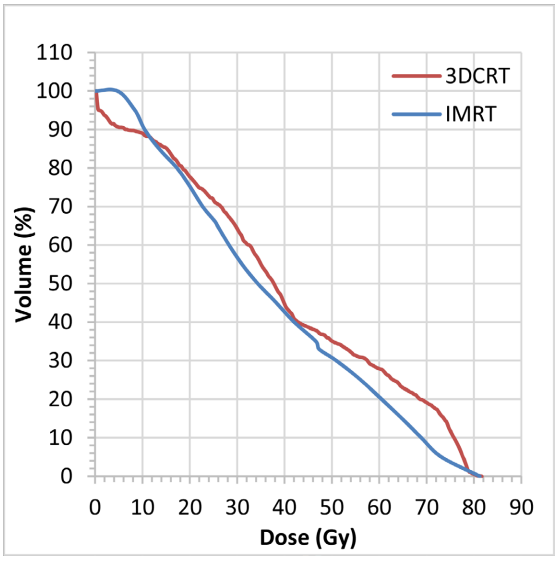

Figure 10. DVH comparison of 3DCRT & IMRT in bladder of PSV group.

RFH is 17.92 Gy and 15.88 Gy, which is half of the doses *i.e.* 35.23 Gy and 34.90 Gy in 3DCRT. Table 9 and Table 10 give the tabulated values of DVH points of rectum and bladder respectively. Thus, femur heads of PSV group are extremely

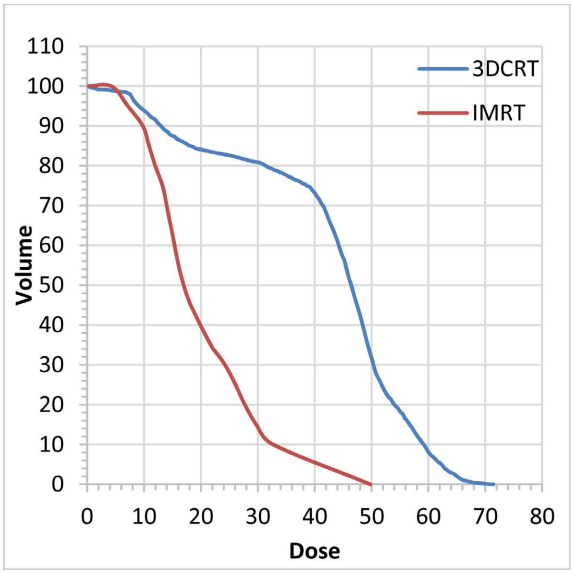

Figure 11. DVH comparison of 3DCRT & IMRT in LFH of PSV group.

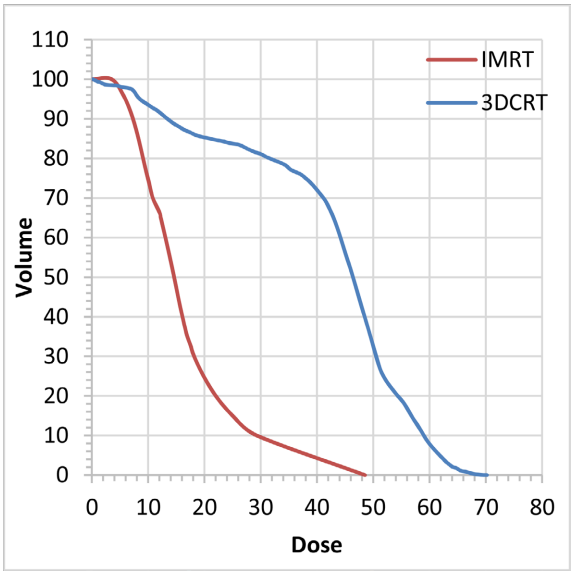

Figure 12. DVH comparison of 3DCRT & IMRT in RFH of PSV group.

Table 9. Comparison of 3DCRT & IMRT w.r.t DVH points in rectum of PSV group.

	IMRT ± SD	3DCRT ± SD	P-value
V25 (%)	55.12 ± 10.53	69.22 ± 16.65	0.05
V40 (%)	36 ± 7.38	44.42 ± 12.87	0.05
V60 (%)	18.22 ± 4.44	28.86 ± 9.46	0.012
V70 (%)	8.75 ± 2.42	18.77 ± 9.31	0.025

Table 10. Comparison of 3DCRT & IMRT w.r.t DVH points in bladder of PSV group.

	IMRT ± SD	3DCRT ± SD	P-value
V25 (%)	52.06 ± 10.38	56.28 ± 14.14	0.128
V40 (%)	34.75 ± 6.36	38.38 ± 10.68	0.176
V60 (%)	19.87 ± 3.84	24.42 ± 7.16	0.042
V70 (%)	13 ± 2.12	16.98 ± 5.28	0.05

spare in IMRT than 3DCRT. In both groups, IMRT spare more volume of OARs along with better dose conformity to PTV than 3DCRT.

4. Discussion

In this study, a dosimetric comparison of 3DCRT and IMRT plans for two groups of patients, was randomly selected from the database of Prowess Panther TPS at the Institute of Nuclear Medicine & Oncology (INMOL) Cancer Hospital. In PO group, IMRT and 3DCRT show statistically the same results for rectum, whereas, for bladder, IMRT is better at V40, V60 and V70 than 3DCRT. IMRT spares all OARs for all DVH points more than 3DCRT for PSV group except for V70 bladder ($p < 0.05$). The dose homogeneity in PTV destroys in IMRT because of the low DVH goal required for rectum. It is found that IMRT is better than 3DCRT in dose conformity to PTV.

A study was performed by evaluating the conformity of dose through Conformity Index (ICRU report 60) after planning treatment by Forward 3DCRT, Inverse 3DCRT & IMRT in Oesophageal, Nasopharangeal, Lungs and prostate cancer patients. Dose conformity achieved by IMRT in all four cancers is greater than the other two techniques [11]. Zelefsky *et al*. concluded lower rates of GU and GI toxicity in 1571 patients with IMRT as compared to 3DCRT [12].

A similar study is performed by Bora Uysal on low and intermediate-risk patients. In IMRT, V60 (volume receiving 60 Gy) is 4.55% and 7.45% in comparison to 3DCRT having 25.70% and 32.4% in rectum and bladder respectively. The mean doses to femur heads in 3DCRT are twice to their doses in IMRT [13].

A previously performed study on physical dosimetric and radiobiologic comparison of 3DCRT and IMRT reveals that IMRT offers increased target dose escalation with a reduced complication to sensitive normal structures. In LFI (Local Field Irradiation) group, the IMRT delivers the same dose (74.7 Gy) to the prostate with 35 fractions in comparison to 3DCRT with 37 fractions with 2 Gy per fraction in each technique. Similarly, in EFI (Extended Field Irradiation) group, the dose delivered with IMRT is higher than 3DCRT when 50 Gy is delivered in 25 fractions to the prostate and nodes, followed by 10 Gy to the prostate only in both 3DCRT and IMRT. The loss of dose homogeneity to PTV is also evident in IMRT in both LFI and EFI groups [14].

During this study, the shoulder in the DVH of PTV in IMRT comes earlier (at low doses) than 3DCRT. It seems to occur because of bad bladder conditions in

patients. Patients have not drunk water before CT simulation. Better results of IMRT can be achieved with the specified selection of patients with enlarged bladders.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Lu, J.J. and Brady, L.W. (2011) Decision Making in Radiation Oncology. Springer, Heidelberg.

[2] Bentel, G.C., Nelson, C.E. and Noell, K.T. (1982) Treatment Planning and Dose Calculation in Radiation Oncology. Elsevier, Amsterdam.

[3] Pollack, A., *et al*. (2002) Prostate Cancer Radiation Dose Response: Results of the M.D. Anderson Phase III Randomized Trial. *International Journal of Radiation Oncology, Biology, Physics*, **53**, 1097-1105.

[4] Oh, C.E., Antes, K., Darby, M., Song, S. and Starkschall, G. (1999) Comparison of 2D Conventional, 3D Conformal, and Intensity-Modulated Treatment Planning Techniques for Patients with Prostate Cancer with Regard to Target-Dose Homogeneity and Dose to Critical, Uninvolved Structures. *Medical Dosimetry*, **24**, 255-263. https://doi.org/10.1016/S0958-3947(99)00030-8

[5] Bogers, J.A., Van Der Maazen, R.W.M. and Visser, A.G. (2002) Conformal Photon-Beam Radiotherapy of Prostate Carcinoma. *European Urology*, **41**, 515-522. https://doi.org/10.1016/S0302-2838(02)00017-9

[6] Morris, D.E., *et al*. (2005) Evidence-Based Review of Three-Dimensional Conformal Radiotherapy for Localized Prostate Cancer: An ASTRO Outcomes Initiative. *International Journal of Radiation Oncology, Biology, Physics*, **62**, 3-19. https://doi.org/10.1016/j.ijrobp.2004.07.666

[7] Runham, J., McDowall, W., Bryant, D. and Martin, J. (2008) A 3D Conformal Radiation Therapy Class Solution for Dose Escalated Prostate Irradiation. *Radiographer*, **55**, 13-17. https://doi.org/10.1002/j.2051-3909.2008.tb00088.x

[8] Ezzell, G.A., Schild, S.E. and Wong, W.W. (2001) Development of a Treatment Planning Protocol for Prostate Treatments Using Intensity Modulated Radiotherapy. *Journal of Applied Clinical Medical Physics*, **2**, 59-68. https://doi.org/10.1120/1.1347156

[9] Cao, T., Dai, Z., Ding, Z., Li, W. and Quan, H. (2019) Analysis of Different Evaluation Indexes for Prostate Stereotactic Body Radiation Therapy Plans: Conformity Index, Homogeneity Index and Gradient Index. *Precision Radiation Oncology*, **3**, 72-79. https://doi.org/10.1002/pro6.1072

[10] Bhat, M. (2007) The Physics of Radiotherapy X-Rays and Electrons: Peter Metcalfe, Tomas Kron and Peter Hoban Medical Physics Publishing, Madison WI. 2007. 916 Pages, Hardcover, US $140.00. ISBN 978-1-930524-35-4. Softcover, US $120.00. ISBN: 978-1-930524-36-1. *Physical and Engineering Sciences in Medicine*, **30**, 295-295. https://doi.org/10.1007/BF03178441

[11] Bauman, G., Rumble, R.B., Chen, J., Loblaw, A. and Warde, P. (2012) Intensity-Modulated Radiotherapy in the Treatment of Prostate Cancer. *Clinical Oncology*, **24**, 461-473. https://doi.org/10.1016/j.clon.2012.05.002

[12] Zelefsky, M.J., *et al*. (2008) Incidence of Late Rectal and Urinary Toxicities after Three-Dimensional Conformal Radiotherapy and Intensity-Modulated Radiotherapy for Localized Prostate Cancer. *International Journal of Radiation Oncology*, *Biology*, *Physics*, **70**, 1124-1129. https://doi.org/10.1016/j.ijrobp.2007.11.044

[13] Tas, U., *et al*. (2012) Aquaporin-1 and Aquaporin-3 Expressions in the Intervertebral Disc of Rats with Aging. *Balkan Medical Journal*, **29**, 349-353. https://doi.org/10.5152/balkanmedj.2012.079

[14] Luxton, G., Hancock, S.L. and Boyer, A.L. (2004) Dosimetry and Radiobiologic Model Comparison of IMRT and 3D Conformal Radiotherapy in Treatment of Carcinoma of the Prostate. *International Journal of Radiation Oncology*, *Biology*, *Physics*, **59**, 267-284. https://doi.org/10.1016/j.ijrobp.2004.01.024