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Attaining a Substantial Dose Gradient in a Three-Dimensional Conformal Radiotherapy (3d-crt) Plan for a Prostate Cancerous Tumour

Zainab Raad Salman[1], Muntather Habeeb Albosaabar[2], Vyan Hussein Abdulhakeem[3], Rozilawati Binti Ahmad[4]*, Fatima Jassim Mohammed[5], Nabaa M. Alazawy[6], Mustafa I. Ahmed Aldulaimy[7], Hiyam A. Altaii[8], Tamara Muayad Abdullah[9]

Abstract

Background: Clinically, better radiotherapy could be achieved by assigning a prescription dose to the tumour volume and a set of dose constraints on critical structures. Once an optimal treatment plan has been achieved, dosimetry is assessed using the physical dose and volume parameters. Aim of the study: The study's goal was to find better ways to treat prostate cancer patients using three-dimensional conformal radiotherapy treatment (3D-CRT) planning systems. These systems were used during the three stages of radiotherapy treatment fractions 0 degrees and 90 degrees of collimator angle. Materials and Methods: 155 patients with prostate cancer were treated with energy (6 MV or 10 MV) They were treated using the 3DCRT technique by the Monaco 5.11 treatment planning system and irradiated using a Synergy linear accelerator manufactured by Elekta. The plan was repeated 12 times with different numbers of beams used: 5, 7, and 9. They were irradiated with two collimator angles of 0 and 90 degrees. The planning target volumes were measured at the original volume of the tumour and at distances of 1 mm, 2 mm, and 3 mm to obtain the gradient index values. Results: The 10 MV energy is higher than the 6 MV plan for target coverage and has a lower dose to the organs at risk. Furthermore, when the number of beams increased to 9, this gave better dose distribution. High doses share better gradient index values to lower the dose to the surrounding healthy tissue. Conclusion: The study shows that the mean dose values for prostate cancer radiotherapy using 6 MV and 10 MV energies are very different depending on the beam configuration and collimator angle. The analysis emphasizes the importance of considering treatment parameters when planning radiation, as they influence dose distribution. The study also highlights variations in the gradient index among different beam configurations and collimator angles.

Keywords: *Three-dimensional conformal radiotherapy treatment (3D-CRT), collimator angle, gradient index (GI), Three phases, prostate cancer.*

[1] Physics Department, College of Science for Women, Baghdad University, Baghdad, Iraq Email: zainab.r@csw.uobaghdad.edu.iq
[2] Programme of Diagnostic Imaging and Radiotherapy, Faculty of Health Sciences, Universiti Kebangsaan Malaysia
Email: P101483@siswa.ukm.edu.my
[3] Oncology and Nuclear Medicine Specialized Hospital, Ninava Directorate Health, Mosul, Iraq. Email: vyanhussein0@gmail.com
[4] Programme of Diagnostic Imaging and Radiotherapy, Faculty of Health Sciences, Universiti Kebangsaan Malaysia
*Corresponding Author Email: rozie.ahmad@ukm.edu.my
[5] Baghdad Center for radiation therapy and nuclear medicine, Baghdad Medical City, Baghdad, Iraq. Email: fjassim501@gmail.com
[6] Programme of Diagnostic Imaging and Radiotherapy, Faculty of Health Sciences, Universiti Kebangsaan Malaysia
Email: P126469@siswa.ukm.edu.my
[7] Department of Physiology, College of Medicine, University of Mosul, Mosul, Iraq. Email: Mustafa.Ibrahim@uomosul.edu.iq
[8] Department of Biology, College of Science, University of Mosul, Mosul, Iraq. Email: hiyamaltaii@uomosul.edu.iq
[9] Radiology techniques department/AL-Noor university college. Email: tamara.muayad@alnoor.edu.iq

Introduction

Prostate cancer is a common and increasing kind of cancer that requires ongoing development of treatment approaches to improve treatment effectiveness and reduce the harmful effects of radiation (1,2). Three-dimensional conformal radiotherapy (3D-CRT) is now a fundamental aspect of prostate cancer treatment, providing accurate and adaptable administration of radiation doses (3–5). Attaining a significant variation in dose is crucial for optimising the effectiveness of therapy while safeguarding neighboring healthy tissues. This research examines a thorough three-phase strategy for enhancing dose gradients in 3D-CRT plans for prostate cancer. It covers essential factors in treatment planning, delivery, and patient results (6).

Prostate cancer is a multifaceted and diverse illness that requires sophisticated treatment methods to achieve both effective tumour control and the protection of other vital tissues. Three-dimensional conformal radiotherapy (3D-CRT) is a crucial therapeutic method that allows oncologists to accurately focus on prostate tumours while reducing radiation exposure to nearby healthy tissues (6,7).

The objective of 3D-CRT is to attain an ideal dose distribution inside the prostate gland, guaranteeing maximum tumour control and minimum radiation-induced damage. An essential element of this optimisation process is achieving a significant dose difference between therapeutic and normal tissue levels. This becomes incredibly challenging with the complex anatomical structure of the pelvis.

As a novelty of this study, it significantly contributes to the current knowledge of prostate cancer radiation therapy dosimetry. It offers new insights and enhances our understanding of the complex relationship between treatment parameters and their effects on the planned target volume (PTV) and rectal doses.

Materials and Methods

This is a retrospective clinical study performed from January 2023 to November 2023 at the Baghdad Center for Radiation Therapy and Nuclear Medicine. A convenience sample was used to collect the data. One hundred fifty-five men diagnosed with prostate cancer participated in the research. Subjects who have had radiation treatment in the past, are less than 25 years old, or have fulfilled the criteria for metastatic cancer were excluded. After the patients gave written permission, irradiation was done using a synergistic linear accelerator (Linac, Elekta, Sweden) and 3D-CRT with 6MV or 10MV energy. The treatment planning system was Monaco 5.11, manufactured by Elekta in Sweden.

The radiation oncologist delineates the tumor and tissue at risk. The anticipated target volume (PTV) was then calculated four times with dosimetric parameters. Three phases of treatment were implemented for the patients. Phase I included a dose of 5,000 cGy, Phase II included 1800 cGy, and Phase III included 600 cGy. During Phase 1, the complexities of treatment planning were examined, considering many elements such as precise identification of therapy targets, determination of dose, and protection of critical structures. The precision in these planning components establishes the basis for succeeding stages, impacting the attainable dose gradients and effectiveness of the therapy.

Phase 2 focuses on executing sophisticated delivery methods, such as intensity-modulated radiotherapy (IMRT) or volumetric-modulated arc therapy (VMAT). These strategies provide

improved dose modulation, allowing for more precise control over the distribution of the dose and the steepness of the gradient.

In Phase 3, we examine the clinical results of the three-phase strategy, highlighting the significance of continuous assessment and adjustment. By examining treatment effectiveness, toxicity profiles, and patient-reported outcomes, our goal is to confirm the validity of the suggested strategy and provide valuable insights for future improvements.

Three to five beams were used. The angle of the collimator was adjusted to zero. An oncologist specialising in radiation treatment took extra precautions by drawing three PTVs at 1mm, 2mm, and 3mm distances from the first PTV to guarantee that the reduced dose would not harm healthy tissue.

Analysis was performed using SPSS 28. You may see the data displayed as the mean and standard deviation. A p-value ≤0.05 was considered significant (8).

Results

The average dose in the planned target prostate cancer volume is computed for the three treatment periods. The findings indicate that the dose delivered to the planning target volume (PTV) was consistently larger than the dose received by the PTV at distances of 1 mm, 2 mm, and 3 mm, respectively. The statistical comparison for the patient undergoing the third phase of radiation therapy is shown in Tables 1, 2, 3, and 4.

For Table 1: the doses of PTV show that as the number of beams grows from 5 to 9, the mean dose for PTV also increases. A statistically significant variation in the mean PTV dose was observed across the various beam numbers, as shown by the p-value of 0.0483. At PTV 1 mm doses, it shows that among the different beam numbers, there is a notable variation in the mean dose for PTV with a 1 mm expansion (p-value: 0.0026*). While comparing PTV with 2 mm and 3 mm expansions, the mean dose does not change significantly across the various beam numbers (p-values > 0.05).

Table (2) compares the mean doses of three different beam counts during phase three therapy (6 MV, 90° collimator angle). PTV doses reveal that the average PTV dose changes dramatically with beam count, rising sharply between 5 and 9 beams. A statistically significant variation in the mean PTV dose across the various beam numbers is shown by the p-value (0.0004*). Among the different beam numbers, the PTV 1 mm doses showed a statistically significant difference in the mean dose for PTV with a 1 mm expansion (p-value: 0.0304*). There is also no statistically significant variation in mean dose across the various beam numbers (p-values > 0.05) according to the PTV 2 mm and 3 mm doses. Particularly for PTV and PTV with a 1 mm expansion, the data indicate that the number of beams affects dose delivery significantly.

Table (1): A Comparison is Made Between the Mean Dose Value in Centigray (cGy) for Different Numbers of Beams Using 6 Mv Energy and 0° Collimator Angle.

	5 Beams	**7 Beams**	**9 Beams**	***p*-value**
PTV	522.3±104.3	529.4±115.3	574.5±91.8	0.0483*
PTV 1 mm	485.2 ± 9.3	544.5±122.8	432.6±56.9	0.0026*
PTV 2 mm	453.7± 56.9	521.6± 53.7	411.9±86.1	0.0843
PTV 3 mm	441.9± 24.4	509.4 ± 41.6	403.8±34.0	0.295

*Significant Difference at a Level less than 0.05.

Table (2): A Comparison is Made Between the Mean Dose Value in Centigray (cGy) for Different Numbers of Beams Using 6 Mv Energy and 90° Collimator Angle.

	5 Beams	**7 Beams**	**9 Beams**	***p*-value**
PTV	595.2± 75.6	470.5±114.3	670.6±83.0	0.0004*
PTV 1 mm	527.2±99.3	459.4± 83.2	620.4±83.9	0.0304*
PTV 2 mm	473.8±127.9	458.3±91.4	523.2±174.2	0.544
PTV 3 mm	452.9±65.3	417.8± 33.1	439.9±62.2	0.634

*Significant Difference at a Level less than 0.05.

A statistically significant change in the mean dose values for the main PTV across the range of beam numbers (5, 7, and 9 beams) is shown by the PTV doses in Table (3), which has a p-value of 0.0132*.This discovery highlights the apparent effect of beam intensity on the dose given to the leading treatment site. Conversely, a p-value of 0.0459* indicates statistical significance across various beam configurations for the mean dose values of PTV with a 1 mm expansion.

This suggests that the number of beams is the most important factor in determining the dose delivered to the target volume within a margin of 1 mm.

It's not possible to get statistical significance at usual confidence levels for PTVs with 2 mm and 3 mm expansions, even though there are patterns in the mean dose values across different beam amounts (p-values of 0.077 and 0.0934 to be exact).

This points to a complex link that may need further research or more significant samples to draw firm conclusions. Phase three treatment is the setting for this investigation's findings, which shed light on the complex relationship between beam number, beam energy (10 MV), and collimator angle (0°). Careful treatment planning and parameter optimisation are crucial for achieving the required dosimetric results, as shown by the statistically significant variations in mean dose values between PTV and PTV with a 1 mm extension. Another possible area for improvement or investigation into alternate dose delivery systems might be the lack of statistical significance in PTVs with more enormous expansions.

Table (3): A Comparison is Made Between the Mean Dose Value in Centigray (cGy) for Different Numbers of Beams Using 10 Mv Energy and 0° Collimator Angle.

	5 Beams	**7 Beams**	**9 Beams**	***p*-value**
PTV	594.2±93.3	594.3± 83.3	602.2±99.4	0.0132*
PTV 1 mm	520.4.5±80.8	480.5± 62.3	463.2±26.1	0.0459*
PTV 2 mm	483.3± 82.5	462.2±54.3	423.54±74.4	0.077
PTV 3 mm	476.4± 63.8	422.4± 98.4	411.1±84.4	0.0934

*Significant Difference at a Level less than 0.05.

Based on the data shown in Table (4), Although there are significant changes in the mean dose levels for the major PTV over a range of beam numbers, the p-value of 0.393 indicates that statistical significance has not been reached. With 10 MV energy and a 90° collimator angle, this means that the number of beams may not have a statistically significant effect on the dose given to the main treatment target.

There is no statistically significant variation in the mean dose values for PTV with a 1 mm extension across the various beam configurations (p-value: 0.437). This indicates that, within a margin of 1 mm, the dose to the target volume is unaffected by the number of beams. With a p-value of 0.016*, we can see that the mean dose values for PTV with a 2 mm expansion are

statistically significant compared to the 3 mm doses. This means that the beam amount significantly affects the dose supplied to the target within a margin of 2 mm.

Similarly, there are substantial changes in mean dose across various beam numbers for PTV with a 3 mm extension ($p = 0.027$). This study's results are very useful because they show how different beam counts affect the dosimetric effects in a treatment case with 10 MV energy and a 90° collimator angle.

The mean dose to the main PTV and PTV with a 1 mm margin does not vary statistically, while more extensive expansions (2 mm and 3 mm) significantly influence. These results highlight the need to customise treatment planning approaches according to individual clinical factors, considering that the effect of beam amount on dosimetric results could change for various target sizes and expansions. Also, there may be a way to improve treatment procedures and optimise beam configurations to reach dosimetric goals, as there are noticeable variances in the mean dose for more extensive expansions.

Table (4): A Comparison is Made Between the Mean Dose Value in Centigray (cGy) for Different Numbers of Beams Using 10 Mv Energy and 90° Collimator Angle.

	5 Beams	**7 Beams**	**9 Beams**	***p*-value**
PTV	653.1±170.6	596.2±59.1	582.1±106.1	0.393
PTV 1 mm	438.2±56.2	462.5±127.9	491.8±76.2	0.437
PTV 2 mm	469.7±51.1	446.1±132.7	570.3±82.3	0.016*
PTV 3 mm	403.9±56.9	478.1±61.9	366.5±127.8	0.027

*Significant Difference at a Level less than 0.05.

Table 5 presents the results of a comprehensive investigation of the average rectum doses in radiation treatment for different beam volumes, collimator angles, and energy levels. The dosimetric details of 5, 7, and 9 beams, with 0° and 90° collimator angles, and 6 MV and 10 MV energy levels are examined in this study. With p-values, which show statistical significance, we can see significant differences (defined as values below 0.05).

The mean rectum dose exhibits a statistically significant change with the number of beams (p-value: 0.0103*) according to the findings of 6 MV; 0° Collimator Angle. It seems that the number of beams significantly impacts rectal dosimetry, as different dose levels are seen for 5, 7, and 9 beams. Different beam configurations result in significantly different rectal mean doses at 10 MV with a 0° collimator angle (p-value: 0.0323*). It is worth mentioning that 7 beams have a larger mean dose than 5 and 9 beams, which might indicate varying doses depending on energy.

Differences in mean rectum dose concerning beam count are statistically significant at 6 MV and 90° collimator angle ($p = 0.0453$*). The collimator angle affects rectal dosimetry, as the 5, 7, and 9 beams have different mean doses. Statistical significance was not achieved (p-value: 0.0934). However, trends in mean dose differences were noticed, according to the 10 MV and 90° collimator angle findings. The results of this extensive study draw attention to the complex relationship between energy level, collimator angle, and number of beams in calculating rectal mean doses during radiation treatment. Careful treatment planning considering these factors is necessary to optimize dosimetry and reduce the risk of harmful effects on the rectum, as shown by the statistically significant differences. Insights into the complex nature of rectal dosimetry provided by the observed differences offer the groundwork for future research efforts to improve treatment procedures and advance radiation therapy.

Table (5): A Comparison of Mean Rectum Doses for 5,7 and 9 Beams, 0, 90 Degree Collimator Angles, and 6 MV & 10 MV Energy Levels.

Number of Beams	Collimator Angle	5 Beams	7 Beams	9 Beams	*p*-value
6 MV	0°	274.1 ± 27.1	322.7 ± 75.4	210.4.1 ± 64.2	0.0103*
10 MV	0°	211.2 ± 53.3	307.2 ± 94.7	237.1 ± 41.3	0.0323*
6 MV	90°	356.4± 44.2	319.8 ± 81.5	277.5 ± 54.3	0.0453*
10 MV	90°	310.4 ± 7.32	369.6 ± 50.7	334.1 ± 75.1	0.0934

*Significant Difference at a Level less than 0.05.

Tables 6–9 provide the findings, which highlight significant findings and statistical significance. Beam 5 shows a much higher GI for PTV and PTV 2 mm at 6 MV energy and 0° collimator angle compared to Beam 7 and Beam 9, highlighting better dose conformity. Proof that beam design has a complex effect on dose distribution is shown by a notable variation in PTV 1 mm. Beam 5's much lower GI for PTV 1 mm at 90° Collimator Angle and 6MV than Beam 7 and 9 suggests better conformance at this energy level. The complex relationship between the collimator angle and the beam arrangement is shown by the small changes in GI between beams.

With 10 MV energy, Beam 5 has a much lower GI for PTV, PTV 2 mm, and PTV 3 mm at the 0° collimator angle than Beam 7 and Beam 9, which indicates better dose conformity. The significant disparities in PTV 1 mm and PTV 3 mm show the crucial importance of beam arrangement in influencing dose distribution. Beam 5 shows a markedly reduced GI for PTV and PTV 3 mm at 90° collimator angle, suggesting better conformance; it also shows a notable change for PTV 1 mm, demonstrating the complex interaction between collimator angle and dose distribution. Distinct PTV expansions have different effects on GI in Beam 7 and Beam 9, indicating how the connection between beam design and energy level is complex.

Table (6): A Gradient Index Comparison at 0° Collimator Angles for Beams 5, 7, and 9 for 6 MV Energy.

PTV	PTV 1 mm	PTV 2 mm	PTV 3 mm	*p*-value
Beam 5	2.71 ± 0.75	1.98 ± 0.24	2.71 ± 0.54	< 0.00001*
Beam 7	2.43 ± 0.43	2.53 ± 0.94	2.65 ± 0.87	0.959
Beam 9	2.86 ± 0.15	2.85 ± 0.53	2.34 ± 0.45	0.54332
p-value	0.0593	0.0433*	< 0.00001*	

*Significant Difference at a Level less than 0.05.

Table (7): A Gradient Index Comparison at 90° Collimator Angles for Beams 5, 7, and 9 for 6 MV Energy.

PTV	PTV 1 mm	PTV 2 mm	PTV 3 mm	p-value
Beam 5	3.31 ± 0.93	1.89 ± 0.99	2.54 ± 0.76	0.02445*
Beam 7	2.54 ± 0.84	2.74 ± 1.00	2.45 ± 0.25	0.5442
Beam 9	2.89 ± 0.41	2.44 ± 0.23	2.86 ± 0.77	0.0655
p-value	0.0123*	0.03302*	0.0774	

*Significant Difference at a Level less than 0.05.

Table (8): A Gradient Index Comparison at 0° Collimator Angles for Beams 5, 7, and 9 for 10 MV Energy.

PTV	PTV 1 mm	PTV 2 mm	PTV 3 mm	p-value
Beam 5	2.93 ± 0.96	2.44 ± 0.74	2.93 ± 0.78	0.095
Beam 7	2.55 ± 0.66	2.32 ± 0.82	2.12 ± 0.55	0.0854
Beam 9	2.35 ± 0.75	2.64 ± 0.54	2.64 ± 0.32	0.0765
p-value	0.0052*	0.0643	0.02455*	

*Significant Difference at a Level less than 0.05.

Table (9): A Gradient Index Comparison at 90° Collimator Angles for Beams 5, 7, and 9 for 10 MV Energy.

PTV	PTV 1 mm	PTV 2 mm	PTV 3 mm	p-value
Beam 5	2.42 ± 0.91	2.81 ± 0.95	2.52 ± 0.75	0.0674
Beam 7	2.54 ± 0.54	3.09 ± 1.02	2.37± 0.97	0.0432*
Beam 9	2.12 ± 0.75	2.22 ± 0.84	2.39 ± 0.62	0.0165*
p-value	0.0065*	0.0432*	0.03933*	

*Significant Difference at a Level less than 0.05.

Discussion

This study looks at the dosimetric complexity of radiation therapy for prostate cancer over three treatment phases. It does this by looking at how planned target volume (PTV) and rectum doses change when different beam configurations, energy levels, and collimator angles are used. Tables (1) through (5) show the results, which shed light on the complex relationship between these characteristics and how they affect dosimetry.

Tables 1, 2, and 3 show the effects of beam number, demonstrating that the research consistently finds a substantial increase in mean PTV dose with increasing beams (5 to 9). This trend holds over all three treatment periods. The enormous effect of beam amount on the main treatment target is shown by the statistically significant changes in PTV doses (p-value: 0.0483, 0.0004*, 0.0132*). The third phase's investigation of PTV doses demonstrates a significant variance in mean dose values (p-value: 0.0132*), confirming the strong effect of beam intensity on the given dose, as shown in the Impact of Beam Configurations of Table 3. Differences in PTV 1 mm doses are statistically significant (p-value: 0.0459*), demonstrating how beam designs affect nearby structures. The research shows that PTVs with 1 mm expansions have distinct effects and significant differences in the mean doses (p-values: 0.0026*, 0.0304*, 0.0459*). On the other hand, PTVs with 2 mm and 3 mm expansions do not show any statistically significant alterations, suggesting a complicated link that needs further investigation.

The experiment found that a p-value of 0.393 suggests that the number of beams may not have a big effect on the dose to the primary PTV at the given settings (10 MV, 90° collimator angle). Nevertheless, beam designs still affect PTVs with 1 mm expansions (p-value: 0.437).

The study's findings on rectal dosimetry highlight the importance of beam amount, especially at 6 MV with a 0° collimator angle (p-value: 0.0103*) and a 90° collimator angle (p-value: 0.0453*). Interestingly, the results highlight how the collimator angle may affect rectal dosimetry.

There are significant differences in the mean rectum dose between beam configurations at 10 MV and 0° collimator angle (p-value: 0.0323*), which could mean a dosimetric difference that depends on energy. However, no statistical significance is attained at 10 MV with a 90° collimator angle (p-value: 0.0934), suggesting a complex connection that requires more research.

The research highlights the critical need for careful treatment planning when dealing with prostate cancer radiation therapy, taking into consideration different beam configurations, energy levels, and collimator angles to produce the best dosimetric results. Rectum and PTV mean dose levels differed significantly, indicating the necessity for individualised treatment plans considering these characteristics' complex influence on dosimetry.

Future studies should look at more significant samples to get to the bottom, particularly with PTVs with more significant expansions. Research into other dose delivery devices or treatment regimens would be necessary to optimise dosimetry further and minimise side effects. This study's thorough dosimetric analysis adds to our knowledge of the interplay between treatment parameters and the impact on doses to target and organs at risk. Clinicians may use the results to improve radiation therapy for prostate cancer and create more effective treatment regimens. With an emphasis on 6 MV and 10 MV energy levels, the tables (6-9) that follow provide an exhaustive examination of the Gradient Index (GI) in prostate cancer radiation with different beam configurations (5, 7, and 9 beams) and collimator angles (0° and 90°). Considering the variance in the Gradient Index across various situations is warranted since it is a significant metric in treatment planning that indicates the dose conformance to the target volume.

In beams 7 and 9, there are notable variations in PTV 1 mm and PTV 3 mm at 0° collimator angle and 6 mV energy, indicating different dose conformities for these setups. Beam 5's PTV and PTV 1 mm show substantial variances at a 90° collimator angle, suggesting other dose distributions. These results indicate that the collimator angle affects the GI differently for every beam arrangement. At 0° Collimator Angle for Beam 5, there are clear differences between PTV and PTV 3 mm for 10 MV energy. This shows that the energy level has an effect on dose conformity. There seems to be a more noticeable impact of energy at a 90° collimator angle, as shown by the statistically significant variations in all parameters for Beam 7 and Beam 9. These findings highlight the need to customize treatment programs according to beam design and energy level.

For this study, Tyagi et al. compared intensity-modulated radiation therapy (IMRT) plans for cervical carcinoma (Ca Cx) using 6 MV and 15 MV photon energies, looking at the dosimetric parameters of planning target volume (PTV) and organs at risk (OAR), homogeneity index (HI), conformity index at the 98% level (CI 98%), integral dose to normal tissue (NTID), and total monitor units (MUs). The research found that both energy modalities achieved similar PTV coverage in 16 patients who received a homogenous dose of 50 Gy in 25 segments. One advantage of the 6 MV photon plans for Ca Cx IMRT is that they show better target coverage, greater conformity, and better OAR sparing than the other plans (9).

The gradient index (GI) is an evaluation tool for planning radiation therapy. It represents a description of the dose fall-off outside the planning target volume. It is the ratio between the prescribed dose volume at 50% and 100% of the isodose line. The purpose of the GI is to evaluate the steep dose outside the target to show the best dose distribution. The minimum GI value means the steep gradient dose outside the PTV and more dose sparing to the organ at risk (10,11).

Bedford et al., 2000 aimed to find the correct coplanar care method for prostate only (PO) or prostate supplement seminal vesicle (PSV) conformal 6-field radiotherapy. The plans were contrasted with 80% or more of the recommended dose (V80) by rectal volumes: usual rectal, bladder, and femoral head. The resistance of the femoral head was 52 Gy with an overall volume of 10%. The optimised six-field plans have been shown to boost rectal performance at both standard and escalating doses. Furthermore, a smaller improvement in rectal NTCP with tailored six-field planes will benefit TCProm dose-scaling (12).

The effectiveness and efficacy of 3D-CRT for localised prostate cancer were tested in a systematic evidence assessment by Morris et al., 2005. The authors offered simple suggestions regarding the main clinical results of using 3D-CRT for localised prostate cancer compared to traditional cancer treatments. We have achieved the technological goals of 3D-CRT. It is still

important to get subset-specific clinical data on hormone therapy via randomised controlled trials and follow-ups (13).

Moran et al. (2005) introduced a novel method of gradient compensation. It involves using a distance parameter, usually 1 mm, as the geometer's tolerance for comparing the dose with the local dosimetric fluctuations and a dose gradient at each location in the distribution. It has been shown that the approach for dosimetric analytical analysis of dose calculation and algorithms for leaf sequencing is both effective and adaptable. The developers claim the technology is compatible with different dose disparities and overlay displays. Their research shows that this strategy works well for separating dosimetric discrepancies caused by film misalignment or dose grid measurement errors from more fundamental geometric variances. Additionally, the system performed well regarding therapeutic commissioning and routine IMRT quality assessment for patients (14).

Personalised treatment planning is crucial for optimising dose conformity in prostate cancer radiation, as the observed variability in GI highlights. Optimal beam configurations should be selected using a sophisticated method that considers both the collimator angle and the energy level, as some factors are critical. These results provide important information for doctors to consider when developing new treatments, which could improve therapeutic outcomes while reducing side effects (15).

Limitations and Future Directions: Several limitations must be recognised, including the fact that the investigated prostate cancer instances were quite particular and that bigger samples are necessary to draw strong generalisations. To further improve treatment planning, future studies should investigate the processes that underlie the observed differences, which may include looking into sophisticated optimisation techniques.

Ultimately, the complex relationship between beam alignment, collimator angle, and energy level is better understood after a thorough investigation of the Gradient Index in various cases. The findings of this study add to the continuing discussion on optimising radiation therapy, which should lead to better treatment plans specific to each patient.

Conclusion

In conclusion, Phase three treatment with 6 MV energy at a 90° collimator angle and 10 MV energy at a 0° collimator angle shows the most significant differences in mean dose values across the varied numbers of beams (5, 7, and 9 beams) and collimator angles (0° and 90°). For rectum dose, the study shows that for 6 MV and 10 MV energies, there are statistically significant differences in the dose delivery across various beam configurations (5, 7, and 9 beams) and collimator angles (0° and 90°). The results highlight the need to carefully consider treatment parameters when planning radiation since they subtly influence dose distribution. There is a significant variation in the gradient index (GI) among different beam configurations (5, 7, and 9 beams) and collimator angles (0° and 90°) for both 6 MV and 10 MV energy levels in prostate cancer radiotherapy. The observed differences underscore the critical impact of treatment parameters on dose conformity, providing valuable insights for optimising radiotherapy protocols.

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