RESEARCH ARTICLE

Assessment of prostate cancer radiotherapy using three-dimensional treatment planning technique

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Abstract

Objective: To assess the available commercial treatment planning system using three-dimensional conformal radiation therapy with respect to treatment for prostate cancer patients.

Method: This is a cross-sectional study was conducted from June 2021 to February 2022 at the Baghdad Centre for Radiation Therapy and Nuclear Medicine, Baghdad, Iraq, and comprised patients with prostate cancer who were treated with 6MV or 10MV energy using three-dimensional conformal radiation therapy technique, and irradiated using a linear accelerator. The patents were divided into three treatment phases. The prescribed dose in Phase I was 5000 centigrade, in Phase II it was 1800 centigrade, and in Phase III it was 600 centigrade. The number of beams used was 5 and 7. Data was analysed using SPSS 24.

Results: Out of 35 patients, 10 (28.6%) in phase I, 15 (42.8%) in phase II, and 10 (28.6%) in phase III. The PTV dose of 5 and 7 beams 6MV energy at the centre was higher than at 1mm, 2mm, and 3mm p values = (0.351, 0.013*, 0.076, 0.295), respectively. Dose to the rectum comparing 6MV and 10MV for beams 5, and 7. The dose to the rectum on phase one at 6MV and 10MV was similar for 5 beams (p=0.611) and 7 beams (p=0.778). A significant difference was seen for 7 beams (p-value=0.008). Phase three showed significant variations in rectum dose at 6 MV and 10MV for 5 beams (p=0.0004). For bladder, a significant difference observed between the energies for 5 beams on phase one and three (p-value=<0.00001*, 0.002*), while at 7 beams only phase 3 were significant (p-value=0.041*)

Conclusion: The three-dimensional conformal radiation therapy plan with 10MV energy and a higher number of beams gave a higher coverage of dose for prostate tumours and was found to be a safe dose for the rectum and bladder.

Key Words: Nuclear Medicine, Rectum, Urinary Bladder, Prostatic Neoplasms, Particle Accelerators, Tumour, Radiotherapy.

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Introduction

There are various prostate cancer therapies available, with treatment choices depending on the stage of cancer and the presence of other medical issues. The initial tumour can be eliminated with radiotherapy or surgery, which are the two most common treatments. If prostate cancer is diagnosed and treated in its early stages, it has a good chance of being cured.[1,2] Radiotherapy is one of the most successful options for cancer treatment.[3,4] It is currently going through a period of fast-paced transformation. The tremendous advancements in computer technology have been the driving force behind this transformation. With the development of novel treatment planning and delivery techniques, the field of radiation has made considerable strides forward.[4-6]

Radiation therapy (RT) has been used to treat cancer patients for palliative and curative purposes. In curative RT, the primary goal is for the radiation to be delivered at a high enough dose to inhibit tumour growth while minimising radiation exposure to healthy tissues in the vicinity of the tumour.[7,8]

Clinical data indicates that increasing the tumour dosage enhances tumour control in many circumstances. This is especially true for prostate cancer.[9,10] The most significant obstacles to reaching this objective are the difficulties associated with tumour volume delineation, reducing the consequences of mistakes, and the constraints of the dosage delivery system. This restricts the amount of tumour dosage that may be provided and delivered to the patient safely. Treatment planning is now defined and assessed only in terms of physical dosage and volume, with no consideration for other factors.[11]

The aim of current study was planned to assess the available commercial treatment planning system using

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three-dimensional conformal radiation therapy (3D-CRT) with respect to treatment for prostate cancer patients.

Patients and Methods

This cross-sectional study was conducted from June 2021 to February 2022 at the Baghdad Centre for Radiation Therapy and Nuclear Medicine, Baghdad, Iraq. After approval from the ethics review committee of the College of Medicine, Mustansiriyah University, Baghdad, the sample was raised using a convenience sampling technique. The study included 35 patients with prostate cancer. The exclusion criteria are patients with metastatic cancer, patients under age of 18 years, and those who had received previous radiotherapy. After taking written informed consent, the patients were treated with 6MV or 10MV energy using 3D-CRT through the XiO treatment planning system (Elekta, Sweden), and irradiated using a synergy linear accelerator (Linac, Elekta, Sweden).

The radiation oncologist delineated the tumour and organs at risk (OARs). Afterwards, the planned target volume (PTV) was determined and repeated 4 times to use different parameters. The patents were divided into three treatment phases. The prescribed dose in Phase I was 5000 centigrade (cGy), in Phase II it was 1800cGy, and in Phase III it was 600cGy. The number of beams used was 5-7. The collimator angle was set at 00. To ensure that the dose after the PTV margin was decreased and did not affect the normal tissue, a radiation oncologist drew 3 additional PTVs at 1mm, 2mm and 3mm from the original PTV.

Data was analysed using SPSS 24. Data was expressed as mean and standard deviation values. P<0.05 was considered significant.[12]

Results

Of the 35 patients, 10(28.6%) were in phase I, 15(42.8%) in phase II and 10(28.6%) in phase III of treatment (Table 1). The PTV dose of 6MV energy at the centre (5 beams:

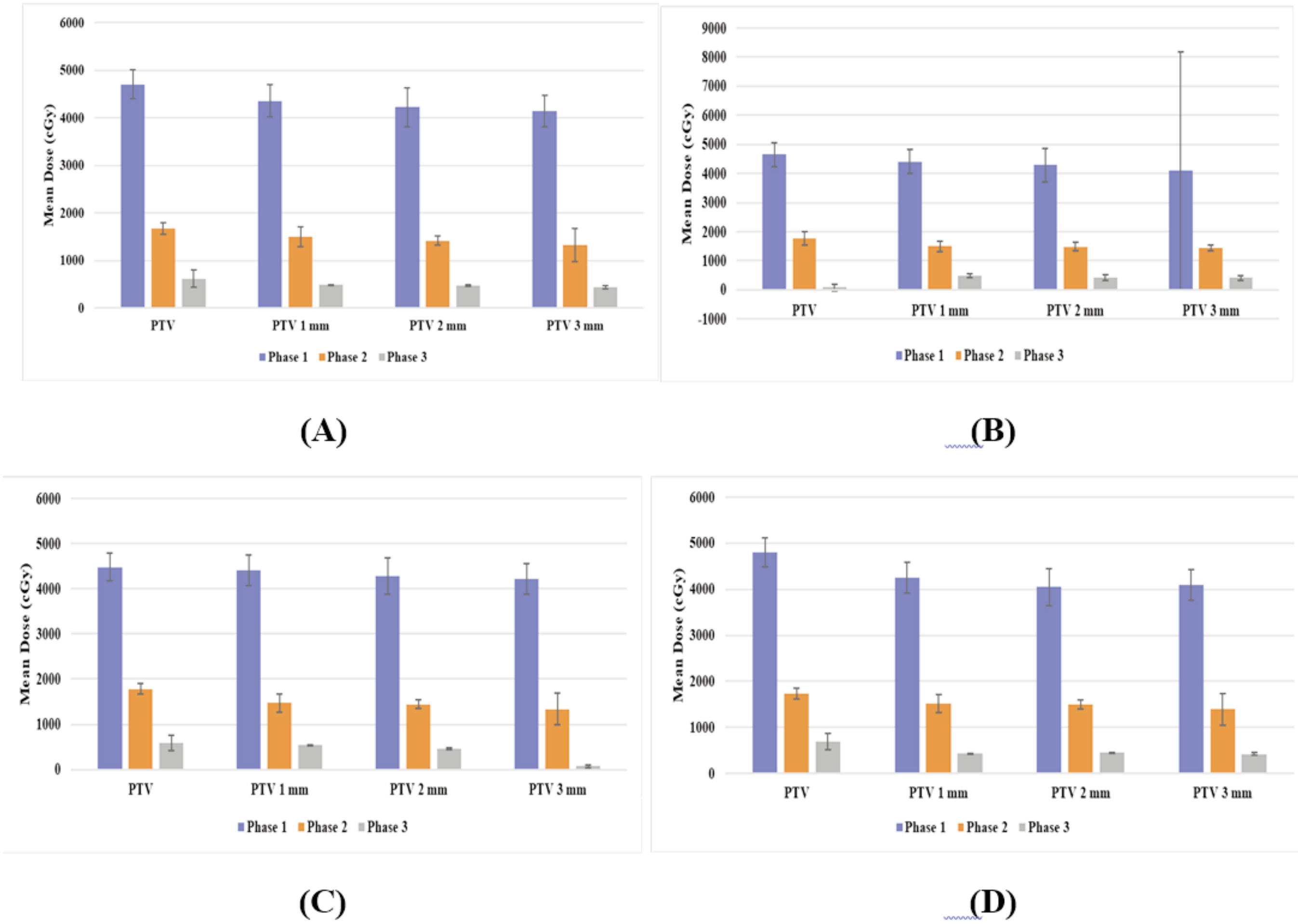

Figure-1: Dose coverage for three phases using (A) 5 beams at 6MV energy, (B) 5 beams at 10MV energy, (C) 7 beams at 6MV energy, and (D) 7 beams at 10MV energy.

619.1±177.6 cGy, 7 beams: 587.2±102.0 cGy) was always higher than the PTV dose at 1mm (5 beams: 485.2±9.3 cGy, 7 beams: 544.5±122.8), 2mm (5 beams: 478.8±16.8 cGy, 7 beams: 460.3±25.1 cGy) and 3mm away (5 beams: 439.9±31.5 cGy, 7 beams: 472±67.1 cGy), p values = (0.351, 0.013*, 0.076, 0.295), respectively. It was shown that the PTV dose of 10 MV energy at the centre (5 beams: 566.7±115.5 cGy, 7 beams: 693.1±140.2 cGy) was also higher than the PTV dose at 1mm (5 beams: 485.5±73.8 cGy, 7 beams: 427.4±57.8 cGy), 2mm (5 beams: 423.3±99.3 cGy, 7 beams: 446.9±70.7cGy) and 3mm (5 beams: 420.3±81.6 cGy, 7 beams: 425.3±82.6 cGy). It

Table: Patient groups with respect to the treatment phase.

Phase Types	No. of Patients	Prescribed Dose
Phase One	10	5000 cGy
Phase Two	15	1800 cGy
Phase Three	10	600 cGy
Total	35	7400 cGy

was noticed that the PTV dose at 2 mm with 7 beams showed a highest value.

The mean dose for patients in phase 1 treatment was much higher than in phases 2 and 3 for beams of 5 and 7, especially the mean PTV dose for phase 3 was shallow (Figure 1). Energy 10MV showed a higher value than the 6MV plan for target coverage.

The mean dose in cGy of rectum and bladder are measured as organs at risks (OARs) in this study (Figure 2). The lower dose to the rectum means that this technique is better. The dose reached to the rectum using a comparison between the energies 6 MV and 10 MV at 00 collimator angle are presented in shown in Figure 2 for the 5, and 7 beams, respectively. No significant difference was found between the dose reached to the rectum on phase one at energy of 6MV and 10 MV (3665.9±926.7179 vs 3363.222±1071.335, p -value = 0.611) for 5 beams, and for the 7 beams 3306 ± 942.4 vs 2944.1 ±1184.7, p -value

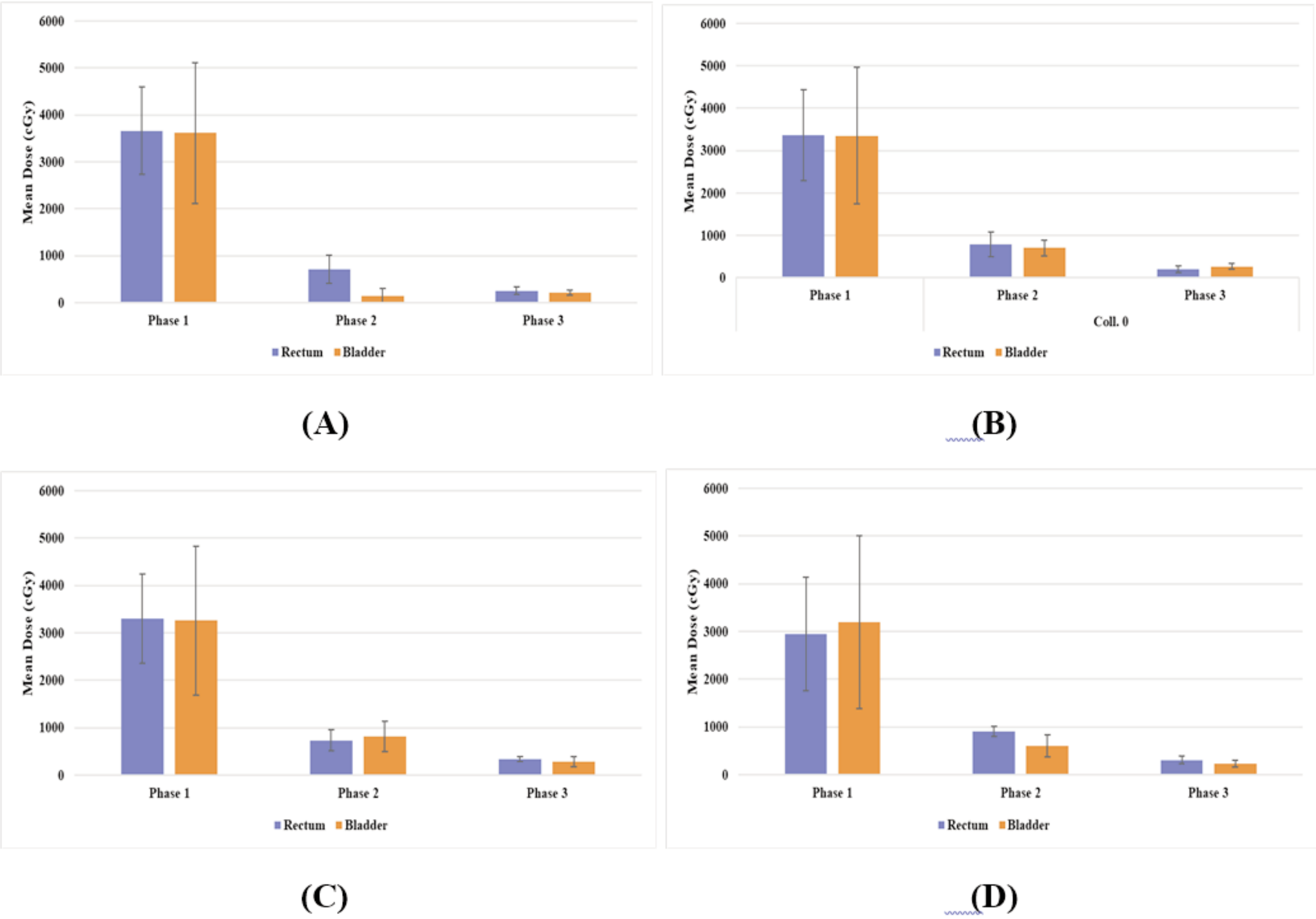

Figure-2: The organs at risks for the three treatment phases using (A) 5 beams at 6MV energy, (B) 5 beams at 10MV energy, (C) 7 beams at 6MV energy, and (D) 7 beams at 10MV energy.

= 0.778). For phase two no significant difference between the 6MV and 10 MV was observed for 5 beams with 715.5333±300.641 vs 788.4667±285.5471, p-value = 0.357, while a highly significant difference between 6 MV and 10 MV was notices at 7 beams 734.2 ± 225.1, 910.1 ± 102.4, p – value = 0.008*. In phase three, highly significant differences occurred between the dose reached to the rectum at energy 6 MV and 10 MV for 5 beams 254.3±80.00979 vs 201.9±83.93178, p – value = 0.0004*. while no significant difference was shown in 7 beams 343.2 ± 50.9, 310.3 ± 87.5, p – value 0.279.

For bladder, a significant difference observed between the energies for 5 beams on phase one and three (p-value=<0.00001*, 0.002*), while at 7 beams only phase 3 were significant (p-value=0.041*).

Phase one in results shows higher mean dose values than phases 2 and 3. It was noticed that the energy 10 MV gives a lower dose to the organs at risk (OARs), such as the bladder and rectum. It was shown that when the number of beams was increased to 7, better dose distribution was noticed.

Discussion

The planner must determine 3D-CRT criteria to continue with the planning process. The quantity of beams and position angles are essential for the target volume and sensitive structures. For these objectives, modern treatment planning systems are equipped with particular tools. If the isocentre is placed in the centre of the PTV, the location of the isocentre may be automatically determined. In some instances, the form of each beam may be determined automatically in the tumour margin set by the user. The collimator angle is always set to a value of 0°. A study[13] noticed that when angles are other than 00, the number of beams should be chosen carefully for prostate treatment planning depending on the patient's body shape and tissue inhomogeneity.

The use of 10MV energy planning showed a higher dose coverage for the tumour than the 6MV energy when using 5 and 7 beams in the current study. The higher energy shows a higher dose of penetration and distribution.[14] Lower dose coverage was achieved when 7 beams were applied at 6MV energy rather than 5 beams. The use of 10MV energy resulted in a lower dose to the rectum and bladder than 6MV. The lower mean dose in the four plans was when 7 beams were selected with 10MV energy.

Gizynska et al. investigated the beam effect and reported that challenging and vague cases were found with patients who had the body form acting as a significant compliment. Planning and optimisation affect the suboptimal dosage specification for typical patient cases.[15]

The current study found that the optimal beam can be worked out relatively quickly using a trial-and-error procedure.

Oldman et al. presented an optimisation approach that provided the opportunity to build a 3D-CRT plan with non-uniform dose distribution within the target volume that contributed to a reduced dose in the rectum volume.[16]

Limitation: The current study did not calculate the sample size, which could have influenced the power of the study.

Conclusion

Using 10MV energy with a 3D-CRT planning technique along with a more significant number of beams, such as 7, provided greater treatment efficacy and dose coverage for prostate cancer tumours, and more protection for the rectum and bladder.

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Conflict of Interest: None.

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References

1. Radiation Therapy Oncology Group (RTOG). RTOG Foundation Publications Guidelines. [Online] 2015 [Cited 2021 May 29]. Available from URL: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.rtog.org/-/media/RTOG/Files/RTOG-Foundation-Publication-Guidelines.pdf
2. Woolley D, Woolley A. Introduction to Toxicology. In: A Guide to Practical Toxicology. 1st ed. Boca Raton, FL: CRC Press. 2008: pp 1-35
3. Al Alani EA, Al Musawi MS, Mahdi AH. Influence of vitamin C on irradiated mice tissues induced DNA double strand breaks DSB using gH2AX marker. J Pak Med Assoc 2021;71(Suppl 8):s117-22.
4. Madlool SA, Abdullah SS, Alabedi HH, Alazawy N, Al-Musawi MJ, Saad D, et al. Optimum Treatment Planning Technique Evaluation For Synchronous Bilateral Breast Cancer With Left Side Supraclavicular Lymph Nodes. Iranian Journal of Medical Physics (IJMP) 2021;18: 414-42. doi: 10.22038/IJMP.2020.49211.1791
5. Alani EA, Almusawi MS, Mahdi AH. Evaluation the role of vitamin C as a radiation protective agent using γ -H2AX for signaling of DNA damage on irradiated mice testis. Period Tche Quim 2020;17:128-39.
6. Gibbons JP. Khan's The Physics of Radiation Therapy, 6th ed. In: Gibbons JP, Dernoski N, McGuire S, Murphy D, eds. New Delhi, India: Wolters Kluwer Pvt. Ltd, 2019: pp 1-570.
7. Sami S, Hameed BS, Alazawy NM, Al-Musawi MJ. Measurements of Electron Beam Dose Distributions in Perspex Block for Different Field Size. J Phys Conf Ser 2021;1829:012025. DOI 10.1088/1742-6596/1829/1/012025.
8. Alwakeel AF, Al Musawi MS, Alabedi HH, Mohammed HJ. Dosimetric assessment of IMRT treatment planning for unilateral

breast cancer patient using Octavius phantom detector. Appl Nanosci 2021;13:549. Doi: doi: 10.1007/s13204-021-01836-1
9. Al-Mamgani A, van Putten WL, Heemsbergen WD, van Leenders GJ, Slot A, Dielwart MF, et al. Update of Dutch multicenter dose-escalation trial of radiotherapy for localized prostate cancer. Int J Radiat Oncol Biol Phys 2008;72:980-8. doi: 10.1016/j.ijrobp.2008.02.073.
10. Pollack A, Zagars GK, Starkschall G, Antolak JA, Lee JJ, Huang E, et al. Prostate cancer radiation dose response: results of the M. D. Anderson phase III randomized trial. Int J Radiat Oncol Biol Phys 2002;53:1097-105. doi: 10.1016/s0360-3016(02)02829-8.
11. Khan FM. Khan's Treatment Planning in Radiation Oncology, 4th ed. In: Khan FM, Gibbons JP, Sperduto PW, eds. Philadelphia, Pennsylvania: Wolters Kluwer, 2016; pp 547.
12. Moore DS, McCabe GP, Craig BA. Introduction to the practice of statistics, 9th ed. New York, US: W.H. Freeman, Macmillan Learning, 2017; pp 20-35.
13. Dai J, Zhu Y. Selecting beam weight and wedge filter on the basis of dose gradient analysis. Med Phys 2000;27:1746-52. doi: 10.1118/1.1286591.
14. Khandpur RS. Handbook of Biomedical Instrumentation, 3rd ed. New Delhi, India: McGraw Hill Education, 2014.
15. Giżyńska MK, Kukołowicz PF, Kordowski P. Implementation of a dose gradient method into optimization of dose distribution in prostate cancer 3D-CRT plans. Rep Pract Oncol Radiother 2014;19:385-91. doi: 10.1016/j.rpor.2014.04.007.
16. Oldham M, Neal AJ, Webb S. The optimisation of wedge filters in radiotherapy of the prostate. Radiother Oncol 1995;37:209-20. doi: 10.1016/0167-8140(95)01650-3.