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Mean Radiation Dose of Rectum in Clinically Localized Prostate Cancer Patients Treated with Moderate Hypofractionated Radiotherapy

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ABSTRACT

Background: Globally, prostate cancer is among the most common cancers affecting men. While external beam radiation therapy (EBRT) is essential for its management, radiation exposure to adjacent organs, including the rectum, may lead to gastrointestinal toxicity. This study aimed to ascertain the average radiation dose to the rectum in patients with moderately hypo-fractionated radiation therapy for clinically localized prostate cancer.

Methods: Between June and August of 2025, a cross-sectional study was carried out at the INMOL Hospital's Department of Radiotherapy in Lahore. There were 55 male patients with histologically confirmed localized prostate adenocarcinoma (T1c–T3a N0 M0) who were between the ages of 40 and 80. All were given 60 Gray (Gy) in 20 fractions (3 Gy per fraction) via Intensity-Modulated Radiation Therapy (IMRT). The dose-volume histograms (DVHs) were used to extract the rectal dosimetric parameters. Chi-square and t-tests were used (p-value <0.05) via SPSS v26.0.

Results: The patients were primarily elderly, with a mean age of 68.4 ± 8.7 years. Within the recommended tolerance limits, the average rectal dose was 29.2 ± 3.6 Gy, indicating consistent treatment delivery. The correlation between age and mean rectal dose was weak and statistically non-significant ($r = 0.18$, $p = 0.12$), but there was a significant relationship between tumor grade and clinical stage ($\chi^2 = 9.12$, $p = 0.037$, Cramer's $V = 0.29$).

Conclusion: Consistent rectal dose limitation was accomplished by moderately hypo-fractionated IMRT without reducing disease coverage.

Keywords: Radiotherapy, Rectum, Radiation Dosage, Dose-Response Relationship, Cross-Sectional Studies.

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INTRODUCTION

One of the most prevalent cancers in men worldwide, prostate cancer contributes significantly to the morbidity and mortality associated with cancer [1]. Around 1.4 million new cases and more than 375,000 deaths were reported worldwide in 2020, according to the World Health Organization [2].

Geographically, the incidence varies; Western nations have higher rates, whereas South and East Asia have comparatively lower rates. Prostate cancer is estimated to affect 5.2% of men in Pakistan [3]. Its development is influenced by a number of aspects, such as advanced age, family history, genetic predisposition, and environmental factors [4].

Elevated serum PSA levels, digital rectal examination (DRE), and transrectal ultrasound-guided biopsy (TRUS) are the main methods used to establish the diagnosis[5]. The treatment options for localized prostate cancer are brachytherapy, EBRT, and surgery [6]. External beam radiation therapy (EBRT) remains a cornerstone treatment, especially with the development of IMRT and imageguided radiation therapy (IGRT), which enable accurate dose delivery to the prostate while preserving nearby organs like the bladder and rectum [7].

Given radiobiological evidence that prostate cancer has a low α/β ratio, moderate hypo-fractionated radiation therapy-which delivers higher doses per fraction over a shorter total treatment duration, has become increasingly popular [8]. However, because of its close proximity to the prostate, the rectum remains a dose-limiting organ at risk despite its therapeutic benefit [9]. In order to reduce the risk of radiation-induced proctitis and other gastrointestinal toxicities, it is imperative to minimize the dose of radiation administered to the rectal area [10].

This study aimed to ascertain the mean radiation dose received by the rectum in patients with clinically localized prostate cancer treated with moderate hypofractionated radiotherapy.

METHODS

This cross-sectional study was conducted from June to August 2025 at the Department of Oncology, Institute of Nuclear Medicine and Oncology (INMOL), Lahore Ref: IRM# INMOL -53-(020) with CPSP approval (Ref no: CPSP/REU/RTH-2022-063-241). The purpose of the study was to calculate the average rectal radiation dose for patients receiving moderate hypofractionated radiation therapy for clinically localized prostate cancer. The total study duration was three months.

Using OpenEpi version 3.0.0 (Atlanta, GA, USA), a sample size of 55 patients was estimated at a

95% confidence level and 10% margin of error 11, considering an expected mean rectal dose of 32.96 ± 3.77 Gy based on previous data. The method used was a non-probability consecutive sampling technique. Male patients with biopsy-proven prostate adenocarcinoma between the ages of 40 and 80 who had been diagnosed with clinically localized prostate cancer (T1c–T3a N0 M0), PSA < 30 ng/mL, Gleason score ≤ 8, and ECOG performance status 0–1 were included. Patients who had undergone androgen suppression treatment, pelvic irradiation, prostatectomy, bladder cancer, transurethral resection of bladder tumor, other cancers, or who declined to participate were not included in the study.

All participants received a thorough history and physical examination, including a digital rectal examination (DRE), following the acquisition of their informed written consent. The baseline tests included PSA levels, echocardiography (ECHO), ECG, RFTs, LFTs, and CBC. MRI of the pelvis, CT scans of the chest and abdomen, and a bone scan to exclude out distant metastases were all part of the imaging work-up. Radiotherapy planning was done using CT simulation. The Eclipse Treatment Planning System (Varian Medical Systems, USA) was utilized to create treatment plans. As the clinical target volume (CTV), the prostate gland and 1 cm of the proximal seminal vesicles were shaped. In order to account for setup variability, a planning target volume (PTV) was created by expanding 0.8 cm circumferentially and 0.6 cm posteriorly around the CTV. During a four-week period, all patients received intensity-modulated radiation therapy (IMRT), which delivered 60 Gy in 20 fractions (3 Gy per fraction). In accordance with RTOG contouring guidelines, the rectum was contoured. Rectal dosimetric parameters, such as mean rectal dose (Dmean), were extracted using dose–volume histograms (DVHs). A pre-prepared proforma was used to record all data while protecting patient privacy.

SPSS version 26.0 was used for statistical analysis. Frequencies and percentages were used to display qualitative variables, such as tumor grade and clinical stage. Pearson's correlation coefficient (r) was used to analyze correlations between continuous variables, and the Chi-square test to evaluate associations between categorical variables (p-value < 0.05).

RESULTS

The study comprised 55 male patients with clinically localized prostate cancer (T1c–T3a N0 M0). The population was primarily older people, as evidenced by the mean age of 68.4 ± 8.7 years. The

average rectal dose during moderate hypofractionated IMRT was 29.2 ± 3.6 Gy, indicating that patients received treatment consistently. The **Table 1** shows population Characteristics.

Table 1: Baseline Characteristics and Descriptive Statistics (n = 55)

Variable	n (%)	Mean ± SD	95% CI (Lower–Upper)	Minimum	Maximum
Age (y) 50–59	8 (14.5)	68.4 ± 8.7	66.0 – 70.8	54	88
Age (y) 60–69	22 (40.0)				
Age (y) ≥70	25 (45.5)				
PSA (ng/mL)	55 (100)	14.1 ± 6.2	12.4 – 15.8	5.3	28.7
Rectal Dose (Gy)	55 (100)	29.2 ± 3.6	28.3 – 30.1	20.0	33.0

*PSA: Prostate-Specific Antigen, Gy: Gray (SI unit of absorbed radiation dose**), y:years***

According to the epidemiologic pattern of prostate cancer in older men, the majority of patients (n= 25, 45.5%) were over 70 years old. The narrow confidence interval (CI) for the mean rectal dose (28.3–30.1 Gy) indicates consistent treatment planning and compliance with rectal dose limitations when using standardized IMRT delivery. To determine whether histopathologic aggressiveness correlated with disease progression, the relationship between tumor grade and clinical stage was evaluated and presented in **Table 2**.

Table 2: Association between Tumor Grade and Clinical Stage

Tumor Grade	Stage I n (%)	Stage II n (%)	Stage III n (%)	Total n (%)	p-value
Grade 1	1 (1.8)	1 (1.8)	2 (3.6)	4 (7.3)	0.037
Grade 2	2 (3.6)	10 (18.2)	11 (20.0)	23 (41.8)	
Grade 3	1 (1.8)	6 (10.9)	9 (16.4)	16 (29.1)	
Grade 4	0 (0)	2 (3.6)	5 (9.1)	7 (12.7)	
Undefined / Not determined	0 (0)	3 (5.5)	2 (3.6)	5 (9.1)	
Total n (%)	**4 (7.3)**	**22 (40.0)**	**29 (52.7)**	**55 (100)**	

Tumor grade and clinical stage were found to be significantly correlated with chi-square test (p = 0.037,). In Stage III disease, higher grades (Grades 3–4) were more frequently observed, indicating that histopathologic differentiation follows clinical development. A correlation analysis between age and mean rectal dose was performed to ascertain whether patient age affected rectal dosimetry are presented in **Table 3**.

Table 3: Correlation between Age and Mean Rectal Dose

Variables	Mean ± SD	r (Pearson)	95% CI (Lower–Upper)	p-value	Interpretation
Age (years)	68.4 ± 8.7	**0.18**	−0.05 – 0.39	**0.12**	Weak, non-significant correlation
Rectal Dose (Gy)	29.2 ± 3.6				

The mean rectal dose and age showed a weak, positive, but non-significant correlation (r = 0.18, p = 0.12). There was no significant linear relationship between increasing age and rectal dose exposure, as indicated by the confidence interval (−0.05–0.39) crossing zero. Therefore, in this cohort, patient age had no discernible impact on dosimetric outcomes.

DISCUSSION

In this study, rectal dosimetry was assessed in patients receiving moderate hypofractionated IMRT for clinically localized prostate cancer. The average rectal dose of 29.2 ± 3.6 Gy showed consistent planning and exact adherence to dose restrictions. Prostate cancer is typically found in older men, as indicated by the mean age of 68.4 ± 8.7 years. While age did not significantly affect rectal dose, a statistically significant correlation between tumor grade and stage (p = 0.037) demonstrated that histopathologic aggressiveness followed disease progression [12].

The average rectal dose for this cohort is similar to that reported in other recent studies using comparable moderate hypofractionation regimens (60 Gy in 20 fractions) [13]. Numerous trials and institutional audits have indicated that the average rectal doses fall within 28–31 Gy, thereby validating a uniform dose administration across various centers [14]. Research employing IMRT and IGRT methods has shown significant decreases in rectal dose exposure compared to 3D-CRT, corroborating the dosimetric benefits reported here. A recent prospective analysis had confirmed that

modern IMRT with daily cone-beam CT achieved mean rectal doses of less than 30 Gy in over 90% of patients [15,16]. Collectively, these findings bolster the stability and reproducibility of rectal sparing that can be achieved through standardized moderate hypofractionation protocols [17].

The correlation between tumor grade and clinical stage that has been observed is consistent with previous histopathologic evidence that suggests advanced T-stage disease is more common in highergrade tumors (Gleason ≥ 7) [18]. According to recent registry-based analyses, the percentage of highgrade cancers in Stage III has gone up, especially in developing countries, as a result of delayed diagnosis and restricted access to screening [19]. A multicenter Asian cohort showed similar patterns, highlighting the necessity of improved early detection and stratified treatment planning [20]. This helps improve treatment personalization by incorporating clinical and imaging parameters into risk stratification models [21].

Similar with our findings, an analysis employing MRI-guided adaptive radiotherapy verified that rectal Dmean and V40 parameters were constant across age groups[22]. In addition, AI-assisted planning algorithms have decreased inter-observer variability in organ-at-risk delineation and increased contouring accuracy[23,24]. Together, these developments improve the consistency of treatment delivery and reduce the possibility of confounding by demographic factors.

The findings of this study are not as broadly applicable as they could be due to its single-center design and small sample size. Volumetric indices like V40 or V60 were not taken into account; only the mean rectal dose was examined, and toxicity correlations were not available. Future prospective, multicenter studies that include patient-reported outcomes, long-term toxicity monitoring, and thorough DVH analysis are advised. Hydrogel spacers, AI-based optimization tools, and adaptive planning could all be used to improve treatment safety and organ preservation[25]. Radiotherapy paradigms for prostate cancer will become safer and more customized as a result of ongoing improvements to these techniques.

CONCLUSION

This study showed that age had no effect on rectal dosimetry, as evidenced by the weak, nonsignificant correlation between patient age and mean rectal dose during moderate hypofractionated IMRT for localized prostate cancer. Precise adherence to image-guided protocols and planning constraints is evident in the consistent treatment delivery and limited dose variability. According to these results, hypofractionated IMRT can be safely used in older adults without

requiring dose modifications based on age. Further multicentric studies that combine radiomic profiling and longterm toxicity are necessary to confirm these results and improve tailored treatment optimization for patients.

LIST OF ABBREVIATIONS

None

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CONFLICT OF INTEREST

None

ETHICAL APPROVAL

This cross-sectional study was conducted from June to August 2025 at the Department of Oncology, Institute of Nuclear Medicine and Oncology (INMOL), Lahore Ref: IRM# INMOL -53-(020) with CPSP approval (Ref no: CPSP/REU/RTH-2022-063-241)**.**

AUTHORS' CONTRIBUTION

All authors have equal contributions as per ICMJE.

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The Ziauddin University is on the list of I4OA, I4OC, and JISC.

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