Original Article

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Impact of Radiotherapy on Electrolyte and Hematological Parameters in Prostate Cancer: Curative vs. Palliative Groups

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ABSTRACT

Background: Prostate cancer is one of the most common cancers in men, with radiotherapy being a key treatment modality. However, radiotherapy often leads to hematological and electrolyte imbalances, adversely impacting patient outcomes.

Objective: To assess the impact of radiotherapy on electrolyte levels (sodium, potassium, calcium, magnesium, phosphate, and chloride) and hematological parameters (leukocyte, erythrocyte, hemoglobin, hematocrit, and platelets) in prostate cancer patients. The study also compares these effects between curative and palliative treatment groups.

Patients and Methods: Twenty prostate cancer patients were included in the study, divided into curative (n=10) and palliative (n=10) groups. Blood samples were collected before and after radiotherapy, they were analyzed using the Swelab Alpha analyzer, while electrolyte levels were measured with Jokoh Ex-DS and Roche Integra 400 Plus analyzers. Patients received 3DCRT and VMAT.

Results: Significant differences were observed in calcium ($p = 0.018$) and phosphate ($p = 0.005$) levels, with higher values in the curative group. Other electrolytes (magnesium, sodium, potassium, and chloride) showed no significant changes. Hematological analysis revealed a significant decrease in white blood cells and hemoglobin in the curative group, indicating bone marrow suppression. In contrast, the palliative group demonstrated stable white blood cell levels and increased platelet counts post-treatment.

Conclusion: Radiotherapy affects biochemical and hematological parameters differently in curative and palliative settings. Personalized monitoring of these parameters is essential to mitigate complications and improve patient outcomes.

Keywords: Prostate cancer, radiotherapy, electrolytes, hematological parameters, curative treatment, palliative care

INTRODUCTION:

Cancer results from the uncontrolled growth of atypical cells, leading to the formation of solid tumors, including prostate cancer (PC) and breast cancer (BC) [1]. Prostate cancer is among the most prevalent male malignancies worldwide, after lung cancer, and is a leading cause of cancer mortality [2,3]. Treatment decisions can be made based on tumor stage, performance status, and histopathological features. Radiotherapy is used as a key treatment component for localized or early-stage disease and is also an essential aspect of symptom control in cases of advanced disease [4,6].

External beam radiation therapy (EBRT), in which high-intensity ionizing radiation is steered to the site of the tumor, is commonly used in modern oncology. During the last two or more decades, External Beam Radiation Therapy (EBRT) approaches have also evolved, including techniques such as three-dimensional conformal radiation therapy (3DCRT), intensity-modulated radiation therapy (IMRT), and volumetric modulated arc therapy (VMAT), providing increased dose conformity and precision [7-9]. VMAT, which is an evolution of IMRT, uses continuous radiation delivery and can modulate gantry speed, dose rate, and segment shape, leading to more efficient treatment times and improved dose conformity [10,11]. On the other hand, 3DCRT reconstructs the three-dimensional pathological state of the tumor using CT imaging with the help of several conformal lead blocks to avoid surrounding healthy tissues [12, 13]. Both VMAT and IMRT produce steep dose gradients surrounding the target volume, allowing for lower doses to OAR and higher amounts within the tumor [13].

Although effective, radiotherapy also causes systemic effects such as changes in serum pH, electrolyte levels, and other blood parameters. Electrolytes (sodium, potassium, magnesium, calcium, and chloride) are critical for cellular activity and homeostasis, and they regulate important processes such as neurotransmission, muscle contraction, and bone matrix [14, 15]. Electrolyte imbalance can lead to altered states like hyponatremia, hypokalemia, hypercalcemia, and hypophosphatemia, which are prevalent in inpatients, especially cancer patients [16]. Cancer per se can compromise regulatory mechanisms of electrolytes as it may involve endocrine glands, influence the activity of ion channels, and alter metabolic pathways [17, 18]. Inorganic matrix components, released by advanced cancers, likely metastasize to bones to change electrolyte balance [18].

Radiotherapy is known to affect hematological parameters through destruction of rapidly dividing hematopoietic stem cells within the bone marrow, resulting in altered production of white blood cells (WBCs), red blood cells (RBCs), and platelets [19-23]. Curative radiotherapy (higher total dose) and more aggressive radiotherapy protocols have greater hematological suppression than those low-dose palliative treatments that are primarily intended for symptom relief.

To our knowledge, this is the first study to compare the electrolytes and hematological parameters among patients with prostate carcinoma undergoing curative and palliative radiotherapy. Although these effects have been examined separately in prior research, we are unaware of any studies that systematically compared these effects across treatment intents. We hypothesize that calcium and phosphate changes will be much more prominent after curative radiotherapy because the bone metabolism is affected in a higher frequency and hemoglobin and WBCs will be suppressed more due to the higher doses administered. In contrast, palliative radiotherapy can lead to stable WBC counts with compensated increase in platelet production. This study intends to elucidate these differences to optimize treatment strategies in a patient-specific context.

Materials and Methods:

This prospective study was performed from 28 October to 29 December 2024 at the Awat Radiation Oncology Center in Erbil, Iraq, a unique center specializing in advanced radiotherapy treatments. The Hawler Medical University, College of Medicine Ethics Committee reviewed and approved the protocol (Meeting code No:1, Paper code: 45, Date: September 22, 2024).

Study Population

A total of twenty prostate cancer patients were enrolled, distributed into two equal groups (curative (n = 10) and palliative treatment (n =10). A total of 173 cases of prostate cancer were selected for this study using convenience sampling based on the following inclusion criteria: (1) histopathologically confirmed prostate cancer; (2) 30–80 age range, and (3) provision of written informed consent. Exclusion criteria were concurrent chemotherapy, pre-existing metabolic, gastrointestinal, renal, cardiovascular, or hematological disorders, and inability to give consent. No formal assessment of functional status was done, but all were ambulatory and able to engage in routine clinical activities.

Data Collection

In both, a trained nurse collected 5 mL of blood from each participant, just before and following the completion of radiotherapy. For hematological analyses, 2 mL of whole blood was contained in EDTA tubes and analyzed using the Swelab Alfa Plus analyzer (Schärfe System) to obtain measurements of white blood cells (WBC), red blood cells (RBC), hemoglobin (Hb), hematocrit (HCT), and platelets (PLT). Serum was obtained by centrifuging the remaining 3 mL of blood and analyzed for electrolyte levels on the Jokoh EX-DS analyzer (sodium, potassium, chloride) and Roche Integra 400 Plus analyzer (magnesium, calcium, phosphate).

Radiotherapy Protocols

The Elekta Infinity machine was used for radiotherapy. For curative treatments, the patients were treated with 6,000 cGy (in 20 fractions) using Volumetric Modulated Arc Therapy (VMAT). Palliation utilized Three-Dimensional Conformal Radiation Therapy (3DCRT) with 2,000 cGy in 5 fractions. Techniques were optimized to avoid exposure of surrounding normal tissue, while maximizing tumor coverage.

Statistical Analysis

The data were coded and analyzed by utilizing SPSS version 29 software Descriptive statistics consisted of means and standard deviations for continuous variables and frequencies for categorical variables regarding socio-demographic and clinical characteristics. The Shapiro-Wilk test was used to analyze normality of data distribution. Changes in biochemical and hematological parameters were evaluated within each group pre and post treatment using paired t-tests and Wilcoxon signed-rank tests. We used independent t-tests or Mann-Whitney U tests for between-group comparisons, as appropriate by data distribution. Statistical significance was defined as a p-value < 0.05.

Result:

Socio-Demographic and Clinical Characteristics of Patients:

A total of 20 prostate cancer patients were included in the study, that consisted of curative (n=10) and palliative (n=10) treatment groups. The average age of the patients included in the curative group was 71.1 (SD = 4.8), while it was 59.2 (SD = 17.1) in the palliative group. All subjects were male, as was to be expected given the emphasis on prostate cancer. The vast majority of patients were based in Hawler, followed by Duhok and Karkuk, which reflects the regional spread of the population.

The curative group received VMAT, with a total dose of 6,000 cGy in 20 fractions of 300 cGy. The palliative group was undergone with Three-Dimensional Conformal Radiation Therapy (3DCRT) with final dose was 2,000 cGy in 5 fractions (400 cGy/day). (A) Blood samples were

Table 1. Descriptive Statistics Summary for Qualitative Data.

		Curative		Palliative	
		Frequency	%	Frequency	%
Gender	M	10	50.00%	10	50.00%
Address	Duhouk	1	5.00%	1	5.00%
	Hawler	9	45.00%	4	20.00%
	Karkuk	1	5.00%	0	0.00%
	Mousl	4	20.00%	0	0.00%
Diagnosis	prostate	10	50.00%	0	0.00%
	metastatic prostate cancer to bone	0	0.00%	10	50.00%
Technique/Modality	VMAT	10	50.00%	0	0.00%
	3DCRT	0	0.00%	10	50.00%
Rx Dose	2000	0	0.00%	10	50.00%
	6000	10	50.00%	0	0.00%
Fractional Dose	300	10	50.00%	0	0.00%
	400	0	0.00%	10	50.00%
No. of Fractions	5	0	0.00%	10	50.00%
	20	10	50.00%	0	0.00%

collected at baseline, (B) mid-treatment, and (C) post-treatment. Calcium (Ca), magnesium (Mg), phosphate (PO_4), sodium (Na), potassium (K), chloride (Cl), white blood cell count (WBC), red blood ceiling count (RBC), hemoglobin (Hb), hematocrit (HCT), and platelet count (PLT) were measured. Tables 1 and 2 outline the two groups' distinct features and treatment strategies, showcasing minor differences in patient demographics and biochemical measurements.

Table 2. Mean and SD by two groups of Curative and Palliative Treatment for Biochemical and Hematological Parameters.

	Curative, vmat, 6000, 300, 20		Palliative, 3dcrt, 2000, 400, 5	
	Mean	SD	Mean	SD
Age	71.1	4.8	59.2	17.1
Ca (A)	9.94	.39	9.32	.64
Mg (A)	1.94	.24	1.96	.29
PO4 (A)	3.62	.25	3.13	.41
Na (A)	135.73	1.81	136.64	2.90
K (A)	4.43	.64	4.77	.79
Cl (A)	107.42	2.62	109.29	2.71
WBC/109 (A)	8.43	2.32	6.45	2.66
RBC/1012 (A)	4.54	.56	4.25	1.28
HGB/(g/dl) (A)	13.23	1.58	11.71	2.31
HCT% (A)	37.28	4.12	34.90	7.52
PLT//103 (A)	197.80	87.16	192.20	51.76
Ca (B)	9.74	.58	---	---
Mg (B)	1.94	.21	---	---
PO4 (B)	3.91	.40	---	---
Na (B)	135.54	1.84	---	---
K (B)	4.49	.55	---	---
Cl (B)	105.77	2.64	---	---
WBC (B)	5.64	2.35	---	---
RBC (B)	4.41	.56	---	---
HGB (B)	12.04	1.61	---	---
HCT (B)	35.29	3.99	---	---
PLT (B)	193.60	61.31	---	---
Ca (C)	9.67	.76	9.15	.80
Mg (C)	1.97	.22	1.89	.33
PO4 (C)	3.40	.54	3.46	.53
Na (C)	136.07	2.21	134.95	4.09
K (C)	4.81	.99	5.07	1.12
Cl (C)	107.78	2.45	108.51	3.22
WBC (C)	4.90	1.57	5.99	2.62
RBC (C)	4.22	.55	4.09	1.32
HGB (C)	12.34	1.57	11.26	2.85
HCT (C)	35.59	4.40	33.21	8.87
PLT (C)	180.80	57.82	217.20	82.17

Rx Type (Curative, Palliative), (vmat,3dcrt), Rx Dose (6000, 2000), Fractional Dose(300, 400), No. of Fractions (20, 5)

Tests of Normality for both Curative and Palliative Treatment Groups:

The p-values obtained from the Shapiro-Wilk test determine whether the data for each parameter follows a normal distribution.

Most parameters exhibit a normal distribution (p-value > 0.05). However, in the curative group, parameters such as RBC (A), PLT (A), Ca (C), and PO4 (C) deviate from normality (p-value ≤ 0.05). In contrast, all parameters in the palliative group show a normal distribution. These findings suggest differences in the distribution patterns of certain parameters between the two groups, potentially reflecting variations in patient characteristics or treatment effects. Table (3) summarizes the results of Shapiro-Wilk tests of normality for various biochemical and hematological parameters in patients undergoing curative and palliative radiation therapy.

Table (3)| Tests of Normality for Biochemical and Hematological Parameters in Curative and Palliative Treatment Groups

Comparison of Biochemical and Hematological Parameters Between Curative and Palliative Treatment Groups:

In the acute phase, the values of Ca and PO_4 were significantly different between the curative (higher Ca and PO_4 levels) and non-curative groups ($p = 0.018$ and $p = 0.005$, respectively). Calcium levels during the chronic phase also differed significantly ($p = 0.049$). Other electrolytes such as magnesium (Mg), sodium (Na), potassium (K) and chloride (Cl) did not result in any substantial differences. A significant drop in the WBC and HGB in the curative cohort indicated the suppression of bone marrow on the hematological examination. Conversely, those in the palliative group had stable WBC counts and significantly increased platelets following treatment.

Only the curative group had mid-treatment data, as the duration of palliative treatments was too short. Conclusion: These results are consistent with the individual effects of curative and palliative protocols, stressing the necessity of constant monitoring in order to intervene for therapy-associated changes. Table (4), Figure 1 and Figure 2 presents a comparison of biochemical and hematological parameters between patients receiving curative (VMAT, 6000 cGy, 300 cGy/fraction, 20 fractions) and palliative (3DCRT, 2000 cGy, 400 cGy/fraction, 5 fractions) treatment For both stages (A=before treatment, C=after treatment).

Group-wise trends in calcium (Ca) and phosphate (PO_4) are depicted in Figure 1 (Time points: Baseline (A), Mid-treatment (B) and Post-treatment (C)). (a) Line graphs to highlight the substantial acute-phase elevations in Ca (left) and PO_4 (right) of the curative group compared to the remission group with chronic-phase elevation of Ca in the curative group.

Figure 2 compares WBC, HGB, and PLT levels between the two groups with line graphs and bar charts. For the curative group, WBC and HGB levels were significantly decreased when compared with pre-treatment levels; but no declines in WBC counts and increases in PLT levels after post-treatment were noted in the palliative group.

Clinical Implications

Some variables did show statistically significant changes, but at least not all of those changes are clinically relevant. As the curative group indicative of changed bone metabolism, it highlights the importance of regular monitoring with elevated calcium and phosphate levels. The highest declines in WBC and HGB seen in the curative group highlight the need to manage immunosuppression and anemia. On the other hand, the palliative group with increased platelet counts may reflect compensatory mechanisms after lower doses of radiotherapy.

Discussion:

This study was performed to explore the impact of radiotherapy on electrolytes and blood parameters in prostate cancer patients. In the acute phase, the palliative treatment group had significant differences in calcium (Ca) and phosphate (PO_4) concentrations compared with the curative treatment group. Potassium and chloride levels were also a bit elevated at the end of treatment in the palliative group. The results of this study offer new, valuable information on the distinct effects of curative and palliative radiotherapy on electrolyte and hematological parameters in patients diagnosed with prostate cancer. These findings also provide novel observations of interest to further investigate.

Acute phase during treatment: Substantial differences existed in Ca and PO_4 levels between the curative and palliative groups. In the work of Z Fekete et al. (2024) and JP Sequeira et al. (2024), treatment groups had significantly different levels of calcium and phosphate, consistent with those of this study [24,25].

Table 3. Tests of Normality for Biochemical and Hematological Parameters in Curative and Palliative Treatment Groups

	Rx Type	Shapiro-Wilk			Sig.
		Statistic	df	P-Value	
Ca (A)	Curative, vmat, 6000, 300, 20	.908	10	.269	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.960	10	.781	Normal Distribution
Mg (A)	Curative, vmat, 6000, 300, 20	.920	10	.356	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.985	10	.987	Normal Distribution
PO4 (A)	Curative, vmat, 6000, 300, 20	.934	10	.492	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.927	10	.423	Normal Distribution
Na (A)	Curative, vmat, 6000, 300, 20	.942	10	.572	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.907	10	.263	Normal Distribution
K (A)	Curative, vmat, 6000, 300, 20	.935	10	.500	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.890	10	.168	Normal Distribution
Cl (A)	Curative, vmat, 6000, 300, 20	.900	10	.217	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.934	10	.491	Normal Distribution
WBC/109 (A)	Curative, vmat, 6000, 300, 20	.964	10	.829	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.947	10	.630	Normal Distribution
RBC/1012 (A)	Curative, vmat, 6000, 300, 20	.798	10	.014	Not Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.929	10	.434	Normal Distribution
HGB/(g/dl) (A)	Curative, vmat, 6000, 300, 20	.930	10	.449	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.932	10	.472	Normal Distribution
HCT% (A)	Curative, vmat, 6000, 300, 20	.926	10	.406	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.897	10	.201	Normal Distribution
PLT//103 (A)	Curative, vmat, 6000, 300, 20	.819	10	.025	Not Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.922	10	.370	Normal Distribution
Ca (C)	Curative, vmat, 6000, 300, 20	.758	10	.004	Not Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.928	10	.430	Normal Distribution
Mg (C)	Curative, vmat, 6000, 300, 20	.946	10	.621	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.851	10	.060	Normal Distribution
PO4 (C)	Curative, vmat, 6000, 300, 20	.843	10	.049	Not Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.952	10	.689	Normal Distribution
Na (C)	Curative, vmat, 6000, 300, 20	.904	10	.242	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.902	10	.228	Normal Distribution
K (C)	Curative, vmat, 6000, 300, 20	.900	10	.220	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.885	10	.150	Normal Distribution
Cl (C)	Curative, vmat, 6000, 300, 20	.899	10	.214	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.890	10	.170	Normal Distribution
WBC (C)	Curative, vmat, 6000, 300, 20	.926	10	.411	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.915	10	.320	Normal Distribution
RBC (C)	Curative, vmat, 6000, 300, 20	.875	10	.115	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.925	10	.401	Normal Distribution
HGB (C)	Curative, vmat, 6000, 300, 20	.914	10	.311	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.962	10	.809	Normal Distribution
HCT (C)	Curative, vmat, 6000, 300, 20	.894	10	.188	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.937	10	.519	Normal Distribution
PLT (C)	Curative, vmat, 6000, 300, 20	.855	10	.066	Normal Distribution
	Palliative, 3dcrt, 2000, 400, 5	.915	10	.316	Normal Distribution

Table 4. Comparison of Biochemical and Hematological Parameters Between Curative and Palliative Treatment Groups

	Groups	N	Mean	SD	test Value	d.f.	P-Value
Ca (A)	Curative, vmat, 6000, 300, 20	10	9.944	0.390	2.616(†)	18	0.018 (S)
	Palliative, 3dcrt, 2000, 400, 5	10	9.325	0.639			
Mg (A)	Curative, vmat, 6000, 300, 20	10	1.941	0.239	-0.125(†)	18	0.902 (NS)
	Palliative, 3dcrt, 2000, 400, 5	10	1.956	0.293			
PO4 (A)	Curative, vmat, 6000, 300, 20	10	3.618	0.254	3.167(†)	18	0.005(HS)
	Palliative, 3dcrt, 2000, 400, 5	10	3.134	0.411			
Na (A)	Curative, vmat, 6000, 300, 20	10	135.730	1.806	-0.843(†)	18	0.411(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	136.640	2.899			
K (A)	Curative, vmat, 6000, 300, 20	10	4.435	0.640	-1.052(†)	18	0.307(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	4.772	0.786			
Cl (A)	Curative, vmat, 6000, 300, 20	10	107.420	2.615	-1.569(†)	18	0.134(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	109.290	2.714			
WBC/109 (A)	Curative, vmat, 6000, 300, 20	10	8.430	2.317	1.774(†)	18	0.093(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	6.450	2.663			
RBC/1012 (A)	Curative, vmat, 6000, 300, 20	10	4.540	0.560	40.00(↓)	18	0.450(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	4.247	1.282			
HGB/(g/dl) (A)	Curative, vmat, 6000, 300, 20	10	13.230	1.583	1.719(†)	18	0.103(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	11.710	2.305			
HCT% (A)	Curative, vmat, 6000, 300, 20	10	37.280	4.122	0.878(†)	18	0.392(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	34.900	7.518			
PLT//103 (A)	Curative, vmat, 6000, 300, 20	10	197.800	87.161	44.00(↓)	18	0.650(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	192.200	51.762			
Ca (C)	Curative, vmat, 6000, 300, 20	10	9.668	0.758	24.00(↓)	18	0.049(S)
	Palliative, 3dcrt, 2000, 400, 5	10	9.154	0.796			
Mg (C)	Curative, vmat, 6000, 300, 20	10	1.967	0.224	0.599(↓)	18	0.556(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	1.892	0.327			
PO4 (C)	Curative, vmat, 6000, 300, 20	10	3.401	0.542	48.00(↓)	18	0.880(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	3.461	0.533			
Na (C)	Curative, vmat, 6000, 300, 20	10	136.070	2.215	0.761(↓)	18	0.456(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	134.950	4.090			
K (C)	Curative, vmat, 6000, 300, 20	10	4.809	0.986	-0.558(↓)	18	0.583(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	5.072	1.116			
Cl (C)	Curative, vmat, 6000, 300, 20	10	107.780	2.453	-0.570(↓)	18	0.576(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	108.510	3.224			
WBC (C)	Curative, vmat, 6000, 300, 20	10	4.900	1.571	-1.130(↓)	18	0.273(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	5.990	2.616			
RBC (C)	Curative, vmat, 6000, 300, 20	10	4.217	0.548	0.278(↓)	18	0.784(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	4.091	1.323			
HGB (C)	Curative, vmat, 6000, 300, 20	10	12.340	1.566	1.049(†)	18	0.308(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	11.260	2.853			
HCT (C)	Curative, vmat, 6000, 300, 20	10	35.590	4.402	0.760(†)	18	0.457(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	33.210	8.871			
PLT (C)	Curative, vmat, 6000, 300, 20	10	180.800	57.815	-1.146(†)	18	0.267(NS)
	Palliative, 3dcrt, 2000, 400, 5	10	217.200	82.172			

HS: Highly Significant, S: Significant, NS: Not Significant Differences
↓: Mann-Whitney U, †: t-test for two sample independent

The elevated Ca levels reported in the curative group were most likely due to enhanced radiation-induced bone resorption resulting from the higher dose (6,000 cGy over 20 fractions) administered through VMAT [26, 27]. This result confirms previous results, which showed that high doses of radiotherapy may lead to an accentuation of the changes in bone metabolism owing to elevated serum Ca and PO_4 concentrations [28, 29]. In particular, one of the most relevant observations is that chronic-phase Ca values remained significantly elevated in the long term in the curative group, suggesting an effect of curative treatments on bone that persists for years.

Although the necessity of Ca and PO_4 monitoring in cancer patients receiving high-dose radiotherapy has been previously described [30, 31]. This study emphasizes the need for both personalized stratification of risk and regular monitoring of BMD additionally even in curative scenarios. That said, hypocalcemia has, for example, been associated with poor prognosis of advanced cancers [32], and the association of both with potentially curative treatments may point towards early bone loss being proinflammatory. Studies on prophylactic measures (e.g., bisphosphonate or denosumab) to counteract such changes are warranted [33].

In contrast, the other electrolytes—magnesium (Mg), sodium (Na), potassium (K), and chloride (Cl) were not significantly different between the two groups. Nonetheless, modest elevations in P, K, and Cl were observed in palliative at M+ post-treatment, but they likely reflect cellular or metabolic adaptation due to lower cumulative doses [34]. This finding suggests that low-dose radiotherapy mainly acts on tumor cells and does not cause systemic electrolyte disorders [10].

In the curative group, there were significant drops in WBC, HGB, and HCT through the study period. In studies by S Costa et al. The total dose SC was delivered in 5 fractions. The increased WBC & PLT counts were consistent with a recent study (2019) & (SQ Mahmood et al, 2024) on the subgroup data, consistent with the present study [29, 35]. However, in the palliative group receiving a total low 0.2 mGy <, bone marrow activity was constant & the PLT counts increased after treatment These variations reflect the variability of the effect of radiation dose on those high-irradiation-sensitive hematopoietic stem cells. The attenuation of WBC and HGB in the curative arm suggests possible immunosuppression and anemia, and the elevation of plasma platelets in the palliative group suggests some form of compensation for bone marrow suppression [36, 37].

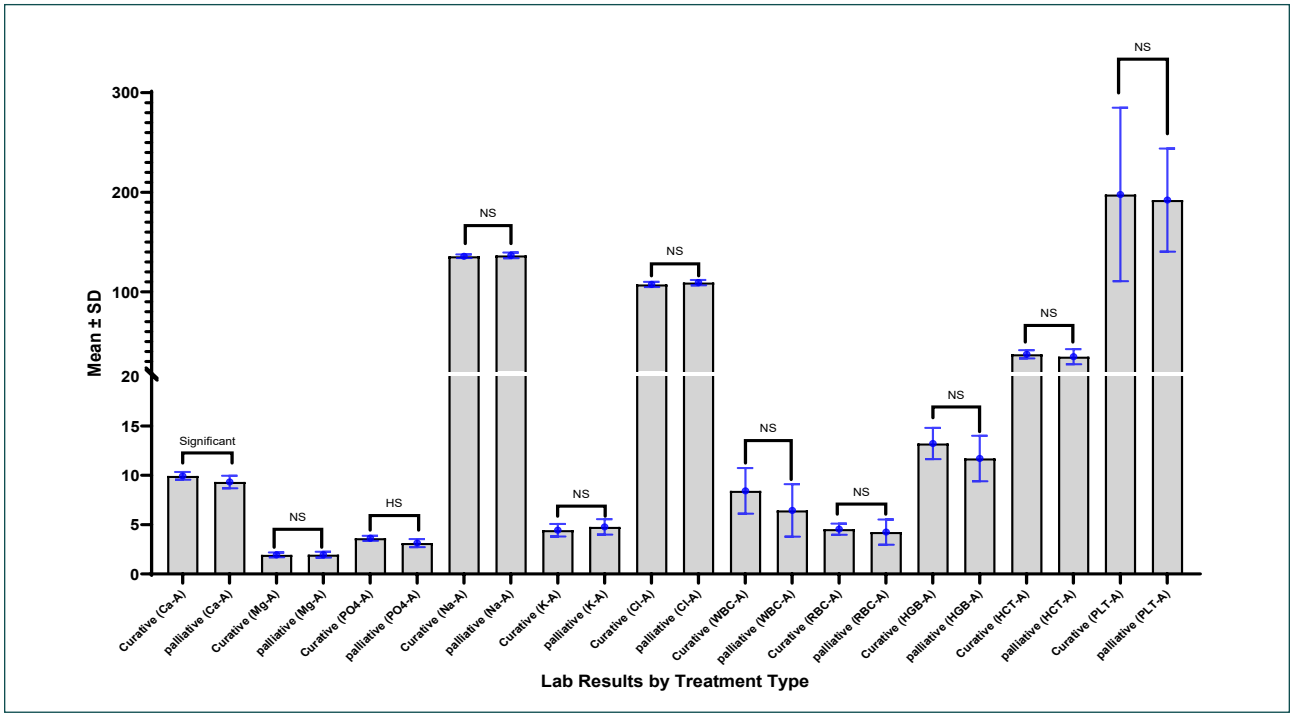

Figure 1. Comparison of Biochemical and Hematological Parameters Between Curative and Palliative Treatment Group (A)

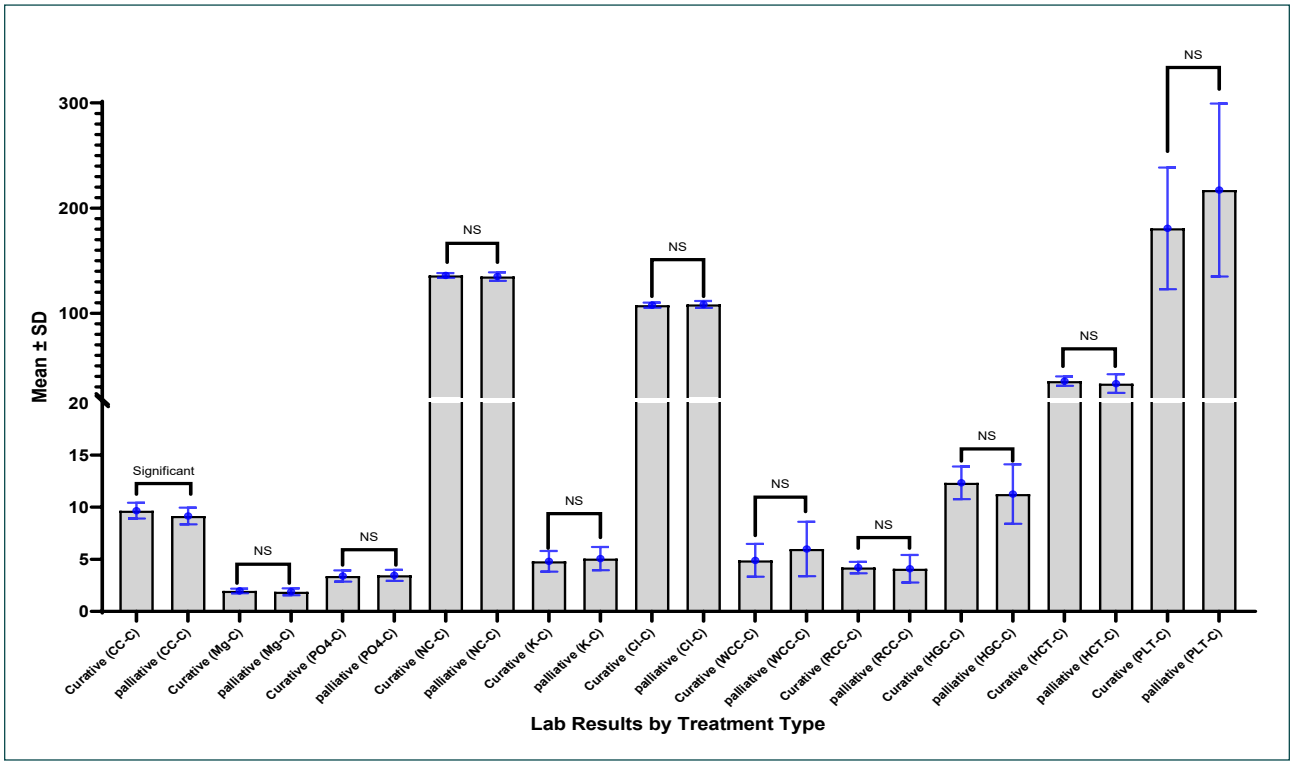

Figure 2. Comparison of Biochemical and Hematological Parameters Between Curative and Palliative Treatment Group (B).

We can observe the unique effects of curative and palliative radiotherapy on the electrolyte and hematological parameters, too. Curative radiotherapy consists of the use of higher doses of radiation in a very precise way (for instance, VMAT), which is an example of an aggressive treatment and affects even more, bone metabolism and bone marrow function [38, 39].

In contrast, palliative radiotherapy (delivered at low doses) using Three-Dimensional Conformal Radiation Therapy (3DCRT) is more aimed at symptom control, along with having a lower threshold of systemic effects [40].

This study has several important limitations despite its contributions. First, the small sample size (N=20) limits the generalizability of the findings and the ability to run powerful statistical tests. Second, since we used a convenience sample, there is an element of selection bias that can create an influence in the distributions for the parameters. Third, confounding variables including medication use, nutritional status and underlying comorbidities were not controlled for systematically, which may have an impact on electrolyte and hematological profiles. Finally, we could not obtain mid-treatment data for the palliative group (the shorter duration of that treatment), which made comparisons at intermediate time points nominal.

Future studies may overcome these limitations in using larger, randomized samples and controlling for potential confounders. Longitudinal follow-up would also improve knowledge of late effects and trajectories of recovery, in both curative and palliative settings. To enrich knowledge in this domain, future studies may center on Monitoring over time: Examining variations in electrolytic and hematological attributes over a protracted span to ensure capturing any delayed impacts; Mechanistic Insights: Exploring the molecular mechanisms of radiation-induced bone resorption and hematopoietic suppression through imaging and biomarkers; Interventional Approaches: Assessing the effectiveness of radioprotective agents (e.g., amifostine) or hyperbaric oxygen therapy to reduce side effects; Approach in Large Populations: impaneling larger cohorts to validate findings here and develop individual risk profiles.

Conclusion:

This study demonstrates the different effects of curative and palliative radiotherapy on biochemical

and hematological parameters in patients with prostate cancer. The increase in Ca and PO_4 in the curative group may reflect the effect of absorption and bone metabolism on high-dose radiation. The hematologic aberrations were predominantly WBC and HGB suppression and were significantly worse in the curative therapies, emphasizing the risk of immunosuppression and anemia. In contrast, palliative radiotherapy developed little in terms of systemic effects, and high PLT counts reflected a phenomenon of marrow compensation. These findings underscore the importance of individualized risk stratification during the entire radiotherapy process. Note: Following curative treatments of hematological malignancies, careful monitoring of both BMD and hematological values in this population is needed to minimize the risk of anemia and osteoporosis. Conversely, the focus of palliative treatment should be on the management of electrolyte disturbances and the prevention of thromboembolic complications. Larger studies over larger patient cohorts and with longer follow-up times are required to not just identify the full impact of radiotherapy but also to help derive improved patient pathway care algorithms.

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