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Radiotherapy In A Patient With Rectal Cancer and Pelvic Kidney: A Dosimetric Study

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ABSTRACT

Pelvic kidney is an important treatment challenge in pelvic malignancies. This study investigated the most appropriate treatment in the presence of simultaneous pelvic kidney in patients with rectal cancer.

This study used computed tomography images of postoperative radiotherapy planning in a male patient with rectal cancer. Coplanar intensity-modulated, non-coplanar intensity-modulated, and volumetric-modulated arc radiotherapy rectal cancer planning was performed with six different scenarios based on tumor location and lymph node status; a dosimetric comparison was then performed.

In a patient with rectal cancer and pelvic kidney, where the external iliac lymph nodes were not included in the radiation field, it was determined that, regardless of rectal tumor localization, optimal ≤45 Gy radiotherapy planning could only be performed with the volumetric-modulated arc therapy technique. In the same scenario, optimal ≤50.4 Gy radiotherapy planning could only be performed in a distally localized rectal tumor and with the volumetric-modulated arc therapy technique. In contrast, when the external iliac lymph nodes were included in the radiation field for the same patient, regardless of rectal tumor localization, no radiotherapy technique ≤45 Gy could protect the pelvic kidney.

In patients with locally advanced rectal cancer and pelvic kidney, oncologic treatment (either radiotherapy first or surgery first) should be decided based on the available radiotherapy technique, lymph node status of rectal cancer, and tumor localization.

Key Words: Pelvic kidney, radiotherapy, rectal cancer

Introduction

Colorectal cancers are the fourth most common type of cancer worldwide, and one-third of them are rectal cancer. The mainstay treatment for rectal cancer is surgery. However, radiotherapy (RT) is applied to patients with American Joint Committee on Cancer stages II (T3-4N0M0) and III (T1-4N1-2M0) rectal cancer, pre- or postoperatively and with or without concurrent chemotherapy; this reduces local recurrence and improves survival, as shown in randomized controlled trials (1-5). Notably, no gold standard RT technique in rectal cancer has yet been established. RT should be delivered in a highly conformal manner with at least three-dimensional conformal RT (3D-CRT) (6).

Three-dimensional CRT has been the most commonly used irradiation technique since some of the previously mentioned randomized controlled trials, and its utility is well known (7). Therefore, it is widely used for treatment of patients with rectal cancer. In difficult situations, such as patients who have undergone previous pelvic surgery and those with T4 rectal tumor, increases in acute side effects can cause interruption of therapy and prolong the RT period; this adversely affects local–regional control and survival (4, 8). Therefore, intensity-modulated RT (IMRT) techniques have increasingly been used in patients with rectal cancer (9). Because no prospective, randomized studies have compared IMRT and 3D-CRT in patients with rectal cancer, the National Comprehensive Cancer Network recommends that IMRT be used only in clinical trials, re-irradiations, patients with oligometastatic cancer, and patients with unique anatomical situations (6).

The kidney is sensitive to radiation and is a dose-limiting organ. The risk of kidney dysfunction secondary to RT is well known. Accordingly, the dose administered to the kidney during RT is maintained as low as possible. Unfortunately, migration and rotation abnormalities in the metanephric tissues and ureteral buds during the gestation process or kidney transplantation can cause pelvic kidney (movement of the kidney into the pelvis) (10). The simultaneous occurrence of rectal cancer with pelvic kidney is quite uncommon. For successful treatment of a patient with rectal cancer and pelvic kidney, it is important to protect the kidney without compromising the oncological outcomes.

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The aim of this study was to determine the most appropriate treatment by comparing three different IMRT techniques, including coplanar IMRT (c-IMRT), non-coplanar IMRT (n-IMRT), and volumetric-modulated arc therapy (VMAT), based on tumor localization and lymph node status in the presence of simultaneous occurrence of rectal cancer with pelvic kidney.

Material and Methods

Ethics Statement: This study was approved by the local ethics committee of the Faculty of Medicine of Ondokuz Mayis University, Samsun, Turkey (acceptance date: 02/5/2019; acceptance number: 2019/353). Written informed consent was obtained from the patient prior to participation in the study.

Case: At a local hospital, a 59-year-old man was diagnosed with rectal adenocarcinoma at 5 cm from the anal verge, with simultaneous pelvic kidney; he was referred to our oncology center for adjuvant treatment after low anterior resection (Figure 1A–E). The patient was staged as T3N0M0. Dimercapto-succinic acid renal scintigraphy revealed that the relative function of the left normally placed kidney was 70%, whereas that of the right pelvic kidney was 30%. Postoperative radiochemotherapy was planned.

Simulation: Three-dimensional external beam RT planning was performed using a computed tomography (CT) simulator (Aquilion LB; Toshiba Medical Systems, Otawara, Japan). CT imaging was performed with a comfortably full bladder at a slice thickness of 3 mm. The datasets were transferred to a treatment planning system (Eclipse 13.7; Varian Medical Systems, Palo Alto, CA, USA).

Delineation of The Volumes and The Organs At Risk: The gross tumor volume (GTV), clinical target volume (CTV), planning target volume (PTV), and organs at risk were defined using individual axial CT slices from the patient with rectal cancer and pelvic right kidney. Both the target volumes and organs at risk were delineated in accordance with the Radiation Therapy Oncology Group consensus panel contouring atlases, based on postoperative changes relative to preoperative CT scans. Organs at risk included the pelvic kidney, bladder, small bowel, and femur heads (11, 12).

Scenarios: The rectum was subdivided into three parts based on the distance of the lower margin of the tumor from the anal verge: proximal third, 12–16 cm; middle third, 6–12 cm; and distal third, <6 cm (5). Each third was considered a separate GTV: GTV-proximal (GTV-P), GTV-middle (GTV-M), and GTV-distal (GTV-D), respectively. Furthermore, CTV-A included the internal iliac, presacral, and perirectal nodal regions, and CTV-B included the external iliac nodal region. Six different scenarios were created based on the location of the tumor and the risk of lymph node involvement: scenario 1 = CTV-A of GTV-P; scenario 2 = CTV-A of GTV-M; scenario 3 = CTV-A of GTV-D; scenario 4 = CTV-A and CTV-B of GTV-P; scenario 5 = CTV-A and CTV-B of GTV-M; scenario 6 = CTV-A and CTV-B of GTV-D (Table 1).

Radiotherapy Planning: c-IMRT, n-IMRT, and VMAT plans were generated for delivery on a linear accelerator (Varian Truebeam SN-2934) using the Eclipse treatment planning system. For c-IMRT, four coplanar radiation fields were generated with angles of 0°, 90°, 180°, and 270°. Thereafter, eight additional subfields were generated by blocking radiation greater than 105% of the maximum dose with multileaf collimation in steps of 5% (13). An 18-MV photon beam was used, and the dose rate was 6 Gy per minute. For non-coplanar IMRT, seven non-coplanar fields without using 0° (180°, 145°, 110°, 75°, 215°, 250° and 285°) were generated with a dynamic wedge technique and inverse planning. A 6-MV photon beam was used, and the dose rate was 3 Gy per minute. For VMAT, a 6-MV photon beam was used, and the dose rate was 6 Gy per minute. Treatment planning was designed as single isocentric with two full rotations and collimator angles of 30–330°. In the boost arc plans, treatment planning was designed as single isocentric with single full rotation and collimator angle of 30°. Optimizations were performed using a photon optimizer, and dose calculations were performed using the anisotropic analytical algorithm, version 13.7.16.

PTV was obtained by allowing a 5-mm margin around CTV in all directions. The center of the PTV was considered the center of irradiation. The prescribed dose to the PTV in the pelvic and boost fields were 45 Gy in 25 fractions and 50.4 Gy in 28 fractions, respectively. The aims of target coverage were to deliver at least 95% and 100% of the prescribed doses to the PTV and CTV, respectively. Differences of less than 10% were maintained between the maximum and prescribed doses. Accepted dose constraints for organs at risk are shown in Table 2 (14-16).

Evaluation of Radiotherapy Planning: All treatment plans were evaluated in accordance with the dose-volume histogram. The evaluated dosimetric parameters were the minimum dose, maximum dose, mean dose, dose received by 2% of the target volume, dose received by 98% of the target volume, conformity index, and homogeneity index. In addition, the following parameters were assessed: the mean dose and volume receiving ≥20 Gy of the

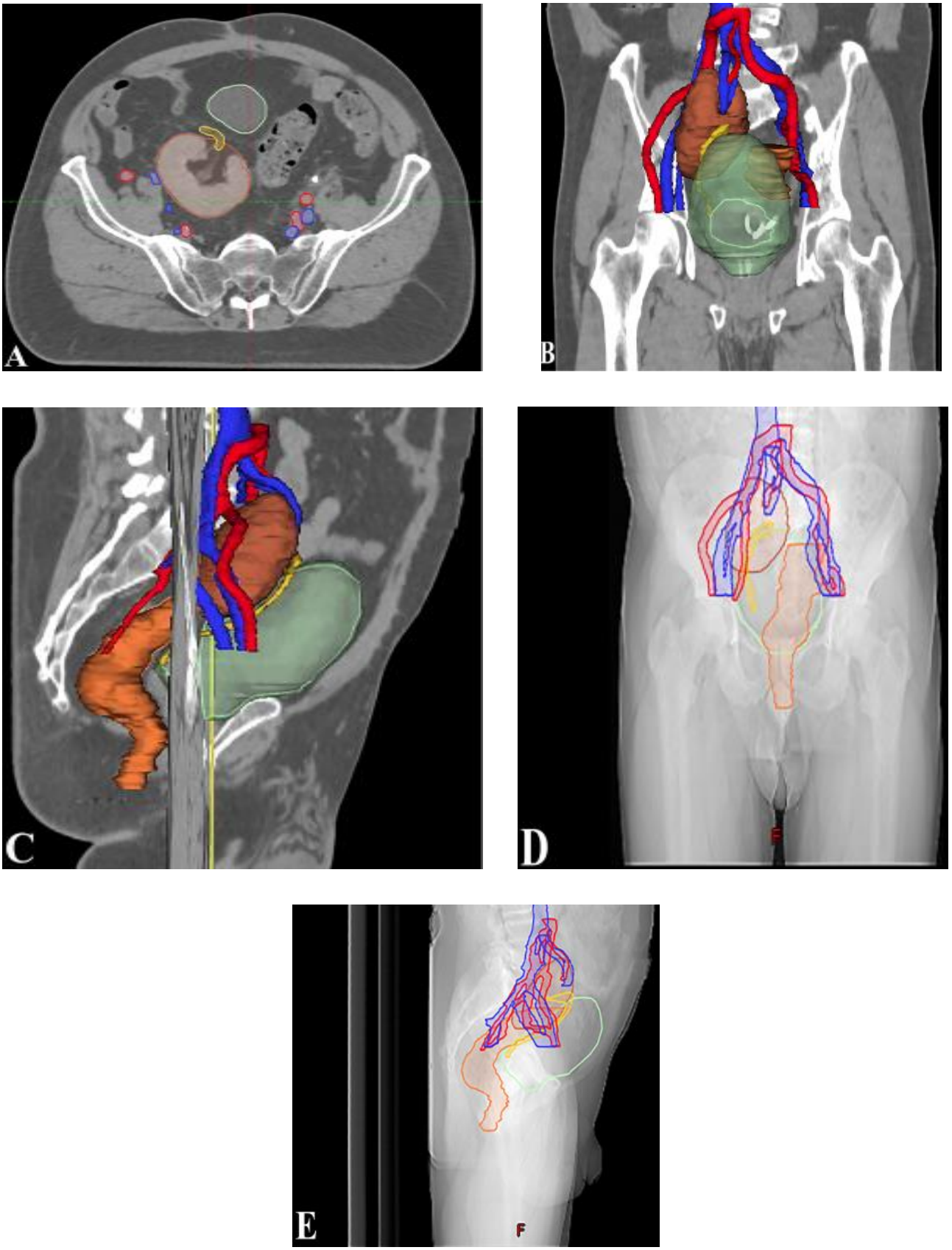

Fig. 1A-E. Three dimensional contouring of pelvic kidney (brown), ureter (yellow), bladder (green), rectum (orange), common iliac and kidney arteries (red) and veins (blue)

prescribed dose for kidneys; the volume receiving ≥40 Gy of the prescribed dose for bladder; the maximum dose for the small bowel; and the volumes receiving ≥40/45 Gy of the prescribed dose for the femur heads. The conformity index was defined in accordance with ICRU 62, and the homogeneity index was defined in accordance with ICRU 83 (17).

Results

Dosimetric Parameters for Planning Target Volumes in 45 Gy: In all scenarios, the most conformal planning was performed with VMAT (conformity index range: 0.55–0.66 for c-IMRT; 0.83–0.86 for n-IMRT; 0.89–0.91 for VMAT); the most homogeneous planning was performed with c-IMRT (homogeneity index range: 0.05–0.06 for c-IMRT; 0.07–0.10 for n-IMRT; 0.08–0.09 for VMAT). Furthermore, RT was shortest with c-IMRT (monitor unit range: 207–212) and longest with n-IMRT (monitor unit range: 1046–1095). When comparing dynamic IMRT techniques, VMAT was twofold faster than n-IMRT (monitor unit range: 513–541 vs. 1046–1095) (Table 3).

Dosimetric Parameters for Organs at Risk at 45 Gy: Scenarios 1, 2, and 3 (external iliac lymph nodes were not included)

With the c-IMRT technique, the dose constraints for the femoral heads and small intestine were not exceeded; however, the dose constraints for the bladder and pelvic kidney were exceeded. With n-IMRT, the dose constraints for all organs at risk, excluding the pelvic kidney, were not exceeded. With VMAT, the dose constraints for all organs at risk, including the pelvic kidney, were not exceeded. Consequently, in a patient with rectal cancer and pelvic kidney, if the external iliac lymph nodes were not included in the radiation field, the best RT planning could only be performed with VMAT, regardless of the tumor localization. Therefore, it was possible to administer the boost dose (Table 4).

Scenarios 4, 5, and 6 (external iliac lymph nodes were included)

With the c-IMRT technique, the dose constraints of the femoral heads and small intestine were not exceeded; however, the dose constraints of the bladder and pelvic kidney were exceeded. In contrast, the dose constraints of all organs at risk, excluding the pelvic kidney, were not exceeded with n-IMRT and VMAT. Consequently, in a patient with rectal cancer and pelvic kidney, if the external iliac lymph nodes were included in the radiation field, no RT technique could protect the pelvic kidney, regardless of the tumor localization (Table 4).

Dosimetric Parameters for Organs at Risk at 50.4 Gy with VMAT: Based on our dosimetric findings, after 45 Gy of RT in a patient with rectal cancer and pelvic kidney, a 5.4 Gy boost dose could be planned only with the VMAT technique in scenarios 1, 2, and 3, where external iliac lymph nodes were not included. In proximally and medially localized rectal tumors, the dose constraints of the femoral heads and bladder were not exceeded; however, the dose constraints of both the pelvic kidney and the small bowel were exceeded. Furthermore, in distally localized rectal tumors, dose limitations of all organs at risk were not exceeded. Consequently, a 5.4 Gy boost dose could be planned only with the VMAT technique and only in scenario 3, where the rectal tumor was distally localized and external iliac lymph nodes were not included (Table 5).

Discussion

RT in patients with locally advanced (T3, T4, and/or node positive) rectal cancer (LARC) is quite complex. RT is standard adjuvant treatment that can be applied postoperatively or preoperatively (5). Postoperative RT is applied over a long course (1.8 Gy in 25–28 fractions) with concurrent fluorouracil-based chemotherapy (postoperative radiochemotherapy); this improves rates of local failure (13 vs. 25%, P = 0.03) and overall survival (55 vs. 40%, P = 0.02) compared to RT alone (18). The advantage of postoperative radiochemotherapy is the ability to provide adjuvant therapy in high-risk patients diagnosed based on the pathology results. However, the first disadvantage of postoperative radiochemotherapy is increased entry of the small bowel into the irradiation field; this increases the rate of acute toxicity (18–20%) in the gastrointestinal system, which interrupts RT and prolongs its duration (4, 18). The second disadvantage is the development of a hypoxic environment after surgery, which reduces the effectiveness of RT and chemotherapy relative to the surgical bed. Thus, both aspects negatively affect prognosis (4, 5, 18, 19).

The above disadvantages may be prevented by preoperative treatment. Specifically, preoperative RT is applied both as a short-course (5 Gy in 5 fractions) treatment without concurrent chemotherapy or as a long-course treatment (1.8 Gy in 25–28 fractions) with concurrent fluorouracil-based chemotherapy (preoperative radiochemotherapy) (2, 20). Preoperative radiochemotherapy has some advantages compared to postoperative radiochemotherapy. First, tumor shrinkage or down-staging can be achieved, which improves the rates of resectability and sphincter preservation (39 vs. 19%). Second, the rates

Table 1. Scenarios

Scenarios	CTV-A	CTV-B	GTV-P	GTV-M	GTV-D
1	+		+		
2	+			+	
3	+				+
4	+	+	+		
5	+	+		+	
6	+	+			+

Abbreviations: CTV-A included internal iliac, presacral and perirectal nodal regions; CTV-B included external iliac nodal region; GTV-P = GTV-proximal; GTV-M = GTV-middle; GTV-D = GTV-distal

Table 2. Dose constraints for organs at risk

Organ	Dose constraint
Kidney	V20 ≤ 33% and mean dose < 18 Gy
Bladder	V40 < 35-50%
Small bowel	Maximum dose < 50 Gy
Femur heads	V40 < 40% and V45 < 25%

Abbreviations: V20 = Volume receiving ≥20 Gy of the prescribed dose; V40 = Volume receiving ≥40 Gy of the prescribed dose; V45 = volume receiving ≥45 Gy of the prescribed dose

Table 3. Dosimetric parameters for planning target volumes in 45 Gy

Scenario	Technique	Mean (cGy)	Min-Max (cGy)	D2 (cGy)	D98 (cGy)	D50 (cGy)	CI	HI	MU
	c-IMRT	4623	4132-4763	4726	4441	4629	0.66	0.06	212
1	n-IMRT	4657	3582-4893	4769	4418	4675	0.86	0.07	1090
	VMAT	4641	3303-4941	4779	4398	4652	0.91	0.08	541
	c-IMRT	4627	4122-4754	4722	4442	4639	0.65	0.06	211
2	n-IMRT	4656	3025-4875	4783	4307	4684	0.83	0.10	1084
	VMAT	4641	3303-4940	4778	4403	4653	0.91	0.08	541
	c-IMRT	4599	4103-4706	4685	4422	4611	0.66	0.05	211
3	n-IMRT	4679	3040-4900	4807	4323	4708	0.83	0.10	1090
	VMAT	4641	3303-4940	4778	4403	4653	0.91	0.08	541
	c-IMRT	4629	4112-4774	4738	4434	4637	0.56	0.06	208
4	n-IMRT	4621	3533-4891	4739	4340	4642	0.85	0.08	1095
	VMAT	4685	3560-4939	4823	4396	4700	0.89	0.09	513
	c-IMRT	4625	4112-4788	4727	4440	4636	0.56	0.06	208
5	n-IMRT	4629	3542-4893	4762	4285	4659	0.84	0.10	1046
	VMAT	4686	3560-4939	4823	4394	4709	0.89	0.09	513
	c-IMRT	4635	4119-4762	4723	4425	4648	0.55	0.06	207
6	n-IMRT	4676	3578-4944	4811	4327	4706	0.84	0.10	1057
	VMAT	4685	3560-4939	4823	4395	4706	0.89	0.09	513

Abbreviations: Min = Minimum; Max = Maximum; D2 = dose received by 2% of the target volume; D98 = dose received by 98% of the target volume; D50 = dose received by 50% of the target volume; CI = Conformity Index; HI = Homogenity Index; MU = Monitor Unit; c-IMRT = Coplanar IMRT; n-IMRT = Non-coplanar IMRT; VMAT = Volumetric Modulated Arc Therapy

Table 4. Dosimetric parameters for organs at risk at 45 Gy

		Pelvic Kidney		SB	B	RF		LF	
Scenario	Technique	V20 (%)	Mean (cGy)	Max (cGy)	V40 (%)	V40 (%)	V45 (%)	V40 (%)	V45 (%)
	c-IMRT	78.8	3585	4763	52.7	0.08	0	0	0
1	n-IMRT	57.5	2456	4853	38.9	0	0	0	0
	VMAT	32.2	1756	4940	29.6	0	0	0	0
	c-IMRT	78.7	3582	4754	52.8	0.1	0	0	0
2	n-IMRT	48.2	2183	4869	37.7	0	0	0	0
	VMAT	32.2	1756	4940	29.6	0	0	0	0
	c-IMRT	78.9	3553	4706	52.2	0.09	0	0	0
3	n-IMRT	48.4	2194	4894	38.1	0	0	0	0
	VMAT	32.2	1756	4940	29	0	0	0	0
	c-IMRT	81.4	3682	4744	73.1	2.3	0.33	0.15	0
4	n-IMRT	67.5	2839	4871	42	0	0	0	0
	VMAT	53.6	2276	4928	33.5	0	0	0	0
	c-IMRT	82.5	3743	4768	72,7	2.66	0.7	0.14	0
5	n-IMRT	66.6	2689	4840	41.2	0	0	0	0
	VMAT	53.6	2276	4928	33.5	0	0	0	0
	c-IMRT	81.3	3687	4739	73.9	2.23	0	0.08	0
6	n-IMRT	65.8	2717	4900	42.4	0	0	0	0
	VMAT	53.7	2276	4928	33.6	0	0	0	0

Abbreviations: V20 = Volume receiving ≥20 Gy of the prescribed dose; Max = Maximum; V40 = Volume receiving ≥40 Gy of the prescribed dose; V45 = volume receiving ≥45 Gy of the prescribed dose; SB = Small Bowel; B = Bladder; RF = Right femur; LF = Left Femur; c-IMRT = Coplanar IMRT; n-IMRT = Non-coplanar IMRT; VMAT = Volumetric Modulated Arc Therapy

Table 5. Dosimetric parameters for organs at risk at 50.4 Gy with VMAT

		Pelvic Kidney		SB	B	RF		LF	
Scenario	Technique	V20 (%)	Mean (cGy)	Max (cGy)	V40 (%)	V40 (%)	V45 (%)	V40 (%)	V45 (%)
1	VMAT	39.3	2035	5490	34.7	0	0	0	0
2	VMAT	37.4	1970	5488	36.8	0	0	0	0
3	VMAT	32.5	1767	4953	32.2	0	0	0	0

Abbreviations: V20 = Volume receiving ≥20 Gy of the prescribed dose; Max = Maximum; V40 = Volume receiving ≥40 Gy of the prescribed dose; V45 = volume receiving ≥45 Gy of the prescribed dose; SB = Small Bowel; B = Bladder; RF = Right femur; LF = Left Femur; c-IMRT = Coplanar IMRT; n-IMRT = Non-coplanar IMRT; VMAT = Volumetric Modulated Arc Therapy

of both acute (27 vs. 40%, $P = 0.001$) and late toxicity (14 vs. 24%, $P = 0.01$) are reduced. These advantages result in improved locoregional recurrence rates (7.1 vs. 10.1%, $P = 0.04$) without changing overall survival (59.6 vs. 59.9, $P = 0.85$). The only disadvantage of preoperative radiochemotherapy is the risk of over-treatment, as 18% of the patients who exhibit local advancement are mainly stage I (T1-2N0) (4, 20). Finally, short-course preoperative RT is an acceptable alternative to preoperative radiochemotherapy for LARC due to the similar rates of locoregional recurrence (7.5 vs. 4.4%, $P = 0.2$), overall survival (74 vs. 70%, $P = 0.6$), and late toxicity (5.8 vs. 8.2%, $P = 0.5$) (21). Following randomized controlled phase 3 trials where these results were obtained, preoperative treatment has been accepted as standard (2, 4, 20, 21). However, the patient described in this report was admitted to our radiation oncology department postoperatively.

Organs at risk in RT planning for patients with LARC and normal anatomy are the small bowel, bladder, and femur heads. These organs at risk should be considered an important part of the planning phase during RT simulation. Because the small bowel is the

main dose-limiting organ, RT planning in the prone position with a full bladder and a belly board device is recommended to reduce the amount of small bowel in the irradiation field (19). However, no dose constraints have been mentioned for organs at risk in both short-course and long-course RT trials; only suggested prescribed doses are provided (2, 18, 20, 21). In addition, anatomy may differ because of congenital (e.g., rotation and migration anomalies) and acquired (e.g., kidney transplantation) factors, as in patients with pelvic kidney. Thus, the prescribed dose may not be appropriate. In the literature, dose constraints for organs at risk including the kidney have been defined in conventional fractionated (1.8–2 Gy per fraction) radiotherapies (14-16). However, there is uncertainty in hypofractionated (5 Gy per fraction) radiotherapies. Therefore, based on the current literature, the application of conventional fractionated RT would be more reliable in patients with LARC and pelvic kidney. Thus, in the present study, we planned postoperative radiochemotherapy in the supine position because no belly board was available.

RT doses of 45–50.4 Gy using three- or four-field techniques with conventional or 3D-CRT for both pre- and postoperative radiochemotherapy have been applied in randomized controlled phase 3 trials (18, 20, 21). Fortunately, tumor response increases with increasing RT dose. Thus, rates of organ preservation, local control, and disease-free survival have been improved. RT dose can increase with acceptable acute and late toxicities by using IMRT (22, 23), brachytherapy (24), or contact X-ray therapy (25, 26). In doses of 45–50.4 Gy, the rates of pathologically complete responses and grade 3–4 acute toxicity were reported as 8–9% and 27%, respectively (4, 21). With doses higher than 60 Gy, these rates were reported as 16–44% and 23–42% with IMRT, 18–43% and 6–10% with brachytherapy, and 54% and 0% with contact X-ray therapy, respectively. Thus, dose escalation above 60 Gy results in improved pathologically complete response and sphincter preservation rates with acceptable toxicity in non-proximally located rectal tumors (22, 25).

In our dosimetric study, we found that, if external iliac lymph nodes were not included in treatment, we could protect the pelvic kidney up to 45 Gy only by using VMAT, regardless of the rectal tumor localization. Based on this result, we planned dose escalation with VMAT in the first three scenarios, which did not include the external iliac lymph nodes. Importantly, we found that the dose escalation up to 50.4 Gy could be given only in distally localized rectal tumors where external iliac lymph nodes were not included in treatment. Finally, when external iliac lymph nodes were included in treatment, we found that a dose of 45 Gy could not be given with pelvic kidney, regardless of tumor localization and RT technique. Thus, we demonstrated the importance of the RT technique, lymph node status, and tumor localization in treatment planning for patients with rectal cancer and simultaneous pelvic kidney.

Pelvic kidney may be congenital or result from transplantation. Although a congenital pelvic kidney is usually hypofunctional compared to a normally localized kidney, it may be the solitary functioning kidney in the patient. A transplanted pelvic kidney is always solitary (27-31). Both types of pelvic kidneys have distinct anatomical properties in terms of arteries, veins, and ureters (31). The presence of simultaneous occurrence of a pelvic malignancy with pelvic kidney is extremely rare. Treatment of pelvic malignancy in a patient with a pelvic kidney is complex and difficult. After pelvic RT, because the kidney is radiosensitive, RT-induced nephropathy may develop, ranging from asymptomatic proteinuria to chronic renal failure (28). Because RT is rarely performed in patients with pelvic kidney, no standard treatment approach has been established because physicians have reported their experiences in the form of case reports. In the English-language literature, there have been only three case reports of patients with rectal cancer and pelvic kidney. The first case, reported by Bokhari et al. in 1996, involved a patient with stage III rectal adenocarcinoma. Lymph node dissection was insufficient due to pelvic kidney; postoperative RT was performed with shielding of the pelvic kidney. Because surgery and postoperative RT were inadequate, local recurrence and distant metastasis both occurred at 8 months after treatment. Thus, the authors recommended translocation, heterotopic autologous transplantation, or nephrectomy when necessary to avoid worsened oncologic outcomes (27). The second case, reported by Takeda et al. in 2017, involved a patient with stage III rectal adenocarcinoma. Those authors mistakenly resected the right pelvic renal artery during laparoscopic surgery and switched to open surgery. Thus, they recommended that preoperative renal anatomy be determined by three-dimensional CT angiography or magnetic resonance angiography to avoid worsened pelvic kidney function (31). The third case, reported by Habibeh et al. in 2017, involved a patient who had rectal posttransplant Epstein-Barr virus-associated lymphoproliferative disorder secondary to kidney transplantation. Treatment constituted chemotherapy followed by moderate-dose (25.4 Gy) RT, which resulted in overall survival of 62 months (30).

The limitations of our study were that it was a dosimetric study of a single case; moreover, RT planning was postoperative, and a belly board device was not used. In the present study, we investigated the oncologic treatment of rectal cancer in a patient with simultaneous pelvic kidney, an extremely rare situation. The anatomical and functional characteristics of the pelvic kidney should be determined before the initiation of any oncologic treatment in patients with rectal cancer. The decision to perform RT should be made by a multidisciplinary tumor board. If possible, the use of a belly board device and preoperative radiochemotherapy should be considered. If necessary, surgical removal of the pelvic kidney outside the RT field should be considered. As further contributions to the literature, we demonstrated the importance of RT technique, tumor localization, and lymph node status in treatment planning for patients with rectal cancer and simultaneous pelvic kidney. Thus, in patients with LARC and pelvic kidney, oncologic treatment planning, including either RT first or surgery first, should be established in accordance with the available RT technique, lymph node status of rectal cancer, and both tumor and kidney localization.

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