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ASSESSMENT THE OPTIMAL PLANNING TARGET VOLUME USING THREE-DIMENSIONAL CONFORMAL RADIOTHERAPY IN GASTROINTESTINAL MALIGNANCIES

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ABSTRACT

Background: Recently, pelvic radiation therapy for treatment rectal malignancies had been increasingly used. The use of portal images has been shown to have a positive impact on treatment, and common practice is to obtain portal images at the beginning of treatment and throughout after. **Objectives:** The study aimed to defining the optimal planning target volume using three-dimensional conformal radiotherapy in rectal malignancies. **Methods:** A retrospective study of 40 patients with rectal cancer treated with 3DCRT were included. The study conducted in Baghdad Radiotherapy and Nuclear Medicine Center, Baghdad Medical City Complex, Baghdad, Iraq, in period between December 2020 and May 2021. **Results:** In rectal cancer, the lateral verification including right and left, and posterior portals were significantly influenced by PI, whereas superior, inferior and anterior direction were unchangeable by portal verification. The highest mean set-up error was 2.18 mm for S-I in Portal 1#. The systematic set-up error for S-I, R-L and A-P were 0.56, 0.53 and 0.34 mm, respectively. The population random errors for S-I, R-L and A-P were 0.33, 0.29 and 0.18 mm, respectively. As a results, the CTV-PTV margins were 7 mm for S-I, 4.7 mm for R-L and 1 mm for A-P. **Conclusions:** CTV-PTV margins were range from 0.9 mm to 7 mm.

KEYWORDS: Gastrointestinal Malignancies, Planning Target Volume, Radiotherapy.

INTRODUCTION

Approximately 4,422,143 new instances of gastrointestinal (GI) cancer are expected to occur worldwide in 2020, making it a persistent health concern. The esophagus, stomach, liver, and pancreas are among the other GI malignancies that are common and have significant death rates, however colorectal tumors make up about 25% of cases.[1] Anemia, intestinal changes, weight loss, bleeding, and stomach pain are early warning indicators. When benign polyps are removed before they develop into malignancy, colorectal cancer can be avoided.[2] In the stomach, submucosal lymphatics are most noticeable, although lymphatic dissemination and nodal involvement are typical at other GI locations. Hematogenous dissemination from GI cancers typically affects the lungs or liver, with rectal cancers being particularly vulnerable. For the majority of GI tract malignancies, radiation treatment is employed as part of primary therapy.[3,4] Compared to surgery alone or adjuvant irradiation, postoperative chemoradiation had better rates of overall survival, disease-free survival, and local and distant disease control.[4]

Tolerance to radiation therapy is dependent on both dosage and volume, therefore it is essential to define the tumor and target volumes correctly. Imaging investigations are necessary for primary or preoperative EBRT in order to pinpoint regions that are at risk. While intensity-modulated radiation therapy (IMRT) is suitable for some areas, patients with GI cancer are advised to get conformal three-dimensional radiation therapy with CT-based treatment planning.[2]

Colon cancer treatment field design is based on failure data patterns, and postoperative management of colon adenocarcinoma requires caution. The initial illness site and regions with a high risk of local recurrence determine the field configuration. Small bowel volume, beam orientation, and tumor beds are all defined with the aid of CT-based planning.[5] Using numerous treatment fields reduces the incidence of small bowel blockage. Small bowel and normal organ sparing may be made easier with intensity-modulated radiation techniques and three-dimensional treatment planning. Local recurrence patterns following surgery are the primary basis for the domains of pelvic radiation treatment. There is a greater chance that incomplete mesorectal excision will leave behind tiny tumor cells.[5, 6]

In comparison to the supine posture, researchers have discovered that employing a 3D planning system during postoperative external beam radiotherapy (EBRT) can reduce the small bowel volume treated. There are currently guidelines available from a number of investigators for the definition and delineation of clinical target volumes (CTVs).[7] The presacral space, primary tumor site, and perineum are among the possible locations with the highest risk of containing the disease that should be included in external-beam treatment fields for rectal carcinoma.[8] The L5/S1 interspace is where the superior and inferior margins of the AP/PA fields should be positioned. In order to prepare with a detailed description of the size of residual tumor, the anatomical placement of clips demarcating the tumor bed, and areas of close margins, careful coordination with the surgical team and pathologists is crucial after surgery.[9]

To confirm treatment setup and guarantee proper isocentre, beam, and MLC shielding configuration, electronic portal imaging (EPI) is utilized. External beam treatments and setup data are monitored by EPIs. Portal images are acquired at the start of treatment and every week after that, and they have a beneficial effect on treatment. Designing more sensitive films, improving image capture with screens, merging diagnostic and therapeutic imaging, and improving the picture quality of digitalized portal films are some ways to improve the quality of portal images.[10,11] In clinical application, EPIDs are utilized for simple film replacement, dosage administration verification, dynamic therapy, treatment verification, picture enhancement, autonomous patient positioning determination, and dynamic monitoring of conventional treatment. These uses rely on the functionality and design of the device.[10] The current study aimed to define the optimal planning target volume using Three-dimensional conformal radiotherapy in rectal malignancies & Estimation of the most and least variable setup in treatment position.

PATIENTS AND METHODS

Study Design

After approval from College of Medicine / University of Baghdad a retrospective study of 40 patients with rectal cancer who treated with 3DCRT were included and identified. The patients' demographic data, and the pathologic features, details of the primary tumor were recorded. The accuracy of the data was further validated for each patient using the medical record and/or surgical histopathology reports.

Setting

The study conducted in Baghdad Radiotherapy and Nuclear Medicine Center, Baghdad Medical City Complex, Baghdad, Iraq, in period between December 2020 and May 2021.

Inclusion criteria: Rectal cancers (T1 to T4, N0 to N1, M0).

Exclusion criteria: Rectal CA with metastatic diseases.

2.1. Data collection

Data were collected retrospectively with review of medical records. The following variables were studied: age, sex, residency, TNM staging, histopathology, grades, treatment modality, dose of RT, height, weight, and BSA.

Setup and portal images assessment

For each patient set-up errors assessment was done via calculated six portal images including superior, inferior, right lateral, left lateral, anterior and posterior. In sum approximately 36 portal images for each patients. At the isocenter, the bone landmark displacements were computed. These portal photos obtained with an EPI were used to evaluate the positioning uncertainties. Both the online image and the planning CT image are matched in every direction. The antero-posterior error is determined in the vertical direction, the change in position along the right-to-left lateral axis is explained in the horizontal direction, and the change in the supero-inferior direction is expressed in the longitudinal direction. The predicted theoretical position shown on the digitally reconstructed radiograph (DRR) picture and the actual position of each beam as shown on the portal images were compared, and the discrepancies were measured. (Figure 1)

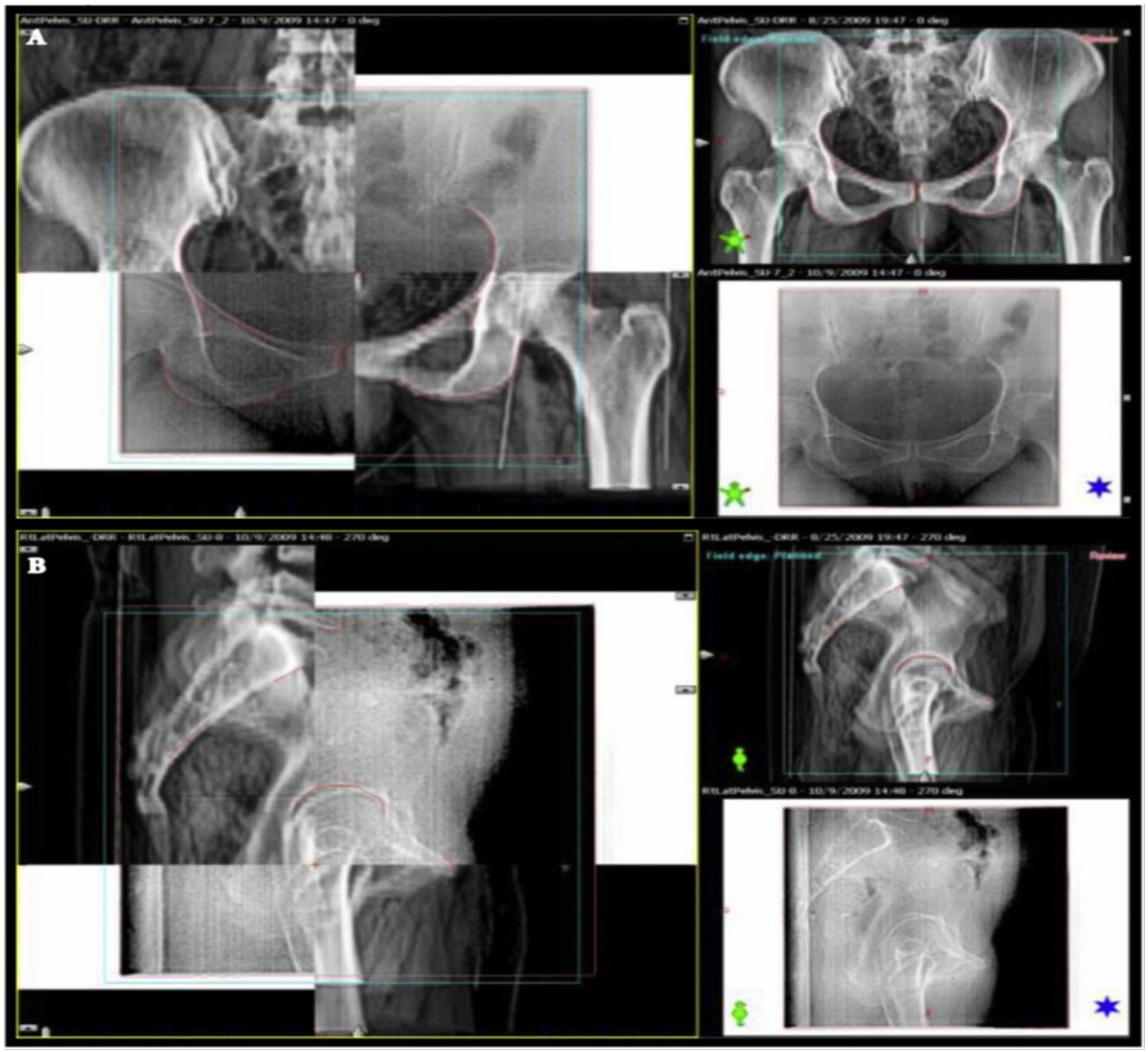

Figure (1): Portal image. A) Antero-posterior view; B) Right lateral view.

Set-up error measurement

All displacements in the two lateral directions—supero-inferior and antero-posterior—were noted for every patient (Figure 2). The average of the x, y, and z displacements was determined. The physics department of the Bagdad Radiotherapy and Nuclear Medicine Center provided the portal imaging mean and the irradiation technique, which were taken into consideration while calculating the PTV margin. The set-up errors calculation was measured according to equations listed below.[12]

m individual (individual mean set-up error)

$$= \frac{\Delta 1 + \Delta 2 + \cdots + \Delta n}{n}$$

M pop (overall population mean set-up error)

$$= \frac{m1 + m2 + \cdots + mp}{P}$$

$\sum^2$ set-up (population systematic set-up errors)

$$= \frac{(m1 - Mpop)^2 + (m2 - Mpop)^2 + \cdots + (mn - Mpop)^2}{(P-1)}$$

σ^2 individual (individual random error)

$$= \frac{(\Delta 1 - m)^2 + (\Delta 2 - m)^2 + \cdots + (\Delta n - m)^2}{(n-1)}$$

σ set-up (random error)

$$= \frac{\sigma 1 + \sigma 2 + \cdots + \sigma p}{P}$$

CTV-PTV margin

$$= a \sum + b\sigma$$

- m : summation of each imaged fraction dividing by number of imaged fraction.
- M : summation of all m and dividing by number of patients.
- a=2.5 and b=0.7 (which are constant values)
- n = number of imaged fraction
- P = number of patients

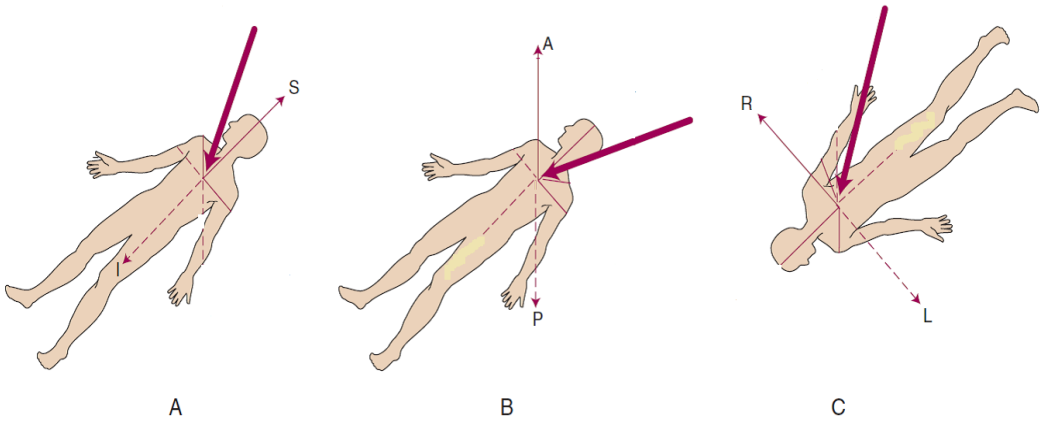

Figure (2): Three-dimensional portal images. A, The superior – inferior (S-I). B, The anterior – posterior (A-P). C, The right – left (R-L).

Tools

1. A CT pore scanner (85 cm) from the Philips ® 16 series: this device uses radiation projection measurements to estimate an object's interior. In contemporary medicine, it is a crucial imaging method. With the use of a belly board for anterior bowel displacement, it offers a three-dimensional picture of the inside of the body that is helpful for both sickness diagnosis and treatment planning. To guarantee more exact setup repeatability, we advise simulating the patient in the supine position in a body mold or other immobilization device if IMRT is planned. The anus should be marked with a radiopaque substance.
2. Linear Accelerator (cone beam CT) [InfinityTM and Synergy®]; 2013. The first linear accelerator to incorporate 3D picture guiding into the treatment setup procedure was the Elekta Synergy system. 2D, 3D, and 4D volumetric cone-beam imaging for soft tissue visualization, 2D real-time, fluoroscopic-like imaging for objects that move frequently, and 2D kV imaging for conventional and orthogonal planar imaging are important imaging technologies. Volumetric Modulated Arc Therapy (VMAT) is a component of the Elekta Infinity system, a holistic therapy approach. By concurrently adjusting the gantry position and speed, MLC leaves, dose rate, and even collimator angle, VMAT allows doctors to "shrink wrap" the dosage around a tumor by combining greater dose conformity with treatment speed.[13]
3. High precision treatment planning for radiation therapy using Monaco® Electa HP version 5. Monaco assists medical professionals in delivering the best possible treatment. Monaco provides quick and effective planning, streamlining processes for treatment delivery and plan generation, and aids doctors in understanding patient biology via the use of biological intelligence and standardized class solutions.[14]
4. Version 5 of Elekta's XiO® Electa system offers a powerful planning system for particle therapy treatments. XiO offers you the features you've come to expect from Elekta treatment planning, including automation capabilities, sophisticated dosage calculations, seamless integration, and a high degree of customization, for accurate plans and efficient workflows. Fast contouring, Fusion, Virtual Sim, Planning, and Review Tools are all included in XiO's all-inclusive planning workflow tools in version 1.[14]

Ethical considerations

A written consent was taken from each patients after explanation of the study's objectives.

Statistical analysis

Electronic data from the view capture tools (Monaco® Electa HP version 5) was used to collect and analyze study data, and SPSS v24 (IBM Inc., Chicago, IL, USA) was used for statistical analysis. The association of clinico-pathologic factors modeled with fisher exact test calculation. The one-way-ANOVA test for independent measures is designed to compare the means of six independent portal images simultaneously. The Post Hoc Tukey HSD (beta) procedure used to facilitated pairwise comparisons within ANOVA data and to differentiated between six portal images means. A two-sided *P* value of less than 0.05 was considered statistically significant.

RESULTS

The mostly distributed age group was 50-59 years in 14(35.0%), with mean age was 52.27±14.245 years as shown in table (1).

Table (1): Patients distribution according to age.

Age (years)	No.	(%)
20-29	1	2.5
30-39	4	10.0
40-49	6	15.0
50-59	14	35.0
60-69	10	25.0
>70	5	12.5
Total	40	100.0

In relation to gender, males were 17**(**42.5%) and females 32(57.5%), as shown in figure (3).

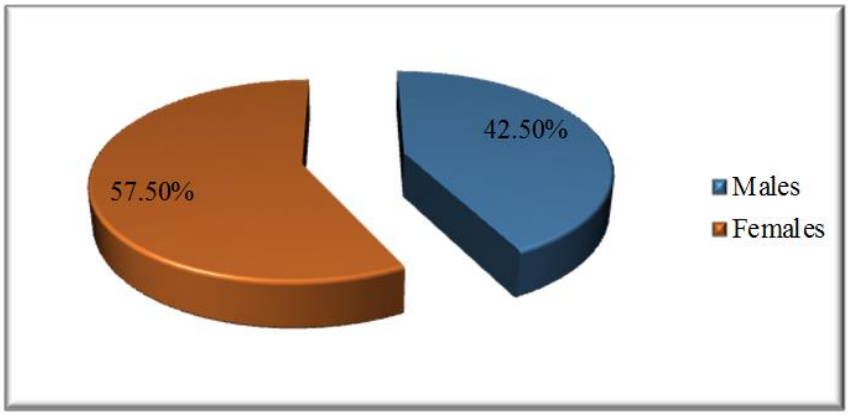

Figure (3): Patients distribution according to the gender.

Regarding BMI, most of patients with rectal cancer had normal BMI as 23.4%, only 11.7% and 5.3% were overweight and obese respectively, as shown in figure (4).

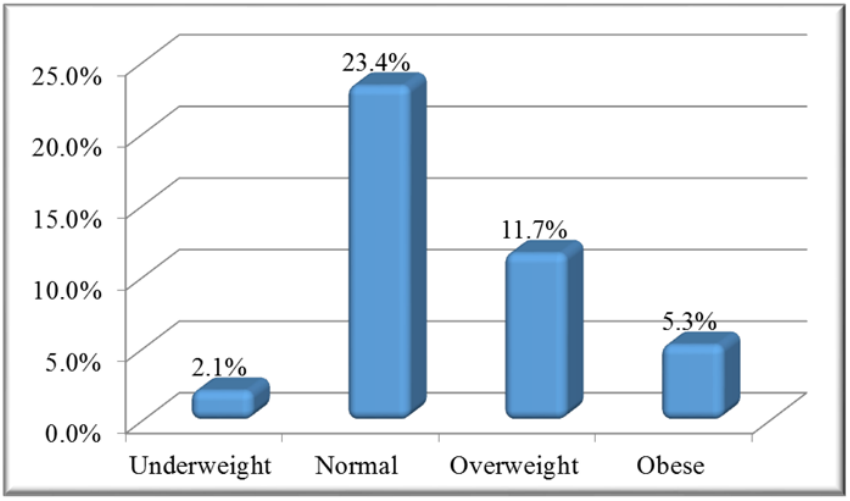

Figure (4): Patients distribution according to BMI.

According disease stages and grades, all results shown in table (2). The most common T-stage in rectal cancer was (T2) in 28(29.8%). The most common N-stage was (N1) in 23(24.5%). Regarding grades, grade II was the common recorded in 29.8%.

Table (2): Patients distribution in relation to T-stage, grades, and N-stage.

Rectal CA	**0**	**1**	**2**	**3**
T-stage		8 (8.5)	28 (29.8)	4 (4.2)
Grade		8 (8.5)	28 (29.8)	4 (4.2)
N-stage	13 (13.8)	23 (24.5)	4 (4.2)	

According to the RT dose, the most common dose recorded was 50.4Gy/28F in 26(65.0%) patients. Other doses prescribed were 25Gy/5F, 45Gy/25F, 50Gy/25F, 54Gy/30F, and 59.4Gy/33F as shown in table (3).

Table (3): Patients distribution according to radiotherapy doses.

Dose (Gy/ F)		**No.**
25/5	1	2.5
45/25	5	12.5
50/25	4	10.0
50.4/28	26	65.0
54/30	2	5.0
59.4/33	2	5.0
Total	40	100.0

Approximately, all rectal cancer case received CCRT (39, 97.5%), while only 1(2.5%) most of the patients received RT (Table 4)

Table (4): Patients distribution according treatment protocol.

Treatment protocols	Rectal cancer	%
CCRT	39	97.5
RT	1	2.5
Total	40	100.0

The portal imaging showed in (Table 5). The high mean value of superior PI was recorded in Portal 4# (4±0.13) mm, whereas the lowest was Portal 5# (1.6±0.05 mm), with no significant difference (p=0.088). The high mean value of inferior PI was recorded in Portal 1# (6.5±0.183 mm), while the lowest was Portal 3# (2.3±0.06mm), with no significant difference (p=0.098). The right high mean PI was recorded in Portal 1# and 5# (4.6±0.122 mm; 4.6±0.1 mm, respectively), while the lowest was Portal 3# (2.4±0.09 mm), with a high significant difference (p=0.03). The left high mean PI was recorded in Portal 3# (3.8±0.09 mm), whereas the lowest was Portal 5# (1.5±0.05 mm), with a high significant difference (p=0.027). concerning the anterior PI records, the high mean PI was recorded in Portal 3# (3.7±0.087 mm), whereas the lowest was Portal 4# (1.4±0.045 mm), with a no significant difference (p=0.08). The posterior PI mean errors, the high mean PI was recorded in Portal 2# (3.2±0.07 mm), whereas the lowest was Portal 3# and 5# (1.6±0.06 mm; 1.6±0.05 mm, respectively), with a high significant difference (p=0.001).

Table (5): Portal imaging.

Rectal Cancer	Portal 1#	Portal 2#	Portal 3#	Portal 4#	Portal 5#	Portal 6#	P- value*
	Mean ±SE (mm)						
Superior	3.8±0.177	3.5±0.065	2.3±0.06	4±0.13	1.6±0.05	2.5±0.087	0.088
Inferior	6.5±0.183	3.9±0.126	2.3±0.06	2.8±0.1	4.3±0.11	3.4±0.074	0.098
Right	4.6±0.122	3.9±0.087	2.4±0.09	2.6±0.074	4.6±0.1	0.38±0.085	**0.03**
Left	3±0.067	3±0.07	3.8±0.09	3.2±0.087	1.5±0.05	2.7±0.065	**0.027**
Anterior	2.3±0.064	1.6±0.054	3.7±0.087	1.4±0.045	1.5±0.048	2±0.066	**0.08**
Posterior	3±0.11	3.2±0.07	1.6±0.06	2.1±0.05	1.6±0.05	2.3±0.06	**0.001**

***One-Way ANOVA analysis and Post Hok Tukey-test**

The highest mean set-up error estimated was 2.18 mm for S-I in Portal 1#, whereas the lowest was 0.97 mm for A-P in Portal 2#. The systematic set-up error for S-I, R-L and A-P were 0.56, 0.53 and 0.34 mm, respectively. The population random errors for S-I, R-L and A-P were 0.33, 0.29 and 0.18 mm, respectively. As a results, the CTV-PTV margins were 7 mm for S-I, 4.7 mm for R-L and 1 mm for A-P. (Table 6)

Table (6): Set-up error (mm) estimating for Portal 1#; 2#; 3#.

		S-I	R-L	A-P
$m_{individual}$ (individual mean set-up error)	m_1	2.18	1.94	1.18
	m_2	1.9	1.5	0.97
	m_3	1.46	1.5	1
M_{pop} (overall population mean set-up error)		0.06	0.057	0.036
$\sum_{set\text{-}up}$ (population systematic set-up errors)		0.56	0.53	0.34
$\dot{O}_{individual}$ random		1.68	1.6	1.24
$\dot{O}_{set\text{-}up}$ random		0.33	0.29	0.18
CTV-PTV margin		7	4.7	1

***m*: individual mean error; M_{pop}: population mean error; $\sum$: systematic error; $\dot{O}$: random error**

The highest mean set-up error estimated was 1.8 mm for S-I in Portal 4#, whereas the lowest was 1 mm for A-P in Portal 5# and 6#. The systematic set-up error for S-I, R-L and A-P were 0.49, 0.5 and 0.33 mm, respectively. The population random errors for S-I, R-L and A-P were 0.27, 0.24 and 0.16 mm, respectively. As a results, the CTV-PTV margins were 4 mm for S-I, 4.2 mm for R-L and 0.9 mm for A-P. (Table 7)

Table (7): Set-up error (mm) estimating for Portal 4#; 5#; 6#.

		S-I	R-L	A-P
$m_{individual}$ (individual mean set-up error)	m_4	1.8	1.6	1.1
	m_5	1.6	1.7	1

	m_6	1.2	1.5	1
M_{pop} (overall population mean set-up error)		0.05	0.056	0.036
$\sum_{set\text{-}up}$ (population systematic set-up errors)		0.49	0.5	0.33
$\dot{O}_{individual}$		1.53	1.45	1.18
$\dot{O}_{set\text{-}up}$		0.27	0.24	0.16
CTV-PTV margin		4	4.2	0.9

***m*: individual mean error; M_{pop}: population mean error; $\sum$: systematic error; $\dot{O}$: random error**

DISCUSSION

This is the first time study for defining the optimal planning target volume using three-dimensional conformal radiotherapy in rectal malignancies and for estimation of the most and least variable setup in RT treatment position in Iraq.

During an RT treatment session, the x-ray intensity that passes through a patient via a radiation port is measured using electronic portal imaging devices, or EPIDs. To confirm the proper beam placement with respect to the patient's anatomy, the radiation signal is electronically transformed into a digital radiography picture.[14]

In this study, forty rectal cancer (17 males, and 23 females) patients aged (52.27±14.245) years.

Similarly, the results of rectal cancer were reported by studies conducted in Misan by Alhilfi et al.,[15] and Khalil et al.,[16] in Duhok. While these results regarding mean age were dislike with a metanalysis study done by Alshewered and Al-Naqqash in 2019 at Baghdad Medical City Oncology Centers in Medical city, they observed 48.7±14.2 years as mean age for 101 patients with rectal cancer. They found slightly elevated of females (51.5%) among males (48.5%) known to be cases of rectal cancer.[17]

Approximately 5.3% of patients had a BMI of 30 m^2/kg or above. These might directly impact dosimetry, EPID, and RT planning. Anatomical changes including weight loss or gain, neck flexion, and variations in lung density also happen regularly during longer treatment periods, which causes variations in dose administration across a number of fractions.[18] Patients who are obese or have a wide pelvic circumference are often thought to be more prone to increased motions and poor repeatability throughout therapy.[19, 20]

In this study, stages of rectal malignancies recorded in different proportions, the mostly tumor size belonged to (T2), (N1), and grade II. These results agree with most previous studies conducting in Iraq like.[15-17] Experienced radiographers, physicists, and radiation oncologists knew what to expect in terms of tumor sizes and treatment field shapes, as well as the number of monitor units delivered, for a given type of treatment. High cancer stages, as represented by T-staging, N-staging (lymph nodes involvement), and high grading, may influence the treatments.[18]

Different protocols and doses were documented, the most common dose was 50.4 Gy/28fx. All rectal cancer case received CCRT (39, 41.4%). These protocols followed most of international guidelines for cancer management as ASCO, ESMO, and NCCN and other.[2,3,8]

Dose calculation problems, incorrect TPS commissioning data (such beam fit faults), and data transmission errors—including choosing the incorrect patient plan—are examples of plan errors. Recalculating the dosage in a homogeneous phantom will not reveal the error if it is caused by the patient's anatomy or a disease-related factor.[18, 21]

Errors resulting from modifications to the patient's anatomy, positioning, size, stage, grade, and lymph node spread from the planning scenario are specifically associated with patient errors.[18]

The identification of patient-related errors will be restricted to circumstances in which the patient did not change between imaging and treatment times and additional imaging data is available, typically obtained before and/or after treatment. For treatment sites where significant anatomical variations are not anticipated, 2D EPID verification models are utilized to provide a consistency check for the dose administered.[21]

This kind of verification requires the use of EPID-based (3D) dose reconstruction algorithms with an independent dose calculation that accounts for homogeneities (such as Monte Carlo, convolution/superposition, or collapsed-cone algorithms). However, 2D EPID verification models are likely to discover errors resulting from inadequate MLC modeling.[18]

The characteristic of EBRT is the precise positioning of the radiation beam on the patient at the designated region. The crucial last stage in the treatment procedure to guarantee precise beam placement is portal imaging, or the imaging of the radiation leaving the patient.[12]

Verification of geometric accuracy at the time of treatment delivery has always been a necessary part of the radiotherapy process. Since the introduction of conformal and intensity-modulated radiotherapy, the consequences of patient positioning errors are more serious. Portal imaging has played a large part in fulfilling the need for improved geometric accuracy.[19]

This study examined how portal imaging has progressed through the development and evolution of electronic portal imaging devices (EPIDs) by measuring 3384 direction (superior, inferior, right, left, anterior, and posterior) of six portals (1#, 2#, 3#, 4#, 5#, and 6#) for 40 patients.

In rectal cancer, the lateral verification including right and left, and posterior portals were significantly influenced by PI, whereas superior, inferior and anterior direction were unchangeable by portal verification. The precision and repeatability of the patient's location during RT therapy are largely determined by portal imaging. To accurately determine the planned target volume (PTV), it is crucial to understand the total setup mistakes that are inherent in the treatment approach being employed. During the first three days of treatment,[20] PIs were obtained every day; after that, they were obtained twice a week for the duration of the radiation therapy. The offline correction protocol was used, and there was no online version. Using the offline review software module, the PIs were examined for setup deviations in terms of translations and rotations with regard to the patient coordinate system.[20, 22]

It has been shown that patients with rectal tumors are more challenging to position correctly on an RT couch.[20-23] Patient setup for RT based on skin/tattoo marks on lax abdomen, susceptible to movement related to bladder/ bowel filling, respiration, and weight changes, contributes to the misalignment.[20]

In this study, we found the superior PIs mean error in portals 1#, 2#, and 3# were higher than portals 4#, 5# and 6# (3.18±0.137 mm versus 2.6±0.04 mm). The inferior PIs portals 1# to 3# were large than portals 4# to 6# (5.51±0.105 mm versus 3.64±0.149 mm), with a significant difference (p=0.036). The PIs 1# to 3# of right direction were higher than portals 4# to 6# (4.11±0.093 mm versus 3.77±0.046 mm), with a high significant difference (p=0.013). The left direction portals had no significant influenced. Only anterior direction portals (1-3#), they were larger than portals (4-6#) (2.33±0.022 mm versus 2.29±0.019 mm), with a significant difference (p=0.028). In regard to posterior direction, there was no significant changes overall PIs. To evaluate the effect of immobilization on the setup accuracy of pelvic RT, several studies have also been conducted employing hip support immobilization devices, knee roll foot and arm support, vac-loc, alpha cradle, infrared markers, and belly board positioning devices. According to all of these investigations, the directions with the largest deviations contain systematic errors that range from 1.5 to 2.8 mm in the ML direction, 2.6 to 3.7 mm in the AP direction, and 2.1 to 4.8 mm in the cranio-caudal (CC) direction.[20-23] The random errors in the AP, medio-lateral (ML), and CC directions ranged from 1 to 3 mm, 2.6 to 3.7 mm, and 2.3 to 4.9 mm, respectively.[20]

Due to the similar positional device and fixed vertical table height (10 cm) used for patient setup and treatment, Singh et al. in 2020 found no significant difference in the systematic errors observed in the CC (y) and AP (z) directions between the two arms of his study; however, they did observe that Arm II had a lower systematic error in the ML (x) direction. In that study, the main deviations in ML (>5 mm) were also lower for Arm II (22% vs. 37% for Arm I).[20]

The study's S-I, R-L, and A-P mean errors were [~2.6 – 3.18 and ~3.64); ~3.77 and 2.98 – 3.46; ~2.29 – 2.33 and ~2.22 – 2.5)], in that order. With the exception of the bilateral (right and left) PIs for 1#, 2#, and 3#, which were bigger than the highest limit of the range (i.e., ~5.51 and 4.11 mm), these findings were also within the range (1.1–3.8 mm) of other studies in the literature.[24,25]

In Portal 1#, the maximum mean set-up error for S-I was 2.18 mm. For S-I, R-L, and A-P, the systematic set-up error was 0.56, 0.53, and 0.34 mm, respectively. For S-I, R-L, and A-P, the population random errors were 0.33, 0.29, and 0.18 mm, respectively. The CTV-PTV margins were therefore 1 mm for A-P, 4.7 mm for R-L, and 7 mm for S-I. Furthermore, the mean set-up error for S-I in Portal 4# was the greatest at 1.8 mm. For S-I, R-L, and A-P, the population random errors were 0.27, 0.24, and 0.16 mm, respectively, while the systematic set-up errors were 0.49, 0.5, and 0.33 mm. Consequently, S-I had CTV-PTV margins of 4 mm, R-L had 4.2 mm, and A-P had 0.9 mm. The research by Murthy et al., which revealed that the random error values for pelvis instances were 1.59 and 2.15 mm, and the average systematic errors along X and Y directions were 1.53 and 1.9 mm, contradicts all of these results.[24]

Studies have attempted to evaluate the influence of various patient-related factors, such as body weight, circumference, and body mass index (BMI), on positioning accuracy during treatment. Skin marks can result in inaccuracies due to skin movement, weight loss, respiratory variability, and patient relaxation.[21]

In order to ascertain if patient body habitus and pelvic circumference affected setup repeatability with or without immobilization devices, Udayashankar et al.[26] as well as Badajena et al.[25] They discovered that while none of the immobilization methods considerably decreased setup repeatability in obese individuals as compared to those who were not immobilized, obese patients and those with a greater pelvic circumference than 105 cm showed noticeably more lateral movement. According to Haslam et al.[27] the repeatability of the setup was impacted by the patient's physical characteristics, including height, weight, age, body mass index, and history of prior surgery.

According to Singh et al., patients with a larger pelvic circumference (>95 cm) tended to have more deviations and were substantially more in the arm I want to

emphasize that patients with a loose, flabby belly have trouble aligning themselves, which leads to setup problems. They also need to be subjected to daily online rectification treatments.[20] Despite the fact that not all setup faults can be fixed, equations that account for rotational inaccuracies in the PTV margin calculation have been given. 28 Smaller systematic errors have been proven to be beneficial since they have a bigger effect on the margin needed for PTV.[25–29]

In contrast to lateral skin tattoos, which can move due to weight loss, respiratory variability, or patient relaxation/tightness when positioned for daily radiation treatment, previous studies have clearly demonstrated that the systematic errors in the A-P direction had significantly decreased when the patient was setup with the fixed vertical height. This is because the pelvic anatomy is relatively fixed with respect to the couch in this position.[29]

Many published trials in recent years have employed various treatment techniques, such as IMRT and IGRT, as well as various immobilization and/or positional devices and methods for quantifying setup errors. However, it is still unclear whether an immobilization device for pelvic malignancies improves the level of setup reproducibility during treatment. Thus, it is imperative that every RT center and organization measure and confirm the inherent mistakes in their own planning, therapy, and immobilization/positioning devices and account for them when calculating the PTV.[20]

CONCLUSIONS

The results of this study have guided quality assurance of the RT center equipment, techniques and revision of the setup and treatment processes for pelvic irradiation for rectal malignancies in Iraq. CTV-PTV margins were range from 0.9 mm to 7 mm.

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