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# Evaluation setup error of bladder cancer and rectum radiotherapy using portal image device

*Zainab Abdul-Qader*[1,*] *, Hiba Al-Hameed* [2]

[1,2]College of Science for Women, University of Baghdad, Baghdad, Iraq
[*]) Email: Zainab.Abed2304@csw.uobaghdad.edu.iq

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The setup error is defined as the difference between the true treatment image represented by the portal image and a picture digitally reconstructed radiograph (DRR) coming from the physics planning as the reference image. the difference between the two pictures helps us measure displacement. The treatment area is dependent on the edges of the setting error. The essential step is to estimate the setting error during treatment. Dosage allocation at PTV is following on set-up edges and evaluating the set-up error for every radiation oncology collective to minimize the therapy error. Position errors explain the variance between the first position at which the patient is scanned at the Computer Tomography simulation and the set-up position in the therapy couch. most used evaluated errors in radiotherapy are random errors and systematic errors. To get an increase in life expectancy for rectum cancer and bladder patients, competence and precision of radiation treatment delivery are sensitive ingredients, together in terms of cancer suppression and the dosage received by critical organs. The EPID (electronic portal imaging device) is utilized to measure the photon intensity transmitted by a patient from an irradiation port through a therapy fraction. The ray signal is transformation electronically inside a two-dimensional (2D) digital radiographic picture for prove true filed placement at relation for the patient's anatomy. The EPID (electronic portal imaging device) are usually utilized for know and correct for between-session variability at tangential bladder and rectum radiation. Based on our hospital policy, EPID recording is performed by either a therapist or radiation oncologist daily. This research aims to define systematic and random errors to patients with bladder tumor (N=15) and rectum (N=10). For systematic error (∑) to bladder is (0.02, 0.03, 0.01) cm, on the x-axis, y-axis, and z-axis, respectively, and (0.04, 0.03, 0.02) cm for the rectum cases. The systematic error μ for the bladder (0.32, 0.21, 0.14( cm, on the x-axis, y-axis, and z-axis, respectively, and (0.33, 0.23, 0.15) cm for rectum cases. Random error σ for the bladder is (0.05, 0.06, 0.04) cm, on the x, y, and z-axis, respectively, and (0.03, 0.04, 0.05) cm, for the rectum cases. Therapy setup is performed using electronic portal imaging (EPID) and radiation therapy utilize linac (Elekta).

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**Keywords:** Radiation therapy; Bladder cancer; Rectum cancer.

## 1. INTRODUCTION

Cancer is an illness whose outcome of an abnormal increase in cells due for the genetic mutations at (DNA) [1-2]. Carcinoma is a complex illness, what develop locally and too, it has the potential to spread to several organs at body [3]. Radiation treatment (RT) is therapy with a use high energy of ionizing radiation and to give a sufficiently huge absorbed dose to a defined tumor and tolerance doses of critical organs [4,5].

RT is a therapy the way utilized to many kinds of tumor: more than 50% from tumor patients receive RT, often utilized to merge with chemotherapy and surgery [6]. RT planning is a technique that need determining the optimal therapeutic agents to treat the patient. The factors are target size, patient site, treatment equipment design, electronic monitoring, and other treatments. If it is treatment plan that is monitored continuously for several weeks [7,8]. By three-dimensional conformal radiotherapy treatment (3-D CRT), purpose therapy who are based 3-D anatomical input and used therapy beam that adjust as carefully as potential to the tumor size purpose deliver suitable dosage to target and less dosage to critical organs [9,10]. Portal crossing dosimetry, use electronic portal imaging machine (EPID) is a technique wherever dose measurement made backwards a patient are used to verify the dose take to who patient [11]. LINAC (linear accelerator) machine that accelerates the charged particles (photon or electron) for high energies out of a linear tube by using high-frequency electromagnetic waves. It treats the superficial tumors using a high energy electron beam or treats the steadfast tumors by put a target into the electron beam course to produce X-rays. Clinically time being hired radiation therapy (RT) photon beams are ordinarily between 4-25 Mega-Volt (MV) [12,13]. Linear accelerator (Elekta) with 160 multileaf collimators (MLC) with 0.5 cm width [14-15]. EPID an important tool with digital technology to develop target localization and maintain clinical efficiency. EPID are very common in the radiation therapy clinic, and they provide a powerful and flexible tool to collect and process data in a quantitative keep to develop therapy accuracy [16]. Patient positioning and motion through radiation treatment planning and therapy are of most importance [17]. Patient centering in rectum tumor radiation treatment necessitates determination based on set-up reproducibility and the site that yields the less irradiation dosage for organs at risk (OARs), principally a small bowel [18]. Bladder tumor is the ninth most common tumor diagnosis internationally the etiology association of bladder tumor with smoking means patients often have doubled comorbidities on a background of mounting weakness with forward age. To those patients, radiation therapy offers probability for long-term symptom control and illnesses [19].

## 2. EXPERIMENTAL

### *2.1 Material*

This research is a retrospective conducted at Al-Amal National Hospital for treating cancer management.

### *2.2 Procedure*

#### *2.2.1 Immobilization Simulation*

The planning operation includes localizing the volume to be treated. This comprise defining the positions of the patient, tumor, target, and normal tissue. A CT Simulation treatment is made up of a CT scanner together with a flat tabletop, a laser patient position, and labelling system, preferably external lasers, CT simulation/3D therapy planning software, and diverse hardcopy execution tools. Virtual simulation software is used to position the beams and plan the treatment. The contouring of the target while critical organs, the positioning of the treated isocenter while beams, a disposition of therapy portal forms, the

descent of digitally reconstructed radiographs DRR, and documentation is all part of the simulation as Figure1 [20].

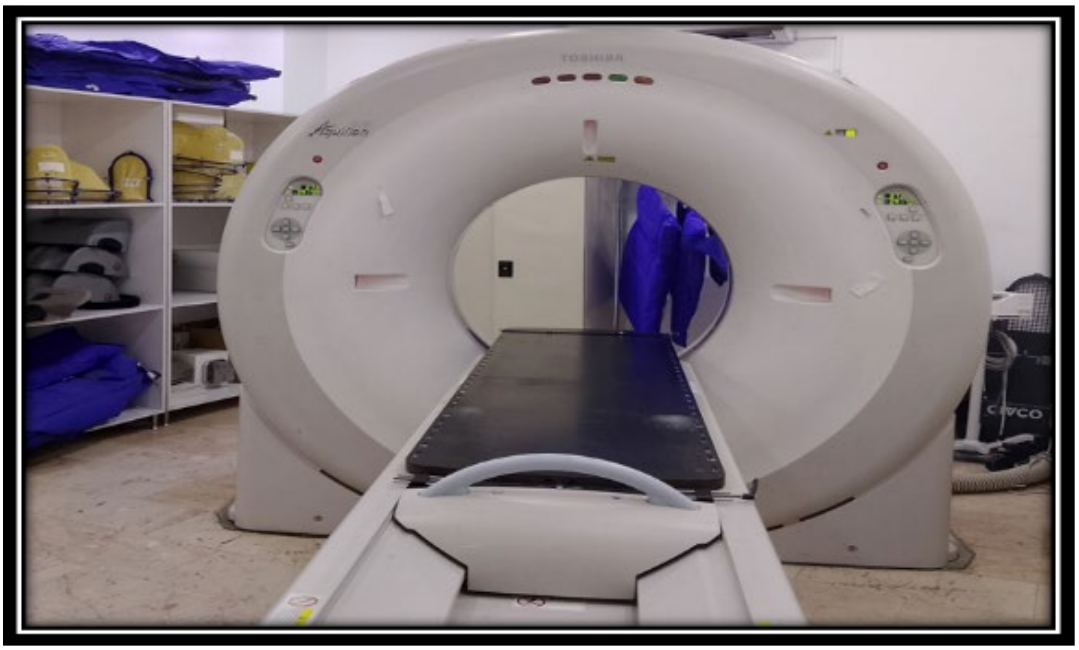

**Figure 1** CT simulation.

CT simulation (3 mm slice thickness) of all pelvis and abdomen is gained at the therapy position. Immobilization devices are used. At the supine position, the patient is positioned with a sleeping pad under head, knee and ankle support pillows, and their arms resting on them chests as at Figure 2.

**Figure 2** Position bladder (Supine) in CT simulation.

At prone position, patient is positioned with a sleeping pad under head, ankle support pillows, and the arms are with level head as in Figure 3.

**Figure 3** Position Rectum (Prone) in CT Simulation.

The radio-opaque lead pellet rectal tattoo is placed ventrally on the rectal edge by the oncologist Photography instructions, patient gave orders to empty bladder and rectum fully and then drink three cups of water and then he waits half-hour prior CT simulation [21-22].

*2.2.2 Delineation and planning*

After a CT Simulation has been gained, them are transported to network Monaco to work delineation tumor and critical organs and are contoured by the oncologist physician, the CTV (clinical target volume) at PTV (planning target volume) edges of 10 mm are added at to set clinical target volume, and then send to TPS to make the therapy plan and it is returned to CT Simulation to make tattoo. Firstly, we put a point of interest ~POI! Called the ‘‘CT Isocenter’’ [23].

At supine or prone position while utilize three radio-opaque labels down laser filed instruction at Computer Tomography simulation plan stride. It is memorable that these marked tattoo on a skin. or patient’s thermoplastic only to be stable to another fraction. Then the CT image is sent from TPS (DRR) is computed to linear accelerator (LINAC). That DRR is considered to be a reference image to install position the patient [24].

Patients they entered for therapy is determined isocenter by laser followed by CT simulation kilovoltage (kV) radiographs to visualize bony anatomy and implanted tattoo. Direction of couch shifts to isocenter rectification wanted is specific by picture recording to bony anatomy and implanted tattoo. The EPID pictures are compared with DRR while a reference the 3D surface pictures are acquired by Align RT. A surface pictures are obtain before to all next set-up step. a systematic error and random error along vertical and longitudinal axes are calculated while compared for the twain systems [25].

Rectum is a fraction from the lower gastrointestinal tract is the final straight portion of the large intestine in body. Rectum is about 4.7 in (12cm) lengthy, and start at the rectosigmoid junction (end of the sigmoid colon) at the level of third sacral vertebra or sacral promontory. Its diameter is similar to that of sigmoid colon at its commencement, but it is dilated near its termination, forming rectal ampulla. It terminates at level of anorectal ring (the level of the puborectalis sling) or the dentate line. Rectum is followed by the anal canal, which is about 1.6 in (4 cm) lengthy, prior the gastrointestinal tract terminates at the anal

verge. Rectum lies in front of the sacrum. It lies behind the bladder in males (left), and the vagina and uterus in females (right) as in Figure 4 [26].

Bladder is a hollow member in body that warehouse urine from the kidney's prior get rid of it by urination. Urine come into bladder via the ureters and comes out across the urethra. Bladder is a distensible organ that sits on the pelvic floor. Typical adult human bladder will hold between10 and 17 fl oz (300 and 500 ml) before the urge to empty occurs, but can hold considerably more as in Figure5. [27].

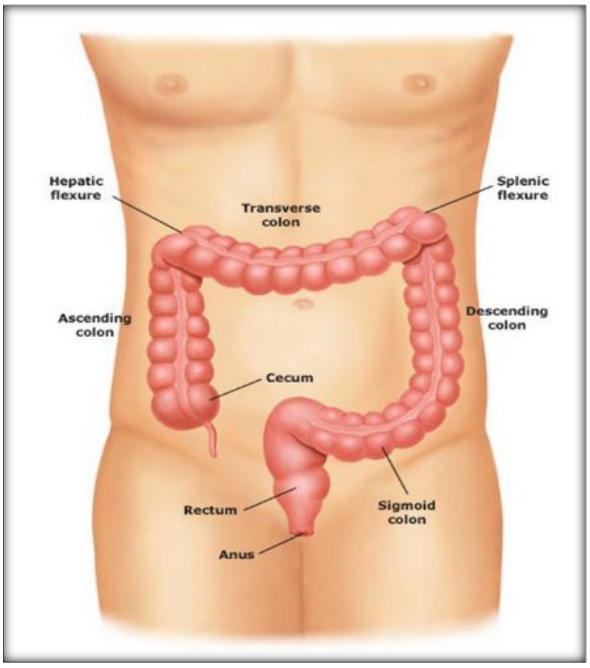


**Figure 4** Shape of Rectum.

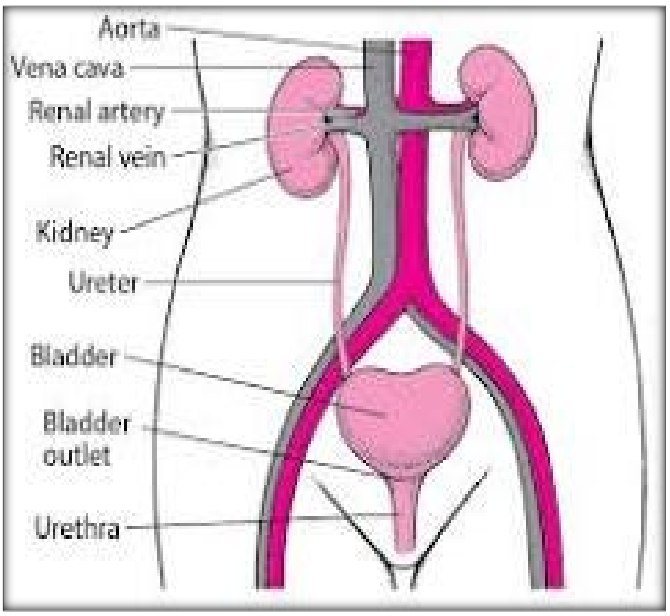


**Figure 5** Shape of Bladder.

Patients ’bladder and rectum cancers are treated together with a 3D-plan, isocentre 4-fields box technicality in a field energy of 6and 10 Mv. Whole beams are applied to person's anatomy and irradiation in every day. One session is 2 Gy delivered to the isocentre, while the 95% in PTV. Total doses ranging from 50 Gy per 25 fractions are applied. Radiotherapy planning system the plan computer tomography simulation at a therapy site is a step for whole patients. A Clinical Target Volume while the normal tissue is summarized in every slice. A completed coverage of a CTV a spot edge of 10 mm is add up to the surroundings to manufacture the planning target volume PTV. Field shape is completed by the coverage the edge regularly distributed for about (5 mm) to account for field penumbra [28]. Figures 6,7 represent a planning treatment system for the bladder and rectum. Total bowel and small bowel are delineated at all CT slice by specifies the outward extensions of to them loops and that way determine the full size occupied by the members. Cranial border of members is outlined at level where duodenum meets jejunum [29].

**Figure 6** Planning Treatment System Bladder.

**Figure 7** Planning Treatment System Rectum.

*2.2.3 Investigation*

Afterward if the displacements are accepted (rectification criterion is set- up >5 mm), following picture it is approved daily. Displacements amidst a DRR while the picture gained by electronic portal images the gantry angles at 0°and 90° projection are rated on straight line three main directions by corresponding static bony tattoo. A CT-image tattoo utilized in (EPID) is a coccyx bone for 90°portal picture [30]. Figures 8,9 represents DDR of bladder and rectum:

**Figure 8** DDR of bladder.

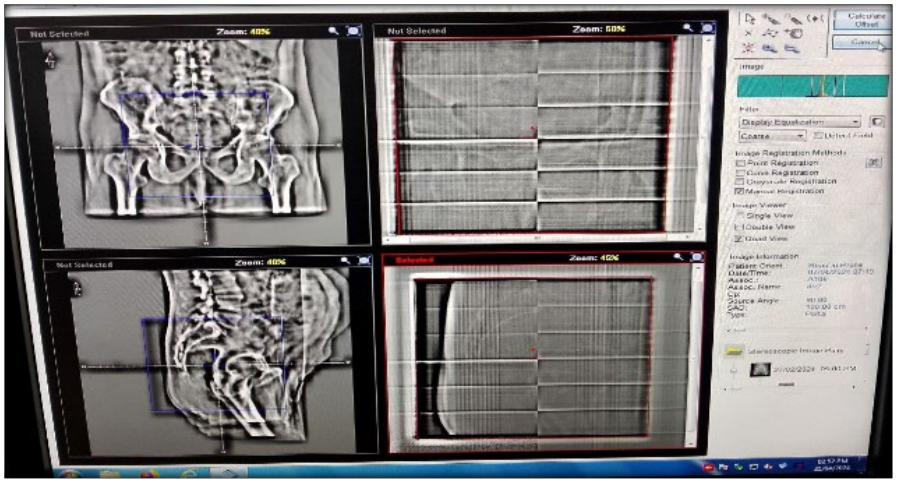

**Figure 9** DDR of rectum.

The steps can be summarized set-up errors in the following Figure 10:

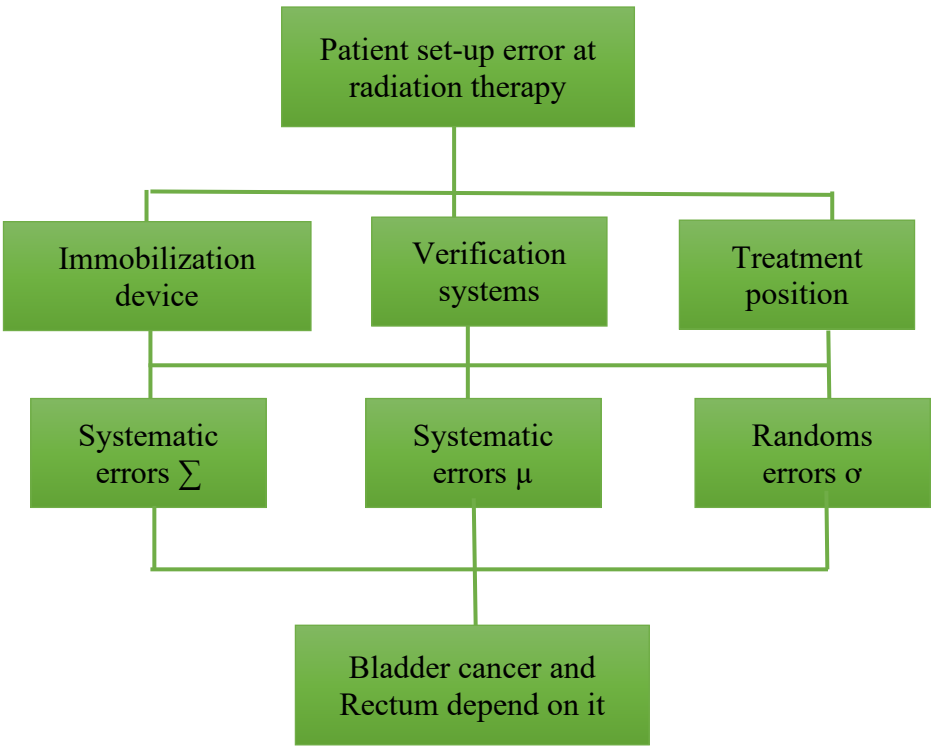


**Figure 10** Workflow setup errors of patient in radiation therapy.

*2.2.4 Electronic portal imaging (EPI)*

Prior all treatment fraction, patient is motionless used suitable positioning device, while them site is certain over laser bias or skin tattoo with in the therapy room. Perpendicular portal picture is gained utilize a high-resolution, plane-tablet, amorphous silicon digital portal image device. This image is compared for DRR generated of perpendicular portal picture gained at angle gantry 0° and 90° utilize treatment planning system (TPS). Three interpretation direction (vertical Y, lateral X, longitudinal Z), are working for research cancer people set-up problem [31].

*2.2.5 Evolution of setup errors*

The estimate the random errors, the systematic errors. 'Systematic errors' defined is an error that is methodical generated at to be sure direction due to sundry specified reasons. That errors can be amendment by calculates like as image - guided radiotherapy. Mostly, two kinds of systematic (μ, Σ) have been utilized to estimate set-up error. The systematic errors (Σ) are generally utilized for an analysis of numerous specimens. 'Random errors' are a casual error which happen resultant to an unknown reason. Even though it can to make little to several range when some calculated, it is tricky to displace. In a ready patient's concatenation, a (Σ) is measures as subsequent. The medium value ($m_1$, $m_2$… mn) m1 it is mean1 and m2 it is mean2 of the perversion amidst the (DRR) digitally reconstructed radiographs while portal image is studied for the (X, Y, Z) axes respectively, for all patients (1, …N). A systematic error μ: are known as the mediocre to all patients' perversion ($m_1$, $m_2$… mn) to (X, Y, Z) axes respectively, as subsequent:

*Systematic errors (μ) = mean ($m_1$, $m_2$,… mn)* (1)

A systematic error (Σ): the standard deviation (SD) to all patient's perversion ($m_1$, $m_2$… mn) for the (Y, X, Z) axes, respectively, as subsequent:

*Systematic errors (Σ) = SD ($m_1$, $m_2$,… mn)* (2)

The random errors are studied as subsequent:

*Random error (σ) = SD ($\sigma_1$, $\sigma_2$, …, σn)* (3)

$\sigma_1$ it is random error 1and $\sigma_2$ it is random error 2,
the standard deviations amidst the digitally reconstructed radiographs while portal images are studied for the (X, Y, Z) axes respectively, for all patients (1, 2, …, n) [32].

## 3. RESULTS AND DISCUSSION

### *3.1 Characteristics of Patients*

The characteristics of the Bladder cancer and Rectum patients included in this research are provided in Schedules 1, 2. Perpendicular image couples are obtained utilizing EPID (electronic portal imaging) for all patients, with 375 picture pairs for Bladder cases and 250 image pairs for Rectum cases. Table 1, 2 illustrate the characteristics of patients with bladder and rectum:

**Table 1** Characteristics of Patients (selection) with Bladder tumor.

| Patients | Characteristics teristics | Patients | Characteristic s |
|---|---|---|---|
| Gender | Male | Gender | Female |
| Bladder | 10 | Bladder | 5 |
| Age | 45-50 | Age | 45-50 |
| Dose | 50 Gy | Dose | 50Gy |
| Fraction | 25 | Fraction | 25 |
| Diagnosis | 67 | Diagnosis | 67 |

**Table 2** Characteristics of Patients (selection) with Rectum tumor.

| Patients | Characteristics |
|---|---|
| Gender | Male |
| Rectum | 10 |
| Age | 45-50 |
| Dose | 50Gy |
| Fraction | 25 |
| Diagnosis | 20 |

**Table 3** Explains values the systematic (μ and Σ) and random errors.

| patient | Systematic error ∑ (cm) | | | Systematic error μ (cm) | | | Random error (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| | X | Y | Z | X | Y | Z | X | Y | Z |
| Bladder | 0.02 | 0.03 | 0.01 | 0.32 | 0.21 | 0.14 | 0.05 | 0.06 | 0.04 |
| Rectum | 0.04 | 0.03 | 0.02 | 0.33 | 0.23 | 0.15 | 0.03 | 0.04 | 0.09 |

*3.2 Systematic error (μ) while systematic error (Σ)*

A μ for (X, Y, Z) axes amid a sum for 15 bladder cancer patients are (0.32, 0.21, 0.14) cm, respectively (Figure 11 A) The X-axis of a Systematic error (μ) appeared a significant several amidst bladder, however, each to (μ) values to X-axis is < 0.35 cm, what holds the view clinically insignificant. They compared the μ (X, Y, Z) axes. B (Σ) for axes amid the sum patients are (0.02, 0.03, 0.01) cm, respectively (Figure 11B). The Y-axis of a Systematic error (Σ) appeared significant several amidst the bladder, however, each to (Σ) value to the X-axis is < 0.034 cm, which holds the view clinically insignificant. They compared an X-axis, Y-axis, and Z-axis.

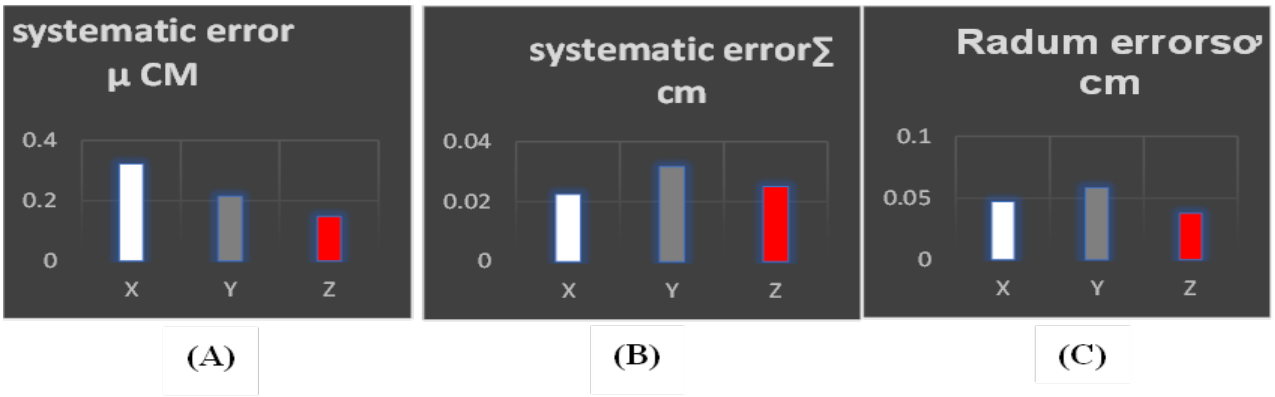


**Figure 11** Systematic errors (μ) A, of the X- axis, Y-axis while Z-axis directions; B, systematic error (∑) to (X, Y, Z) axes; C random errors (σ) of the (X, Y, Z) axes directions of bladder cancer patients (15 patients). The white, gray, and red mention the data for all-patient chain.

A random error (σ) to (X, Y, Z) axes within a sum patient are (0.05, 0.06, 0.04) cm, respectively, as explained at (figure 11 C). The Y-axis of a Systematic error (Σ) appeared a significant several amidst bladder, however each to (Σ) values to X-axis is < 0.06 cm, what hold the view clinically insignificant. They compared the (X, Y, Z) axes, that is considered clinically not important, within the sum, bladder patient.

A systematic error (μ) for (X, Y, Z) axes amid a sum to 10 rectum cancer (X, Y, Z) axes amid the sum patients are (0.33, 0.23, 0.15) cm, respectively figure 12- A, however each to (μ) values to X-axis is < 0.35 cm, what hold the view clinically insignificant. They compared the (X, Y, Z) axes, systematic error (∑) for (X, Y, Z) axes amid (X, Y, Z) axes amid the sum patients are (0.04, 0.03, 0.02) cm, respectively. As shown in figure 12- B, however each to (μ) values to X-axis is < 0.03 cm, what hold the view clinically insignificant. They compared the (X, Y, Z) axes the check rectum indicated no evident several at a systematic error (μ or Σ) to (X, Y, Z) axes. As shown in figure 12- A, B.

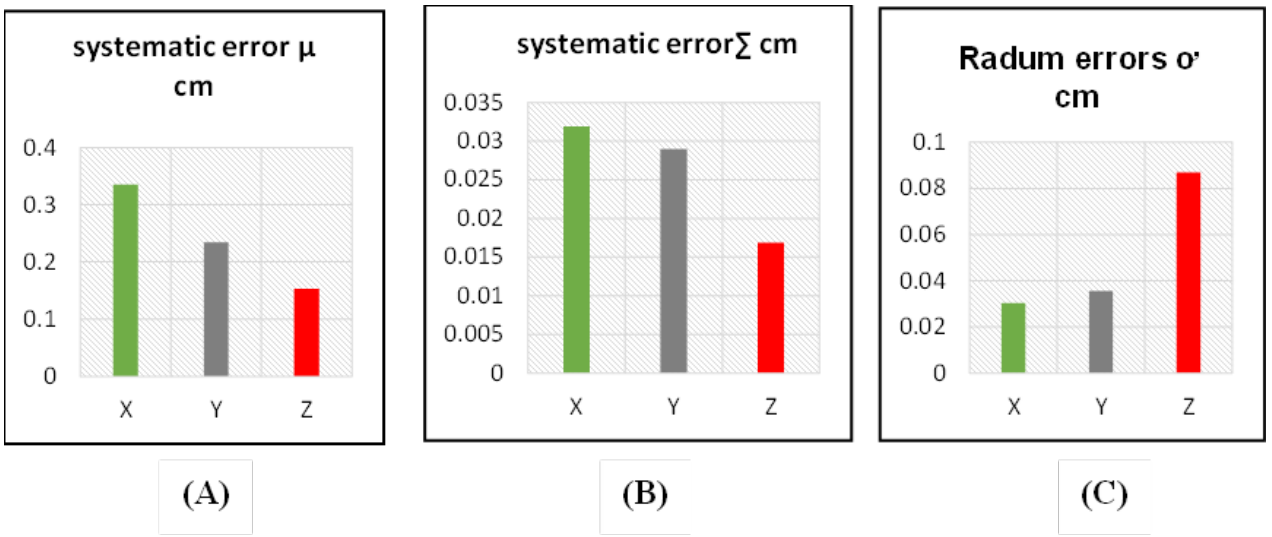


**Figure 12** Systematic errors (μ) A, of the X- axis, Y-axis while Z-axis directions; B, systematic error (∑) to (X, Y, Z) axes; C random errors (σ) of the (X, Y, Z) axes directions of rectum cancer patients (10 patients). The white, gray, and red mention the data for all-patient chain.

A random error to (X, Y, Z) axes within the patients are (0.03, 0.04, 0.09) cm, respectively, as explained in Figure12C, however, each to (μ) values to Z-axis is < 0.09 cm, what hold the view clinically insignificant. They compared the (X, Y, Z) axes. Us compared a random error by means of (X, Y, Z) axes while us observed this the magnitude of each of the random errors is <0.09 cm, what is considered clinically no important, within the sum, rectum patients [32].

This cross-sectional study to define overall inclusive for our configuration steps and for measures the suitable clinical target volume - planning target volume edges for adopt when definition cancer size. Valuation of configuration variance is fundamental in order that an effectiveness of radiation treatment depends on the patient's position, immobilization and clinical experience for employees. And unsuitable contouring of planning target volume may lead to lack at cancer planning or for a raise the dosage at critical organs at the rear of CTV.

The systematic errors and random errors in this research. They are errors produced through the transport of the simulation to the therapy room may be the most substantial reason for systematic errors. Inexactness at skin markers points, while the patient's setup depends on their, as at the research, or markers on a restraint might other sources of systematic error. Another reason that as shifts at the isocenter for therapy room or at a laser filed locator or droop painting top maybe possible sources of errors. The bladder cancer irradiation treatment conducted at our hospital in every day fulfill are as little as ≤ 0.06 cm. The rectum cancer irradiation treatment conducted at our hospital in every day fulfill are as little as ≤ 0.09 cm at both the (X, Y, Z) axes, what appear clinically allowable. As explained in the schedule (3). That mobility is so recurrent at obese patients like ours. As at simulator while radiation therapy, patients are repositioned together with reference for the bias for profiling lasers with the lateral landmarked while skin markers putted at front as well as monitoring for board altitude. Amaoui [30] found the random and systematic errors are bigger at direction of the x-axes than those in the y-axes and z-axes, what could be explained by the mobility of the skin markers (anterior) on the abdominopelvic wall causing tend for the left or to right compared for the veritable isocenter. Likewise, Noghreiyan [24] and others. Our results disagreed with previous research conducted [33]. The set-up uncertainties bladder and rectum patients can be caused by different factors, included the cancer has change in size due to distention or shrinkage after radiation, alteration in patient weight during sessions that can alter the contouring of the tumor, the patient inability to empty the bladder and rectum completely [34]. Which

can cause skin markings to shift into the therapy areas due to inaccurate laser and optical illusion, clinically permissible [35].

## 4. CONCLUSIONS

In this research, apply the correct position of the patient in the room treatment boost separately gives on the better Planning Target Volume (PTV) coverage, without introducing additional hot area in the normal tissue. An extent of systematic error and random error in inter-sessions setup of bladder and rectum radiation treatment were investigated. The results confirm this the setup precision of patient's treatment together with 3DCRT bladder and rectum radiation therapy. At (CTV) edges can within that 90% of the bladder and rectum tumor patients shall extradite ≥ 95% for specified dosage at (CTV) area. A mensuration for accuracy rendering precision of linear accelerator, (EPID, MOSAIQ) software was accepted while inside the tolerance uncertainties. Lastly, the electronic portal image device proposes as a safe system for the emendation of geometrical inter-session's error in radiation therapy division wherever the popular radiation therapy was (3DCRT).

## References

[1] K.P. Olive, D.A. Tuveson, Clin. Cancer Res. 12 (2006) 877 https://doi.org/10.1158/1078-0432.CCR-05-1777
[2] S.H. Hassanpour, M. Dehghani, J. Cancer Res. Pract. 4 (2017) 877 https://doi.org/10.1016/j.jcrpr.2017.07.001
[3] R. Baskar, J. Dai, N. Wenlong, R. Yeo, K.W. Yeoh, Front. Mol. Biosci. 1 (2014) 24 https://doi.org/10.3389/fmolb.2014.00024
[4] J.A. Purdy, P. Poortmans, C.A. Perez, Springer, Berlin Heidelberg, 2011
[5] I.C. Costin, L.G. Marcu, Crit. Rev. Oncol. Hematol. (2022) https://doi.org/10.1016/j.critrevonc.2022.103613
[6] F.M. Di Maggio, F.M. Minafra, L. Forte, G.I. Cammarata, F.P. Lio, C.D. Messa, V. Bravatà, J. Inflamm. 12 (2015) 877 https://doi.org/10.1186/s12950-015-0062-5
[7] J. Van Dyk, Int. J. Radiat. Oncol. Biol. Phys. 71 (2008) 877 https://doi.org/10.1016/j.ijrobp.2007.11.026
[8] S. Momin, Y. Fu, Y. Lei, Y.J. Roper, J.D. Bradley, W.J. Curran, X. Yang, J. Appl. Clin. Med. Phys. 22 (2021) 877 https://doi.org/10.1002/acm2.13170
[9] F.M. Khan, J.P. Gibbons, Khan's The Physics of Radiation Therapy, 6th ed., Wolters Kluwer Health, Baltimore, 2020
[10] J.T. Hepel, M. Tokita, S.G. MacAusland, S.B. Evans, J.R. Hiatt, L.L. Price, D.E. Wazer, Int. J. Radiat. Oncol. Biol. Phys. 75 (2009) 877 https://doi.org/10.1016/j.ijrobp.2008.11.019
[11] R.J.W. Louwe, E.M.F. Damen, M. Van Herk, A.W.H. Minken, O. Törzsök, B.J. Mijnheer, Med. Phys. 30 (2003) 877 https://doi.org/10.1118/1.1591193
[12] S.S. Abdullah, Baghdad Sci. J. 18 (2021) 877
[13] S. Sami, B.S. Hameed, N.M. Alazawy, M.J. Al-Musawi, J. Phys.: Conf. Ser. 1829 (2021) 877 https://doi.org/10.1088/1742-6596/1829/1/012040
[14] H. Jawad, M. Esmaeel, M. Khalil, H. Kamil, A. Ghalib, AIP Conf. Proc. 2398 (2022) 877 https://doi.org/10.1063/5.0080785
[15] G.P. Liney, B. Whelan, B. Oborn, M. Barton, P. Keall, Clin. Oncol. 30 (2018) 877 https://doi.org/10.1016/j.clon.2018.04.003
[16] G.M. Herman, Semin. Radiat. Oncol. 15 (2005) 157–167 https://doi.org/10.1016/j.semradonc.2005.02.003
[17] I. Kaur, S. Rawat, P. Ahlawat, A. Kakria, G. Gupta, U. Saxena, M.B. Mishra, J. Med. Phys. 41 (2016) 877 https://doi.org/10.4103/0971-6203.181646

[18] Y. Yang, S. Cai, T. Zhao, Q. Peng, J. Qian, Y. Tian, Transl. Cancer Res. 9 (2020) 877 https://doi.org/10.21037/tcr.2020.02.14
[19] L.L. Monteiro, J.A. Witjes, P.K. Agarwal, C.B. Anderson, T.J. Bivalacqua, B.H. Bochner, W. Kassouf, World J. Urol. 37 (2019) 877 https://doi.org/10.1007/s00345-018-2442-0
[20] H. Li, C. Noel, H. Chen, H.H. Li, D. Low, K.S. Moore, Med. Phys. 39 (2012) 877 https://doi.org/10.1118/1.4736800
[21] J.F. Wang, H.X. Li, H.H. Huang, Y.M. Zou, J. Huazhong Univ. Sci. Technol. Med. Sci. 36 (2016) 877 https://doi.org/10.1007/s11596-016-1570-1
[22] A. Hijab, B. Tocco, I. Hanson, H. Meijer, C.J. Nyborg, A.S. Bertelsen, S. Hafeez, Front. Oncol. (2021) https://doi.org/10.3389/fonc.2021.652361
[23] W.A. Tome, R.A. Steeves, B.P. Paliwal, J. Appl. Clin. Med. Phys. 1 (2000) 58–67 https://doi.org/10.1120/jacmp.v1i1.2425
[24] V.V. Noghreiyan, S. Nasseri, K.M. Anvari, M.N. Momennezhad, J. Radiother. Pract. 19 (2020) 877 https://doi.org/10.1017/S146039692000022X
[25] C.Y. Jason, M.M. Qureshi, P. Clancy, L.N. Dise, J. Willins, A.E. Hirsch, Quant. Imaging Med. Surg. 5 (2015) 665 https://doi.org/10.3978/j.issn.2223-4292.2015.03.06
[26] J.M. Lee, N.K. Kim, Ann. Coloproctol. 34 (2018) 59 https://doi.org/10.3393/ac.2018.34.2.59
[27] K.M. Georgas, J. Armstrong, J.R. Keast, C.E. Larkins, K.M. McHugh, E.M. Southard-Smith, C. Mendelsohn, Development 142 (2015) 1893–1908 https://doi.org/10.1242/dev.119495
[28] U. Mock, K. Dieckmann, U. Wolff, T.H. Knocke, R. Pötter, Int. J. Radiat. Oncol. Biol. Phys. 45 (1999) 877 https://doi.org/10.1016/S0360-3016(99)00252-8
[29] T.C. Frøseth, T. Strickert, K.S. Solli, Ø. Salvesen, G. Frykholm, R.J. Reidunsdatter, Radiat. Oncol. 10 (2015) 1–9 https://doi.org/10.1186/s13014-015-0462-9
[30] B. Amaoui, A. Hadaoui, D. Mouhssine, S. Semghouli, Radiat. Med. Prot. 1 (2020) 877 https://doi.org/10.1016/j.radmp.2020.03.002
[31] H. Alabedi, Baghdad (2023)
[32] K. Miyahara, M. Kuroda, Y. Yoshimura, H. Aoyama, M. Oita, I. Sugianto, M. Hidenobu, I. Hiroki, K. Norihisa, K. Kuniaki, J. Asaumi, Acta Med. Okayama 72 (2018) 877 https://doi.org/10.18926/AMO/56384
[33] A. K. Rahman, L. S. Chen, M. I. Al-Khalidi, Exp. Theo. NANOTECHNOLOGY 10 (2026) 115–124 https://doi.org/10.1234/etnano.2026.115
[34] P. D. Morais, H. Y. Zhang, R. El-Shazly, T. Novak, Exp. Theo. NANOTECHNOLOGY 10 (2026) 201–213 https://doi.org/10.1234/etnano.2026.201
[35] S. M. Kareem, J. T. Wallace, D. R. Singh, Exp. Theo. NANOTECHNOLOGY 10 (2026) 298–309 https://doi.org/10.1234/etnano.2026.298