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RESEARCH ARTICLE

Assessment of Setup Errors in Breast and Uterus Radiotherapy Using EPID

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ABSTRACT

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 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 (planning treatment volume) follows on set-up edges. Set up errors for the radiation oncology collective to minimize the therapy error. Position errors explain the variance between the first position the patient was scanned at the Computer Tomography (CT) simulation and the set-up position in the therapy couch. The most commonly evaluated errors in radiotherapy are random errors and systematic errors. Tumors of breast cancer and the uterus are the most common conditions in women. We use the EPID (electronic portal imaging device) to measure the photon intensity a patient transmits from an irradiation port through a therapy fraction. This research aims to define a systematic random error for patients with breast (right and left) cancer (N = 15) and uterus cancer (N = 9). The systematic error for a breast patients was (0.02, 0.04, 0.06 cm) on the (x, y, z) axes, whereas for uterus patients, it was (0.07, 0.09, 0.03 cm). The breast cases had a random error of (0.02, 0.08, 0.01 cm) on the (x, y, z) axes, respectively, while the uterus cases had a random error of (0.02, 0.18, 0.04 cm). Radiation therapy uses a linear accelerator (Elekta).

Keywords: Breast cancer, Electronic portal image device (EPID), LINAC, Radiation therapy, Uterus cancer

Introduction

Radiation therapy is one of the main therapies used for cancer treatment, involving delivered ionizing radiation to kill cancer cells and shrink cancer. [1,2] Controlling the absorbed dose released to the cancer is crucial, and we should also aim to obtain as little radiation as possible in normal cells. [3,4]

Three-dimensional conformal radiotherapy treatment (3-D CRT), which is based on 3D body input, aims to give the tumor the right amount of radiation while keeping the dose to vital organs as low as possible. [5,6] Portal crossing dosimetry, using an electronic portal imaging machine (EPID), is a technique wherever dose measurements made backward a patient is used to verify the dose to the patient. [7–9]

In radiation treatment, careful and red tape target localization is required for effective results. The electronic portal imaging device (EPID) supplies important instruments together with digital technology to improve target localization while preserving clinical aptitude. Radiotherapy clinics widely use EPIDs powerful and flexible devices that can combine and operate data quantitatively, thereby improving therapy precision for any therapy position. [10] Portal imaging can measure set-up uncertainty by applying megavoltage film or an electronic portal imaging device (EPID). [11] We can classify a setup error into two types: systematic error and random error. The systematic component of setup errors arises from errors made during therapy preparation, while the random component describes errors made during therapy enforcement. Systematic error production

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occurs when the dosage allocation deviates from the clinical target volume (CTV), while random errors obscure the dosage allocation around the CTV. The radiation therapy investigation process aids in ensuring that the PTV aligns with the therapy planning.[12,13] Many oncology hospitals routinely use portal imaging to calculate patient setup errors.[14] Abnormal cell growth due to a change in DNA[15] causes cancers of the breast and uterus. Radiotherapy is a type of tumor therapy that employs high-energy ionizing radiation to deliver a large, absorbed dose to a specific target volume, thereby eliminating the tumor with the least amount of damage to the surrounding healthy tissues.[16] This work aimed to verify whether correct treatment setup errors utilize the EPID (electronic portal image devices) for breast and uterus cancer patients' treatment via three-dimensional conformal radiation therapy while also assessing the setup edge and defining a systematic and random error of radiotherapy for these patients.

Materials and methods

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

From November 2023 to March 2024.

Immobilization simulation and planning

The planning operation involves the localization of the treated volume. This comprises defining the position of the tumor and normal tissue in a patient. The CT (computed tomography) simulation consists of a CT scanner, a flat tabletop, an external laser for patient position adjustment, a tattoo system for marking the patient's body, and tools for patient stabilization. We use virtual simulation software for the treated isocenter beams to determine the contouring of the target and critical organs, as well as the position from which the beams plan their treatment. The simulation includes the taking of the CT image, DRR (digitally reconstructed radiographs), and documentation based on the image.[17,18]

DRR the image produced through the TPS (treatment planning system) using utilizing imported pictures of a CT simulation. One can generate DRR at any level, not just the picture conquest level. Therapy projects can setup the fineness of DRR in several ranges; however, this depends on the CT simulation data.[19] We compared the EPID device pictures (portal images) with DRR, and used Align RT's 3D surface pictures as a reference. Before setting up the patient, we obtained a surface picture. We calculated a systematic error and a random error along the vertical, longitudinal, and Coronal axes during the therapy session.[20]

A breast is composed of glandular tissue, which produces milk, and adipose tissue. However, the ratio of glandular to adipose tissue varies among individuals. A mamma is heavily affected by the sex hormone estrogenic. As menopause approaches, the level of oestrogen decreases, leading to a reduction in glandular texture. The pectoralis main muscle, which soon extends from the second to sixth rib, forms the basis of a mamma, which grows while lolling. The Cooper bond anchors a mamma to the pectoralis main fascia. However, these bonds are elastic, allowing for movement at the breast. In general, as women age and grow older, their Cooper bonds tend to stretch together, leading to the formation of a breast pouch. In terms of specific gravity, the lower pole of a mammary gland is larger than the upper pole. The breast's side rim is located at position.[21]

A filed setup was used for perfect breast radiation with two merroirs. The therapy was delivered with the TPS (treatment planning system) armed together with an electronic portal image device (EPID).[22,23] The setup involved positioning the breast at a supine site, with one arm raised high overhead. A fixative angle of the arms' favouritism was used to replicate site.[24] We determined the median and profiling limits through physical examination. We selected a lower or medium-sized clavicle head as the cranial fringe, allowing for the supraclavicular lymph node, and used 2 cm beneath a breast tuck as the caudal boundary. We sliced the CT simulation into a thicker form (3 mm). A picture set-up transports for an irradiation TPS. The preceding description detailed a procedure for contouring the PTV and critical organs. The PTV was produced by removing (5 mm) of a skin surface to form the total tumor. The basal setup followed the skin space process, selecting an optimal median and side-opposed tangent trend. Once we identified the median and side isocentre of the simulator, we applied the beam-on-beam technique to the plan lump. We specified a total of 40.5 Gy at 15 fractions, paired with a 6 MV photon, for the entire target tumor.[25] Used program XiO- Monaco is a comprehensive 3D IMRT treatment planning platform that combines the latest tools and most robust calculation algorithms with an intuitive, user-friendly interface, allowing users to generate plans quickly and accurately to optimize radiation therapy delivery. As shown in Fig. 1.

The EPID data were looked at to find out more about the skin markers CTV (clinical target volume) that were in an irradiation portal image. In patients, bony and medial tattoos are preferred when the tattoo site changes by more than 3 mm together, as they are in a more stable anatomical area.[26]

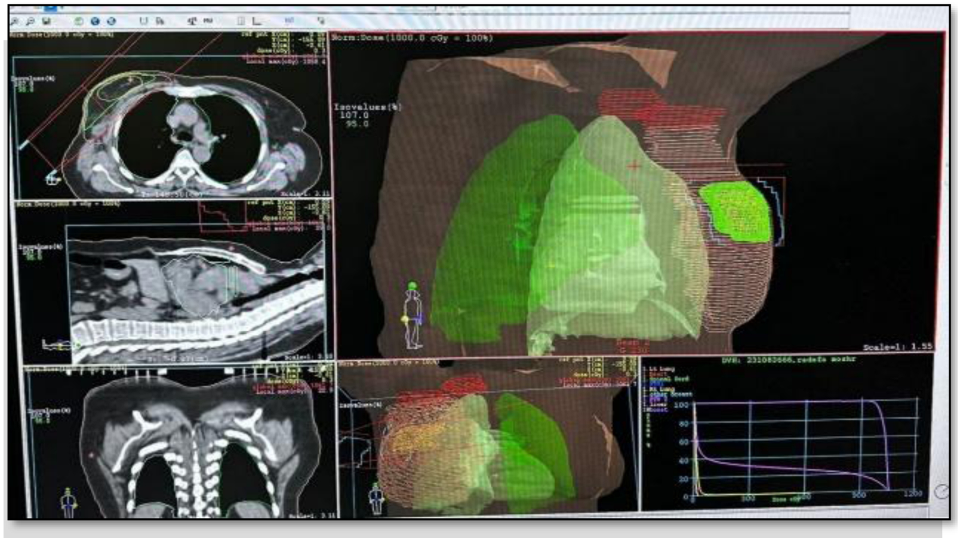


Fig. 1. Planning treatment system breast from the XIO program.

A uterus is an inverted pear-shaped muscle member in a woman's reproductive system, located between a bladder and a rectum. The uterus positions itself to supply and deliver the inseminated eggs to the unborn child.[27] The uterus censors of the patients were treated together using a 3D-plan, isocenter 4-fields box technique, operating at a field energy of 10 Mv. Whole beams were applied to a person's anatomy and irradiation in everyday life. One session was 2 Gy delivered to the isocenter, while the 95% was in PTV. We applied total doses ranging from 50 Gy to 25 fractions.

The simulator was the first step in recording radiation therapy images. External fixing devices assisted in positioning the patient's supine. Add the CTV edges of 10 mm to the surrounding area to calculate the PTV, which is used for treatment volume planning. The Treatment Planning System (TPS) creates a treatment plan for patients by covering the CTV and PTV, reducing radiation exposure to normal tissue, and summarizing it in each slice. The coverage completes the field shape, with the edge regularly distributed for approximately 5 mm to account for field penumbra. We then obtained localization radiographs for whole beams, which are representative of the intended optimal therapy site. Beams align while the isocenters where tattoos on a skin utilize midline longitudinal, lateral longitudinal, and pass-board horizontal laser fields. Through radiotherapy therapy, determination steps are aligned with laser-dropping together with a tattoo on the skin. Using the base of a simulator image, we were able to accurately assess the beam bias. Utilize an imaging system (EPID); first, double-exposed investigation images were obtained; follow up by containing images during the therapy course. The images are completed daily throughout the treatment. Information evaluation of set-up displacements indicates to picture at an AP while left side view. A criterion step for determining setup errors was the visible comparison of simulator films while the investigation picture was being taken. If necessary, we applied the first revision to the beam site before starting radiotherapy.[28] Fig. 2 illustrate Planning treatment system uterus XIO program.

Investigation

Our foundational daily routine investigation utilizes electronic portal images (EPI). The virtual simulator transported the circumference of the target breast volume to the DRR images. In all sessions, the appropriate site was verified by chance amidst skin markers and room therapy laser beaming the axial, sagittal (X), longitudinal (Y), and coronal (Z). The first anterior portal is obtained, then the side image. At the base of the chest wall (contour lung and ribs), an optimized shifts beeline the SI (superior-inferior), RL (right-left), while (AP) anterior-posterior axes.[25]

Before initiating the therapy, the patient utilized the Immobilization External System, which was set up in conjunction with the therapy laser, using a marker as a leader. We set the linear accelerator head angles to (0°) frontal and 90° side to obtain a perpendicular portal picture using a (6 MV) X-ray field, and then modelled the radiation time using 3 MU monitor units. We obtained the portal image by capturing pro-therapy images for each patient. We compared the portal image with DRR, using image.[29]

Afterwards, if the displacements meet the rectification criterion of >5 mm, the following picture

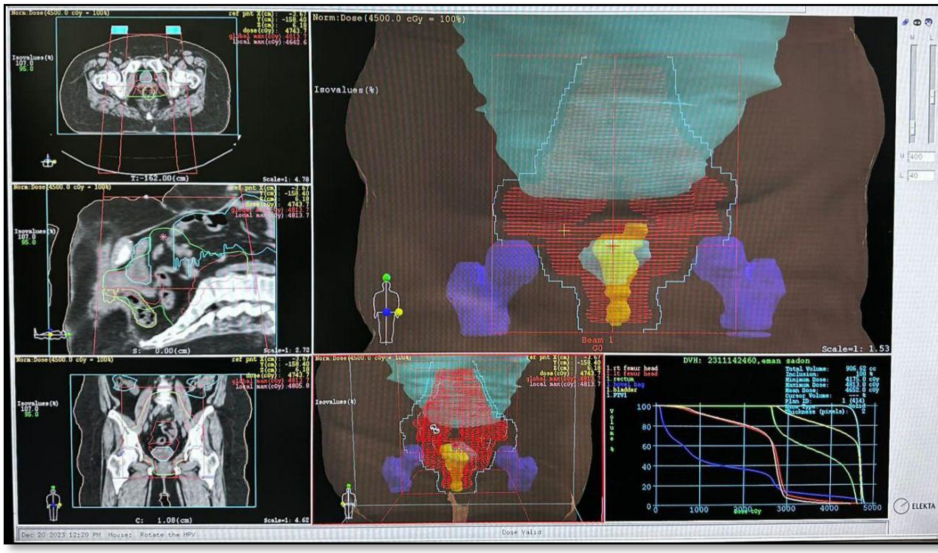


Fig. 2. Planning treatment system uterus XIO program.

Fig. 3. DDR of breast.

receives daily approval. The displacements within a DRR were measured using electronic portal images, and a corresponding static bone tattoo rated the gantry angles at 0° and 90° projection on a straight line in three main directions. The coccyx bone served as a CT-image tattoo for the 90° portal picture in the EPID.[29,30] Figs. 3 and 4 represents DRR of breast and uterus.

Electronic portal image device (EPID)

Before each treatment fraction, the patient remained motionless and utilized a suitable positioning device, ensuring the site was clear of laser bias or skin tattoos within the therapy room. The perpendicular portal picture was obtained utilizing a high-resolution, plane-tablet, amorphous silicon digital portal image device. We compared this image for DRR, which was generated from a perpendicular portal picture obtained at gantry angles of 0° and 90° using a treatment planning system (TPS). The three interpretation directions (vertical Y, lateral X, and longitudinal Z) were effective for cancer research participants who set up problems.[30]

Evolution of the set-up error

The estimate of random errors, the systematic errors systematic errors defined are errors that are

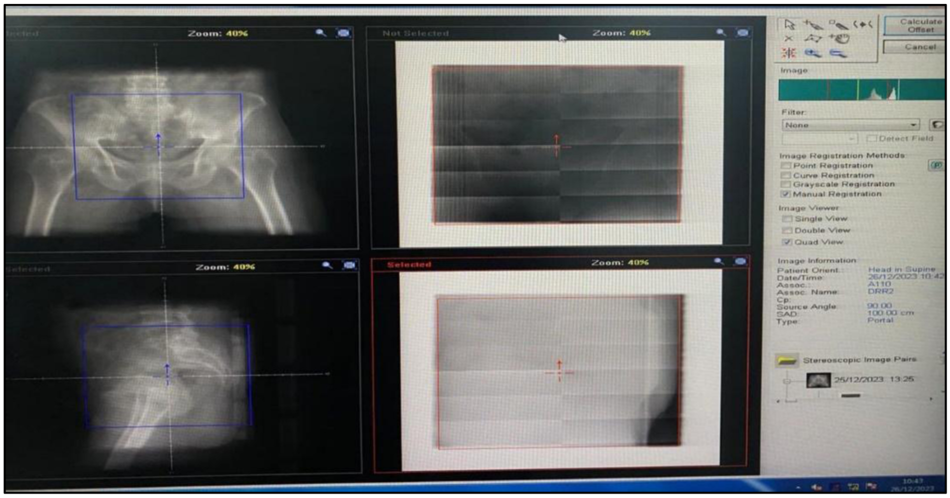


Fig. 4. DDR of uterus.

methodically generated in be certain direction due to various specified reasons. Those errors can be amended by calculations like image - guided radiotherapy. Mostly, (2) kinds of systematic (μ, Σ) have been utilized to estimate set-up errors. The systematic errors (Σ) are utilized for an analysis of numerous specimens.

Random errors are casual errors which happen for an unknown reason. Even though it can make little to several ranges when some are calculated, it is tricky to displace. In a ready patient's concatenation, a (Σ) was measured as subsequent. The medium value (m_1, m_2, $\cdots$, m_n) of the perversion amidst the (DRR) digitally reconstructed radiographs while the portal image was studied for the (X, Y, Z) axes respectively, for all patients (1, $\cdots$N).

A systematic error μ: were defined as the mediocre to all patients' perversion (m_1, m_2, $\cdots$, m_n) to (X, Y, Z) axes respectively, as subsequent:

$$\textbf{Systematicerrors}\,(\mu) = \textbf{mean}\,(\mathbf{m}_1, \mathbf{m}_2, \cdots, \mathbf{m_n}) \quad (1)$$

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

$$\textbf{Systematicerrors}\,(\boldsymbol{\Sigma}) = \textbf{SD}\,(\mathbf{m}_1, \mathbf{m}_2, \cdots, \mathbf{m_n}) \quad (2)$$

The random errors were studied as subsequent:

$$\textbf{Randomerror}\,(\sigma) = \textbf{SD}\,(\sigma_1, \sigma_2, \cdots, \mathbf{a_n}) \quad (3)$$

The standard deviations amidst the digitally reconstructed radiographs while portal images were studied for the (X, Y, Z) axes, respectively, for all patients (1, 2, n).[22]

Results and discussion

1. **Characteristics of patients**

Tables 1 and 2 explain the characteristics of the breast and uterus carcinoma patients included in that research. We obtained perpendicular image couples using the EPID electronic portal image device for all patients, which included 225 image husbands for breast cases (right and left) and 225 image pairs for uterus cases.

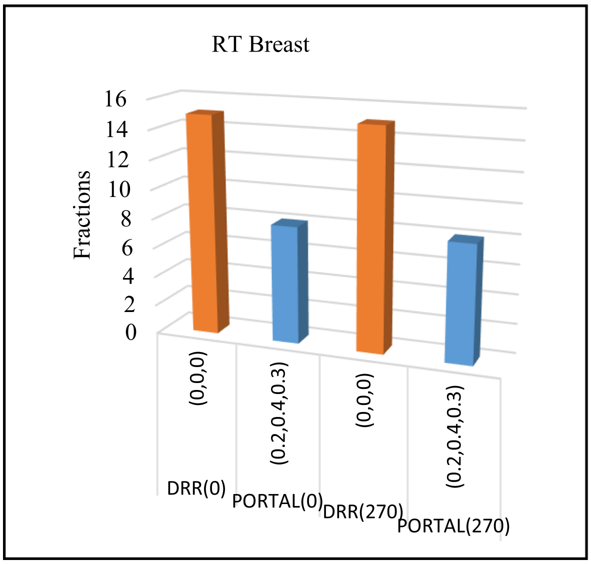
Table 1. Properties of patients (selection) together with breast carcinoma (right and left).

Patients	Characteristics
Breast number	15
Age	45–50
Dose	40.5 Gy
Fraction	15
Diagnosis	50

Table 2. Properties of patients (selection) together with uterus carcinoma.

Patients	Characteristics
Uterus number	9
Age	45–50
Dose	50 Gy
Fraction	25
Diagnosis	54

2. The relationship between fractions and digitally reconstructed radiographs is significant. The most common DRR, or portal image, is for the breast and uterus. The relationship between fractions and DRR, portal right and left breast, Uterus. As shown in Figs. 5 and 6.



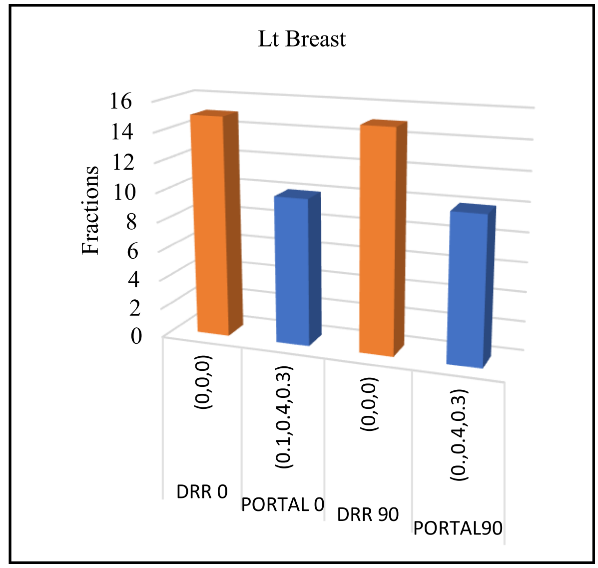


Fig. 5. The relationship between fractions and DRR, portal right and left breast.

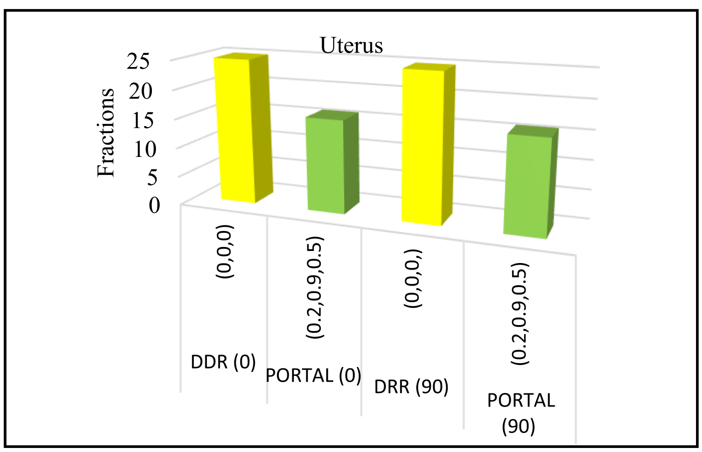


Fig. 6. The relationship between fractions and DRR, portal, uterus.

3. **The systematic error (μ) while systematic error (Σ)**

A μ for (X, Y, Z) axes amid a sum for 15 breast tumor patients were 0.41, 0.39, 0.29 cm, respectively as shown in Fig. 7A. A (Σ) for axes amid the sum patients were 0.02cm, 0.04 cm, and 0.06 cm, respectively Fig. 7B. A check by left breast while right breast indicated not clarity several at the systematic errors (μ or Σ) to axes Fig. 7A, C. The Z-axis of a Systematic error (μ) appeared a significant several amidst (right, left) sides; however each to (μ) values to a Z-axis was $<$ 0.8 cm, what hold the view clinically insignificant. They compared the (μ, Fig. 7B) and the Σ Fig. 7D for (X, Y, Z) axes. A size to Systematic error ($\sum$) and systematic error (μ). An X-axis direction was Fig. 7 represent (A, B, C and D).

Significantly bigger than that from the Y-axis within a sum, (left, right) of people suffering from breast cancer. But ceiling to systematic errors (μ) were $<$ 1.2 cm; what is holding the view clinically is not important. Not important, various systematic errors (Σ) were noticed amidst X, Y, and Z directions within the sum, left while right patients. The random errors for the X, Y, and Z axes within a sum patient were 0.02 cm, 0.08 cm, and 0.01 cm, respectively, as illustrated in Fig. 8A. We compared a random error using the (X, Y, Z) axes shown in Fig. 8B. The size of each random error was less than 0.25 cm, which is not clinically significant, and it was the same for both the left and right patients.[22] A systematic error (μ) for (X, Y, Z) axes amid a sum to nine uterus tumor (X, Y, Z) axes amid the sum patients were 0.07 cm, 0.09 cm, and 0.03 cm, respectively Fig. 9A, B. The check uterus indicated no evident several at a systematic error (μ or Σ) to (X, Y, Z) axes Fig. 10. The systematic error's X-axis measures approximately 2.8 cm, while the Y-the patients' random errors to the X,

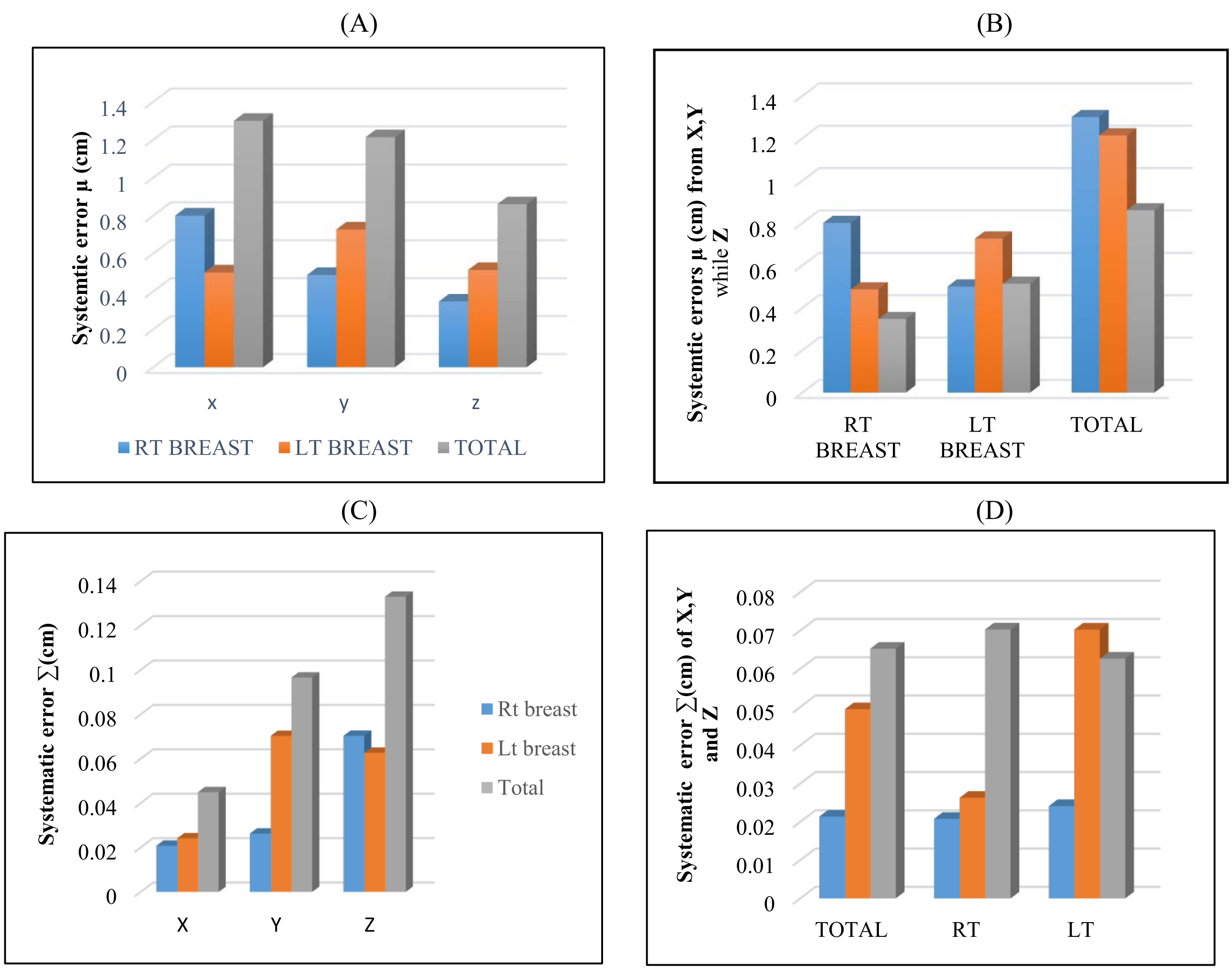


Fig. 7. A, systematic error (μ) of the (X, Y, Z) axes; B, the μ of the right while left side breast tumor patients (right 9 and left 6 people suffering from breast cancer); C, systematic error (Σ) for (X, Y, Z) axes; D, systematic errors (Σ) for (right, left) side people suffering from breast cancer. A blue, apricot, and gray mention a data to all-patient chain, (right, left) side people suffering from breast cancer, respectively.

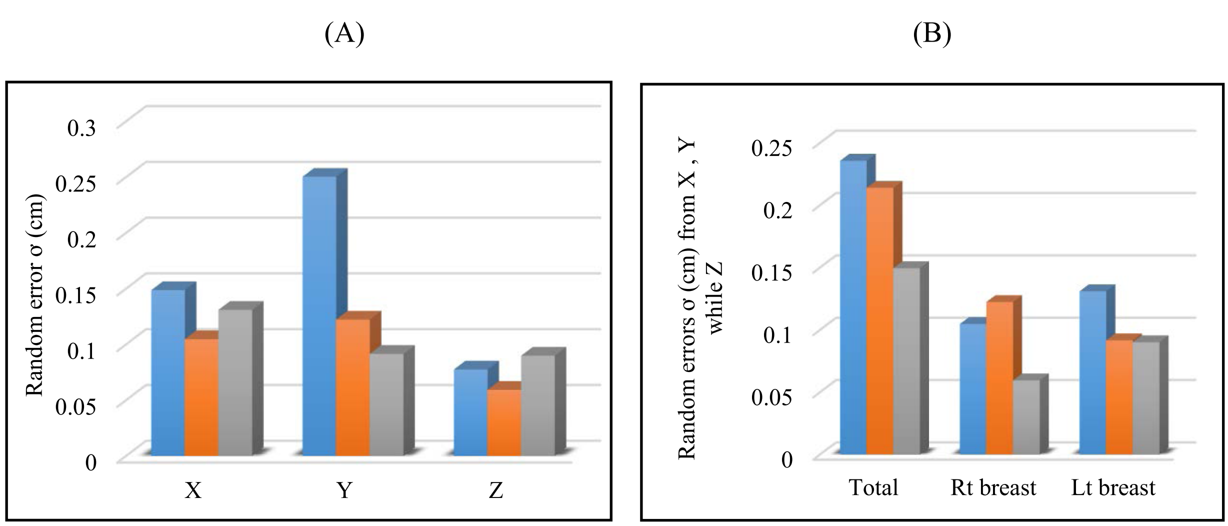


Fig. 8. A, random errors (σ) to (X, Y, Z) axes; B, random errors (σ) to (right, left) side people suffering from breast cancer. A blue, apricot, and gray mention the data to all-patient chain (right, left) people suffering from breast cancer, respectively.

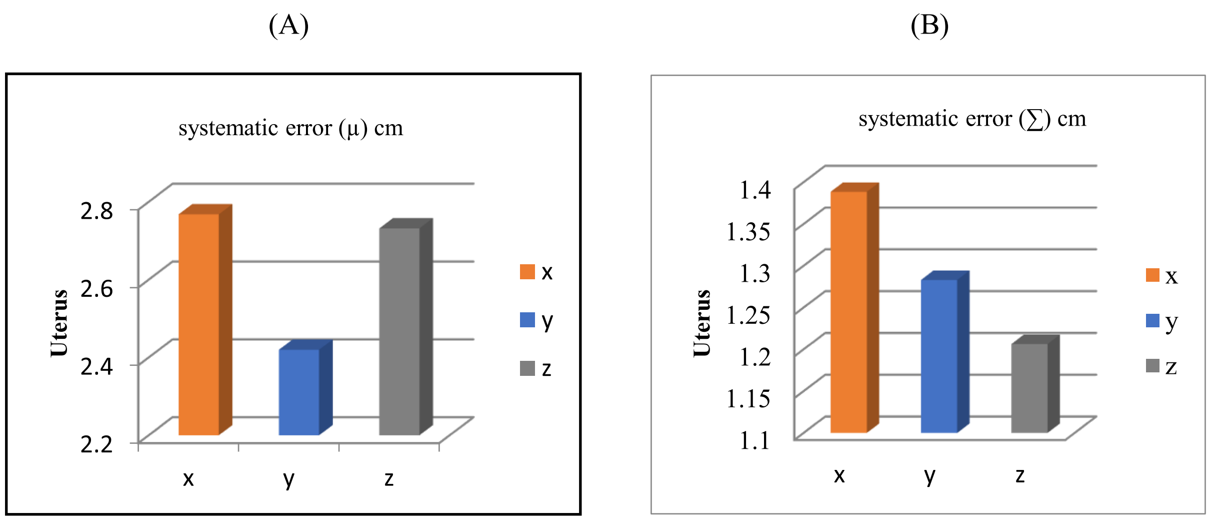


Fig. 9. Systematic errors (μ) A, of the X- axis, Y-axis while Z-axis directions; B, systematic error ($\sum$) to (X, Y, Z) axes; of uterus tumor patients (9 patients). The blue, apricot, and Gray mention the data for all-patient chain.

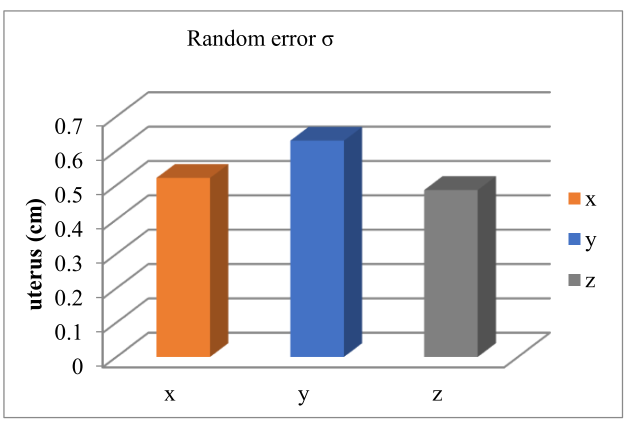


Fig. 10. Random errors (σ) to (X, Y, Z) axes mention a data to all-patient series, uterus tumor patients, respectively. The blue, apricot, gray pillar mentions a data to (X, Y, Z) axes, respectively.

Y, and Z axes were 0.02 cm, 0.18 cm, and 0.04 cm, respectively, We compared a random error using (X, Y, Z) axes, and while we observed this, the magnitude of each of the random errors was <0.7 cm, which is considered clinically not important, within the sum, left while right patients were.[22]

Those images were then calculated and corrected for systematic errors (μ, Σ) while random errors (σ), as explain at Table 3:

Table 3. The systematic errors (μ while Σ) while random errors (σ) at a pertinent former research breast and uterus.

	Systematic error $\sum$ (cm)			Systematic error μ (cm)			Random error (cm)		
patient	X	Y	Z	X	Y	Z	X	Y	Z
Breast	0.02	0.04	0.06	0.41	0.39	0.29	0.02	0.08	0.01
Uterus	0.07	0.09	0.03	0.39	0.34	0.4	0.02	0.18	0.04

In our study of 15 people with breast cancer, we found that the systematic error while random error at breast tumor irradiation treatment that was done every day in our hospital was as little as 1.4 cm in all four directions, which is clinically acceptable. Schedule (3) summarizes the setup error we identified during the research. The generality of this research utilized cranio-caudal distance (CCD), inferior centra margin ICM, and central lung distance CLD to evaluate a set-up error of the (X, Y, Z) axes directions. The research was meticulously prepared, and the set-up error was carefully evaluated by investigating the site at a skin surface in the state of use (cranio-caudal distance, inferior centra margin, or central lung distance). The skin surface is utilized for the mammary gland, and a PTV is located immediately down the skin. The investigation used a skin surface to carefully rotate an error to the X-, Y-, and Z-axes, a technique rarely reported before. It utilized picture processing software for the investigation because of the improvement in skin surface investigation, which was complicated to fulfill to make a visible determination. It was noted that the clinical approval was adequate. Scientists use systematic, random errors as a criterion for evaluating the precision of radiation therapy investigations. But, in the studied operation of the systematic errors for all patients, while axes to deviation of all therapy are obversed, a systematic error (μ) is minus to distance of the deviation. The results of that study looked at the full value of deflection in all therapies. However, because of the limitations of this study, the shape of the breast that was being studied changed during treatment, and differences in the ability to reveal (MV, KV) pictures affected the results. Everyone or both of those problems have occurred in patients and have increased the setup error. However, all the set-up error values observed here were sufficiently small for breast radiation therapy. Our findings disagreed with the previous research conducted. Miyahara[22] found. Hayder Alabedi[30] and others found that the random and systematic errors were larger in the direction of the x-axes than in the y- and z-axes.

This study displays hospital clinical expertise, as well as the conformal systematic errors and random errors that have been discussed in numerous previous research studies. The errors produced through the transport of the simulation to the therapy room may be the most substantial reason for systematic errors. Inexactness at skin marker points, while the patient's setup depends on them, as at the research, or markers on a restraint might be other sources of systematic error. Another reason is that shifts at the center of the therapy room or at a laser-field locator or droop painting are top sources of errors. Uterus cancer irradiation treatment conducted at our hospital every day fulfilled as little as $\leq$ 2.8 cm at the (X, Y, Z) axes, which appears clinically allowable. That mobility is so recurrent in obese patients like ours. As at the simulator while radiation therapy, patients were repositioned together with reference for the bias for profiling lasers with the lateral landmarked while skin markers were put at the front as well as monitoring for board altitude. Amaoui,[29] found that the random and systematic errors were larger in the direction of the x-axes than in the y-axes and z-axes. Our results contradicted the findings of previous studies. The set-up uncertainties for breast and uterus patients can be caused by different factors, including the cancer's change in size due to distention or shrinkage after radiation, alteration in patient weight during sessions that can alter the contouring of the tumor, and the patient's inability to empty the bladder and rectum. To breast patients, set-up errors can still occur due to the lung movement during the CT simulator picture or portal picture, which can cause skin markings to shift into the therapy areas due to inaccurate laser and optical illusion, clinically permissible.

Conclusion

In this research, applying the correct position of the patient in the room treatment boost separately gives better Planning Target Volume (PTV) coverage without introducing additional hot areas in the normal tissue. The study investigated the extent of systematic and random errors in the intersession setup of breast and uterus radiation treatment. The results validate the accuracy of the patient's treatment setup, in conjunction with 3DCRT breast and uterus radiation therapy. At the margins of the CT scan (CTV), approximately 90% of patients with breast and uterine tumors will receive a dose of less than 95% for the specified area. We accepted measurement for accuracy and rendering precision of the linear accelerator (EPID, MOSAIQ) software, ensuring it remained within tolerance uncertainties. Finally, we propose the electronic portal image device as a secure method to detect geometrical intersession errors in the radiation therapy division, particularly in areas where 3DCRT radiation therapy is prevalent. It is suggested that to beat systematic error while random error, portal pictures must be taken daily.

Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for republication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- Authors sign on ethical consideration's approval.
- Ethical Clearance: The project was approved by the local ethical committee at University of Baghdad.

Authors' contribution statement

H. A .designed the study, Z. A. performed the experiments and analyzed the data. Wrote the paper with input from all authors.

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تقييم خطأ الاعداد للعلاج الاشعاعي لسرطان الثدي والرحم باستخدام جهاز تصوير البوابة الالكتروني

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الخلاصة

الفرق بين صورة العلاج الحقيقية التي تمثلها صورة البوابة وصورة الأشعة السينية المعاد بناؤها رقميًا (DRR) القادمة من تخطيط الفيزياء حيث تساعدنا صورة المرجع في قياس الإزاحة. تعتمد منطقة العلاج على حواف خطأ الإعداد. الخطوة الأساسية هي تقدير خطأ الإعداد أثناء العلاج. يتبع تخصيص الجرعة عند PTV (تخطيط حجم العلاج) حواف الإعداد. أخطاء الإعداد لمجموعة الأورام الإشعاعية لتقليل خطأ العلاج. تشرح أخطاء الموضع التباين بين الموضع الأول الذي تم فيه مسح المريض في محاكاة التصوير المقطعي المحوسب (CT) وموضع الإعداد في أريكة العلاج. الأخطاء الأكثر شيوعًا التي يتم تقييمها في العلاج الإشعاعي هي الأخطاء العشوائية والأخطاء المنهجية. أورام سرطان الثدي والرحم هي الحالات الأكثر شيوعًا عند النساء. نستخدم EPID (جهاز التصوير الإلكتروني للبوابة) لقياس شدة الفوتون الذي ينقله المريض من منفذ الإشعاع عبر جزء العلاج. يهدف هذا البحث إلى تحديد خطأ عشوائي منهجي لمرضى سرطان الثدي (الأيمن والأيسر) (ن = 15) وسرطان الرحم (ن = 9). وكان الخطأ المنهجي لدى مريضات الثدي (0.02، 0.04، 0.06 سم) على المحاور (x، y، z)، أما لدى مريضات الرحم فكان (0.07، 0.09، 0.03 سم). وكان لدى حالات الثدي خطأ عشوائي قدره (0.02، 0.08، 0.01 سم) على المحاور (x، y، z)، على التوالي، بينما كان لدى حالات الرحم خطأ عشوائي قدره (0.02، 0.18، 0.04 سم). يستخدم العلاج الإشعاعي مسرع خطي (Elekta) .

الكلمات المفتاحية: سرطان الثدي، جهاز تصوير البوابة الالكترونية EPID ،لاي نك LINAC ، العلاج الاشعاعي ، سرطان الرحم.