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The Effect of Treatment Set-Up Errors Correction on Dose Distribution to Organs at Risk in 3D Conformal Radiotherapy of Prostate Cancer

M.Ali Morsy[1], A. Raouf Ahmed[2], *K.M. Elshahat*[3], K.A. Shnishin[4]
[1] *Dar El Fouad Hospital- Cairo – Egypt*
[2] *Physics Department- Faculty of Science- Port Said University- Port Said,Egypt*
[3]*Radiation Oncology Dept. – Faculty of Medicine - Al Azhar University- Cairo, Egypt*
[4]*Physics Department- Faculty of Science- Port Said University- Port Said,Egypt*
Corresponding Author: M.Ali Morsy

Abstract: *The purpose of this work was the determination of the set-up errors for Prostate cancer patients by The purpose of this work was investigation of the dose distribution and dose-volume variations of planning target volume (PTV) and organ at risks (OARs) in fifteen prostate cancer patients treated with 3D Conformal RT 5 beams techniques, treatment plans were created using EclipseTM version 13.6 as treatment planning system. The electronic portal imaging device (EPID) used to determine the set-up errors as tool to verify the Prostate patient treatment positioning. The prescribed dose was 7600 cGy in 38 fractions to dose coverage D95 (PTV). The bladder volume receiving dose >7000 cGy should be <35% volume and >6500 cGy should be <50% volume, and the rectum volume receiving dose >6500 cGy should be <25%volume and receiving >5000 cGy should be <50% volume. The femur head volume receiving dose >5000 cGy should be <5% volume in our clinic's dose-volume criteria for OARs according to Quantitative Analysis of Normal Tissue Effects in the Clinic (QUANTEC). In the work, the calculation of PTV margins are calculated according to ICRU Report 62 is suggested as an optimum margin for target volume coverage which is <5 mm in all three directions. We determine the effect of set-up errors on the dose distribution and dose volume histogram (DVH) by calculating the dose distribution and dose volume histogram (DVH) of PTV and OARs of actual approved treatment plan and treatment plan with set-up errors.For dosimetric comparisons between them. We investigated dose distribution and DVHs of all treatment plans and compared D95 (PTV), V6500 cGy and V5000 cGy of rectum doses, V7000 cGy, and V7000 cGy of bladder doses and 5000 cGy of femur head. The results show that the averagedifference in dose distribution coverage of target were approximately 1.7% between the approved treatment plan and treatment plan with set-up errors. And the average differences in V95 of PTVs are 0.6% and the mean doses are 2%, and the dose received by Bladder increased about 4.8% and Rectum about 5.5% and head of femurs 2.7%. This study has been made between the previous published work and the new approach of this study.*

Keywords: *Prostate Cancer; 3D conformal radiation therapy; EPID; Radiotherapy; ICRU (50&60)*

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I. Introduction

Several studies have demonstrated the effect of patient positioning on setup reproducibility and dose distribution to organs at risk in 3D conformal radiotherapy of prostate cancer. The patient positioning in Prostate radiotherapy (RT) should be decided based on both reproducibility and on which position that yields the lowest radiation dose to the organs at risk (OAR), and thereby less side effects to patients. The present randomized work aimed to evaluate the influence of patient positioning on setup reproducibility and dose distribution to OAR in Prostate cancer patients. The aim of radiotherapy is to deliver a prescribed dose to the tumor and minimizing dose to the surrounding healthy organs and tissues. Due to the geometrical uncertainties in dose delivering the clinical target volume (CTV) is expanded by specified margin to obtain the planning target volume (PTV). The patient setup uncertainties are substantial for the accuracy of the dose delivery. Achieving reproducibility during radiotherapy treatment can involve reducing motion in both patient bony anatomy and internal organ motion. This may complement or even reduce the need for intensive set-up errors correction strategy. The most optimal prostate patient positioning should be based on both patient set-up correction and which position gives the lowest possible dose to the surrounding healthy organs and tissues. The goal of this work is evaluating the effect of patients repositioning on both setup errors and dose distribution to tumor the OAR.

II. Experimental Work

Direct measurements of patient's reproducibility for prostate cancer patients are extracted by using an electronic portal imaging device (EPID) to give an optimum margin for PTV margins in all three directions and give the lowest possible dose to the OARs (Bladder, Rectum, femur head). In period of time between Dec 201*6* and Dec 2017 fifteen prostate cancer patients were treated as patient group with 3D Conformal Radiotherapy [5]. Computed tomography (CT) scans (2.5 mm slice thickness) of the whole pelvis were obtained in the treatment position. Patients are immobilized and treated in the supine position on a solid flat carbon fiber couch top. In the supine position, patients were positioned with a pillow under their heads, knee and ankle support pillows, and their arms resting on their chests with anterior and lateral laser lights to align midline and lateral skin tattoos to prevent lateral rotation. The CT slices were imported to the treatment planning system TPS (EclipseTM version 13.6) and the Analytical Anisotropic Algorithm (AAA) was used for dose calculation. The PTV was delineated with margin was 10 mm from the CTV in each CT slice according to international guidelines. The bladder, rectum and femur heads were delineated in each CT slice by contouring tools in TPS. On the simulator room, the isocenter of the planned RT beams was determined and the orientation of the simulator beams were identified. A Linear accelerator– Varian model DMX– high energy (dual energies 6.0 and 15 MV) photon beam and multi electron energies (6.0, 9.0, 12, and 15 MeV) has been used as treatment device. Treatment electronic portal images (EPIs) were obtained of the posterior and lateral treatment fields by Electronic Portal Image Device (EPID) vision aS500 that used as verification Device [12].

III. Experimental Measurements

Radiotherapy was given 200 cGy per one Fraction, 5 fractions per one week [15], 38 fractions to total dose 7600 cGy. The patients were treated with 15 MV high energy photons by Varian Medical linear accelerator treated with 3D Conformal RT five beams techniques, the dose distribution for different fixed 5 fields technique is suitable for covering the PTV by 95% isodose lines and minimizing the dose to the OAR. Beams are customized by Multi leaves collimator MLCs to include the PTV. The EPIs were registered with the reference DRRs from the approved treatment with average of 10 paired images per each patient at orthogonal gantry angles 0˚ and 90˚ using a typical exposure time 1 MU at a dose rate of 300 MU/min. DRR-EPI matching was based upon the identification and outlining of bony landmarks in the pelvic region by two dedicated observers. Sufficient stable anatomy needs to be visible in the verification images to ensure accurate matching can be made. The pelvic rim is routinely used on the anterior image to verify the position in the superior– inferior direction. In lateral fields the femora, although visible, should not be used as the position varies too easily. The acetabulum and sacrum are more stable and better visualized. Treatment setup errors were defined as difference deviations between the Portal image acquisition (DRR) and the actual position of the bony landmarks. Setup difference deviations were translated into treatment table shift values x, y, and z in the three orthogonal directions in a treatment table-oriented coordinate system that corresponded to the lateral, longitudinal, and vertical directions. The set-up errors in radiotherapy divided to Systematic and Random errors:

1- Systematic error: the term systematic error may be used when referring to the individual patient, or to the treatment population, these types of errors referred to as treatment preparation errors.

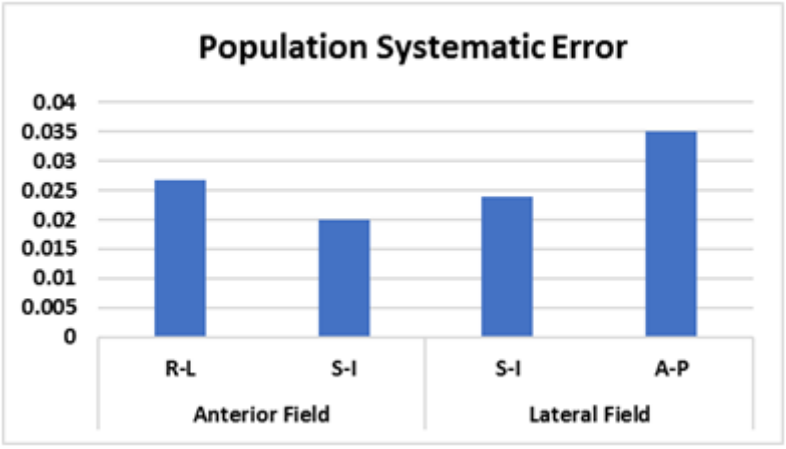
2- Random error: is always present in a measurement. Random errors show up as different results for the same repeated measurement, these types of errors referred to as treatment execution errors.

IV. The Effect of Patient Positioning On Setup Deviations

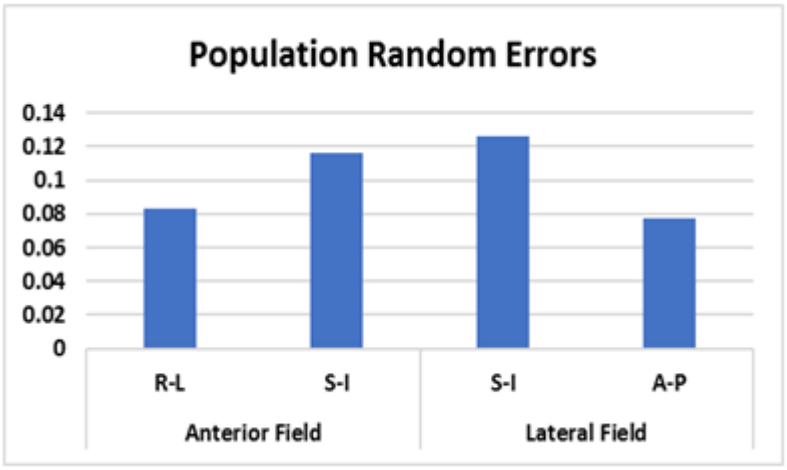
The obtained measurements data consisted of repeated observations of the setup errors correction. The measurements of each patient were made at irregular times according to the verification protocol. According to data analysis for matching between standard DDRs for prostate patient were included current work and portal image taken during all sessions for each case. The displacement data was used to investigate and analyses population systematic (Σ) and random errors (σ) and set-up margins. For all patients, population systematic (Σ) and random errors (σ) were calculated as the standard deviation of the setup from the mean in each specified direction. The results for the population of patients can be seen in Table, (1). Using matching protocol

	Anterior Field		Lateral Field	
	Right-Left	Superior-Inferior	Superior-Inferior	Anterior-Posterior
$\sum_{pop}$	0.027 cm	0.02 cm	0.0239 cm	0.035 cm
σ_{pop}	0.098 cm	0.0047 cm	-0.0047 cm	-0.03 cm

Table, (1) The variation of patient set-up errors in Anterior and Lateral fields And Figure (1&2) shows that the variation of patient set-up errors in Anterior and Lateral fields:



Figure, (1) The Population Systematic Error in Anterior and Lateral fields



Figure, (*2*) The Population Random Error in Anterior and Lateral fields

From above tables and figures we can summarize that the random errors describe the deviation between treatment fractions that can occur in any direction during the course of treatment and will give rise to a blur in the dose distribution. Random errors occur during the treatment and are therefore considered to be execution errors. Offline protocols cannot correct for random errors and the margin used must take that into account. For set-up margins, The International Commission on Radiation Units and measurements (ICRU) report 62 = ($\sqrt{\Sigma 2} + \sigma 2$) was used to examine the effect of treatment positioning on the setup error vector by measuring CTV-PTV margins for Prostate cancer. Table (2) shows the calculated CTV-PTV margins for Prostate cancer the CTV to PTV margins according to ICRU Report 62. Statistical analyses were carried out using Excel software 2016. Overall mean and set-up errors for Prostate cancer along three major axes are measured and estimated in vertical, longitudinal and lateral directions. The mean displacement using bony anatomy in the pelvis and no correction expected to be in the range of 2-5 mm depending on site and size of treatment field. It is observed that, there is a significant difference in displacements for major three axes. Approximately 75 % of displacements are within the tolerance uncertainties.

V. The effect of patient positioning on dose distributions to organs at risk

Dose volumes and doses to OAR were characterized by their mean values and variation ranges. Dose distributions for OAR are presented in Table (2). We investigated dose distribution and DVHs of all treatment plans and compared D95 (PTV), V6500 cGy and V5000 cGy of rectum doses, V7000 cGy, and V7000 cGy of bladder doses and 5000 cGy of femur head. The results show that the average difference in dose distribution coverage of target were approximately 1.7% between the approved treatment plan and treatment plan with set-up errors. And the average differences in V95 of PTVs are 0.6% and the mean doses are 2%, and the dose received by Bladder increased about 4.8% and Rectum about 5.5% and head of femurs 2.7%.

PTV &OARs	Mean Doses (cGy)		Variation Range (cGy)
PTV	D95	6950-7130 cGy	180 cGy
Bladder	V6500 cGy	6570 -6930 cGy	360 cGy
	V7000 cGy	7050-7201 cGy	151 cGy
Rectum	V5000 cGy	5050 - 5600 cGy	550 cGy
	V6500 cGy	6530-6720 cGy	190 cGy
Femur heads	V5000 cGy	5020 -5309 cGy	289 cGy

VI. Discussion

The present work aimed to create evidence for the best optimal treatment position with respect to reproducibility and lowest possible dose to OAR in RT of prostate cancer patients. Patients were assigned to supine positioning. Setup errors were expressed as setup displacement deviation calculated from table shift values without any protocol corrections in the lateral, longitudinal and vertical directions. The length of this shifts was used to calculate the most optimal CTV-PTV margins for Prostate cancer. In addition, we explored the dose distributions to OAR that effected by daily correction of patient set-up errors. The results show that dose coverage of target and OAR's doses depend on the daily correction of set-up errors due to the change in geometry of target and OARs, In the work, the calculation of PTV margins are calculated according to ICRU Report 62 is suggested as an optimum margin for target volume coverage which is <5 mm in all three directions. We determine the effect of set-up errors on the dose distribution and dose volume histogram (DVH) by calculating the dose distribution and dose volume histogram (DVH) of PTV and OARs of actual approved treatment plan and treatment plan with set-up errors. For dosimetric comparisons between them. We investigated dose distribution and DVHs of all treatment plans and compared D95 (PTV), V6500 cGy and V5000 cGy of rectum doses, V7000 cGy, and V7000 cGy of bladder doses and 5000 cGy of femur head. The results show that the average difference in dose distribution coverage of target were approximately 1.7% between the approved treatment plan and treatment plan with set-up errors. And the average differences in V95 of PTVs are 0.6% and the mean doses are 2%, and the dose received by Bladder increased about 4.8% and Rectum about 5.5% and head of femurs 2.7%. This study showed us, we had high precise dose delivery in the linear accelerator and we can be sure about the calculation accuracy for our plans.

VII. Conclusion

Our method,which relies on the geometry of prostate and OARs to determine the optimal treatment position. The patient positioning in pelvic radiotherapy(RT) should be decided based on both reproducibility and on which position that yields the lowest radiation dose to the organs at risk (OAR), and thereby less side effects to patients. The present randomized study aimed to evaluate the influence of patient positioning on setup reproducibility and dose distribution to OAR in prostate cancer patients. The treatment position set-up correction for prostate cancer patients may be safely guided by practical considerations and individual factors.

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