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Assessment of Difference in Planning Target Volume Margins and Deviation in Lateral, Longitudinal, Vertical Axis using Thermoplastic Pelvic Cast versus Knee Rest During Immobilization for Computed Tomography in Patients with Cervical Cancer

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Abstract

Aim: To identify the most reproducible technique of patient positioning and immobilization in patients with carcinoma cervix.

Background: Radiotherapy aims at controlled killing of tumors cells without harming the normal tissue surrounding the disease. The basic aim of radiotherapy planning is to ensure adequate coverage of target with the planned dose and to save the normal tissue. Adequate margins for setup errors are necessary, the margins applied must not be huge as that would adversely affect normal tissue. This study compares the knee rest with thermoplastic pelvic cast in patients with carcinoma cervix with an aim of identifying the most reproducible method.

Material and methods: Cross-sectional study was done in patients of carcinoma cervix undergoing radiotherapy from April 2021 to June 2022 at our institution. Immobilization was performed on 20 patients (Thermoplastic pelvic cast i.e., Pelvic cast pelvic masks=10, Knee-rest=10). The systemic error, random error and planning target volume (PTV) margins were calculated for both the techniques and statistically analysed.

Result: The systemic error in lateral (x-axis), longitudinal (y-axis) and vertical (z-axis) in thermoplastic pelvic cast and knee rest are 0.61cm, 0.39cm, 0.15cm and 0.17cm, 0.4cm, 0.32cm respectively. Random error are lateral (x-axis), longitudinal (y-axis), and vertical (z-axis) are 0.07cm, 0.63cm, 0.08cm and 0.10cm, 0.44cm, 0.22cm. CTV-PTV margin using van herk's formula in lateral (x-axis), longitudinal (y-axis) and vertical axis (z-axis) using thermoplastic pelvic cast and knee rest are 1.59cm, 1.44cm, 0.44cm and 0.49cm, 1.31cm, 0.96cm respectively. CTV-PTV margin using Stroom's formula in lateral (x-axis), longitudinal (y-axis) and vertical axis (z-axis) using thermoplastic pelvic cast and knee rest are 1.28cm, 1.24cm, 0.36cm and 0.41cm, 1.11cm, 0.80cm respectively.

Conclusion: Among the two techniques, knee rest technique is least time consuming and most economically viable in developing countries.

Keywords: Immobilization device; Knee rest; Error; Planning target volume.

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INTRODUCTION

The basic aim of radiotherapy planning is proper immobilization to ensure adequate coverage of target with the planned dose and to save the normal tissue. With evolution of techniques, such as three dimensional conformal Radiotherapy, intensity modulated Radiotherapy, knowledge for setup errors is essential. In pelvic malignancies a major issue is variation in patient positioning while delivering external beam radiotherapy. For pelvic radiotherapy, several patient positioning and immobilization techniques have being practiced. It is not feasible to perform frequent on board image verification with kilovoltage cone beam computed tomo therapy (kv-CBCT) or electronic portal image device (EPID). Therefore, less time consuming, most economical technique for patient positioning and immobilization with maximum reproducibility must be adapted. Here we are comparing thermoplastic pelvic cast with knee rest in patients with carcinoma cervix.

Aim

The aim of the present study is to identify the most reproducible technique of patient positioning and immobilization in patients with carcinoma cervix. The objective is to quantify and compare the deviation in lateral (x), longitudinal (y), vertical (z) axis and planning target volume (PTV) margins in patients with carcinoma cervix using thermoplastic pelvic cast and knee rest.

MATERIALS AND METHOD

Sample collection and sample size: After clearance from the institutional ethical committee, a cross-sectional study started. Cross-sectional study data of 20 patients of carcinoma cervix planned for radiotherapy during a period from April 2021 to June 2022.

Patient positioning and immobilization: All patients underwent computed tomographic scan for radiotherapy planning. All the patients were positioned in a supine position with hands above the head or on chest based on the patient comfort. And for all patients the pelvic base plate was fixed on the CT scan couch as well as on the treatment couch. This base plate helps in indexer level marking by means of positioning indicators in both the systems, namely: thermoplastic pelvic cast and knee rest. The details of both the patient positioning techniques are as follows:

Thermoplastic pelvic cast: Patient is kept in supine position and thermoplastic pelvic cast is used for immobilization device.

Knee rest: Patient is kept in supine position and only knee rest is used as immobilization device.

Kv-CBCT verification system helps in evaluation of setup accuracy by generating systemic as well random errors of treatment. The aim of the study was to study systematic setup error (∑), random error (σ), isocentre deviation in the lateral (x), vertical (z), longitudinal (y) axis of patient position of the Thermoplastic pelvic cast (Pelvicast pelvic masks) and knee rest group of patients. Two groups of 10 patients of carcinoma cervix in each group were selected by alternate method. All patients had pre-treatment verifications on the treatment machine in which Kv-CBCT was taken to compare with the planning simulation. The kV-CBCT were recorded once weekly for each patient from the record and verify system interfaced to the treatment machine.

A total of 100 setup positions were recorded for each patient in terms of x,y,z axis. The setup deviation of the patient was calculated by taking the difference between the planned (approved) and treatment setup positions in each direction. Random (σ) and systematic (∑) setup error were then calculated for each group in each group in each direction. Average systematic error (∑) is calculated by taking mean of setup errors of all fractions od x, y, and z axis respectively, during the treatment.

Statistical analysis

The total setup error is the deviation in the patient positioning on the treatment day as compared to the ct simulation day. The combination of systemic error and random error on each day of treatment is the total setup error. The systemic error persists throughout the course of treatment. The systemic error in particular direction is calculated as the mean of all the displacements measured through out the treatment for each patient. For all the patients in each of the two groups, the distribution of systemic error in a particular direction was expressed by the standard deviation (1SD) from the value of mean displacements of all the individual patients in x, y, and z axis.

The random error varies day to day during course of treatment. For all patients in each group, random error in each direction is expressed by the standard deviation from all the individual random error values.

The correlation of deviation of total, systemic and random error is related by the formula.

$TE2=\sum 2 + \sigma 2$

A three dimensional (3D) vector was calculated for systemic and random error for both the group of patients. The planning target volume (PTV) margins for each axis were calculated by van Herk formula:

PTV (mm) = $2.5\sum + 0.7\sigma$

In the above equation, $\sum$ is the standard deviation of systemic error, σ is the standard deviation of random error. The random error, systemic error and PTV margins in each group is tabulated and analysed with F-test for testing the statistical significance.

RESULTS

The translational displacement in all three axis: lateral (x-axis), longitudinal (y-axis) and vertical (z-axis) were recorded 50 kV-CBCT images for 10 patients using thermoplastic pelvic cast. The Systematic (∑) and Random (σ) errors as well as the corresponding CTV-PTV margins for the 3 directions were calculated. (table 1)

The translational displacement in all three axis: lateral (x-axis), longitudinal (y-axis) and vertical (z-axis) were recorded 50 kV-CBCT images for 10 patients using knee rest. The Systematic (∑) and Random (σ) errors as well as the corresponding CTV-PTV margins for the 3 directions were calculated. (table 2)

The p-value is >0.05 in both thermoplastic mould and knee-rest in lateral (x-axis), longitudinal (y-axis) and vertical (z-axis) shows a non-significant difference. (graph 1, graph 2, graph 3)

Table 1: Thermoplastic Mould

Thermoplastic Mould			
Directions	**Systematic Error (∑)(cm)**	**Random Error (σ)(cm)**	**Van Herck's Formula (2.5*∑+0.7*σ)(cm)**
X (lateral axis)	0.618	0.074	1.596
Y (longitudinal axis)	0.398	0.639	1.442
Z (vertical axis)	0.155	0.084	0.446

Table 2: Knee-Rest

Knee-Rest			
Directions	**Systematic Error (∑)(cm)**	**Random Error (σ)(cm)**	**Van Herck's Formula (2.5*∑+0.7*σ)(cm)**
X (lateral axis)	0.17	0.104	0.497
Y (longitudinal axis)	0.401	0.444	1.313
Z (vertical axis)	0.324	0.226	0.968

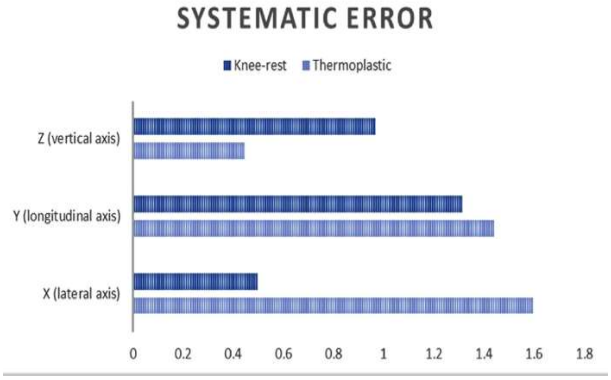

Fig. 1: Systematic error

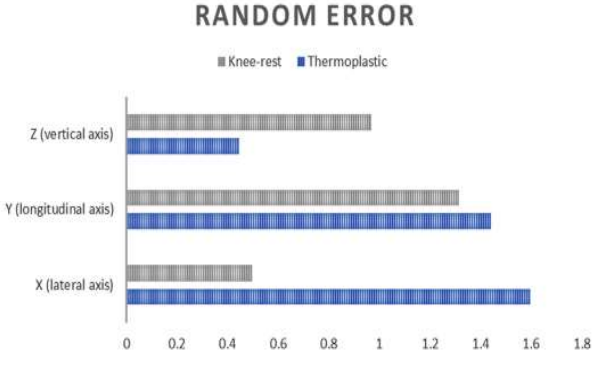

Fig. 2: Random error

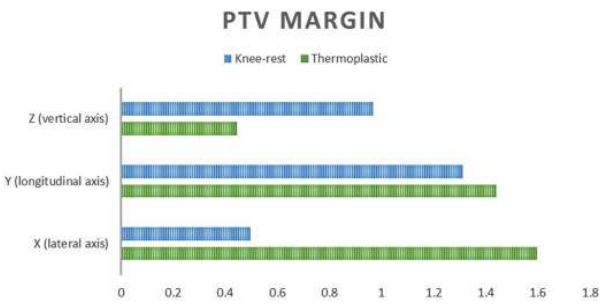

Fig. 3: PTV margin

DISCUSSION

During the treatment planning and treatment delivery various uncertainties can arise in gynecological malignancies, which can occur due to internal organ motion or the filling status of the Organs at risk (OAR) i.e. bladder, rectum and also due to set-up variations. Uncertainties arising due to set-up variation can be caused by both interfraction and intra-fraction motion.

There are modern forms of Radiotherapy that are equipped with Image guidance system which allows for verification of the treatment planning process. But for the correct implementation of optical margin must be taken around the target. There are many factors which includes different patient immobilization positions (prone vs supine), varying measurements methods (electronic portal imaging device, KV-CBCT, Mv-CBCT) or measurement frequencies (daily or twice weekly or once a week) and different treatment techniques (3DCRT, IMRT, and VMAT) which can influence the determination of this optimal PTV margins.

The CTV-PTV margins derived in our study were 1.5,1.4 and 0.4 cm respectively in lateral (x) axis, longitudinal (y) axis, and vertical (z) axis using thermoplastic pelvic cast, and 0.4, 1.3, 0.9cm respectively in lateral (x) axis, longitudinal (y) axis, and vertical axis in knee rest as immobilization device. The Systematic error in lateral (x) axis, longitudinal (y) axis, and vertical (z) axis using thermoplastic pelvic castare 0.618cm, 0.398cm, 0.155cm and 0.17cm, 0.401cm, and 0.324cm in lateral (x) axis, longitudinal (y) axis, and vertical (z) axis using knee-rest. The Random error were 0.074cm, 0.639cm, and 0.084cm lateral (x) axis, longitudinal (y) axis, and vertical (z) axis using thermoplastic pelvic cast. The Random error were 0.104cm, 0.444cm, and 0.226cm lateral (x) axis, longitudinal (y) axis, and vertical (z) axis using knee-rest. Patni *et al.* demonstrated a CTV-PTV margins expansion of 0.584cm, 1.036, and 0.566cm in lateral, longitudinal and vertical axis respectively.[1] Thondykandy *et al.* demonstrated that a margin of 10mm applied in both vertical and longitudinal axis and 7mm margin along the lateral axis has adequate target volume coverage in pelvic malignancies in supine position.[2] Another study recommends a 7mm CTV-PTC margins in all directions when using daily imaging for setup corrections.[3] As per the Santanammm *et al.* systematic error, random error, in lateral (x-axis), longitudinal (y-axis) and vertical axis (z-axis) are 0.37mm, 0.36mm, 0.24mm and 0.33mm, 0.38mm, 0.38mm respectively. The PTV margin using van herk's formula in lateral (x-axis), longitudinal (y-axis) and vertical axis (z-axis) are 1.15mm, 1.16mm, and 0.86mm.

Stroom *et al.*[4] also proposed a 5mm CTV-PTV margin based on a study on 14 patients with user defined landmarks. In a study CTV-PTV margins that were proposed are 0.7,1.7, and 0.4 cm respectively in Kalita AK *et.al.*[5] Rash *et al.*, evaluated mean shift values of 7mm (0-28mm) in AP, 2.9mm (0-12mm) in SI, and 3mm (0-7mm) in medio-lateral directions were found in 145 cone beam CT images of 5 patients who had post-operative adjuvant RT with fiducials that had been placed in vaginal apex before treatment.[6] In Yao *et al* study[7] the PTV margins obtained from inter-fraction errors were 5.6, 8.3, and 9.6mm in the AP, SI and ML directions respectively.[8]

In this study while evaluating the translational error it was seen that the maximum displacement was seen in y axis (longitudinal axis) in both thermoplastic pelvic cast and knee-rest.

CONCLUSION

We have evaluated the setup uncertainty of two immobilization devices for cervical cancer by using IMRT technique. The results of this study is that there is no significant difference in deviation in lateral (x-axis), longitudinal (y-axis), and vertical (z-axis) using thermoplastic pelvic cast and knee rest in patient with cervical carcinoma. The maximum deviation is observed in longitudinal axis (y-axis) is both thermoplastic pelvic cast and knee rest. The daily use of Kv-CBCT serves as an important measure for appropriate treatment delivery for malignancies under image guidance. Here we can use Knee rest is also for proper positioning and immobilization positioning during daily treatment instead of using thermoplastic pelvic cast which will be time saving and economical.

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