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ASSESSMENT OF SETUP-ERRORS IN 3D-CONFORMAL RADIOTHERAPY FOR HEAD AND NECK CANCER PATIENTS USING AN ELECTRONIC PORTAL IMAGING DEVICE

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ABSTRACT

Patient setup is crucial in radiotherapy since treatment is delivered as fractionated treatment over a period of time. Using own institutional margins by considering the setup errors will provide better radiotherapy outcome. Therefore, this study aims to assess set up errors for head and neck cancer patients using an electronic portal imaging device at Apeksha Hospital, Maharagama, Sri Lanka. A total of 101 head and neck cancer patients who were immobilized with thermoplastic mask were selected in this study. Stored data from July 2021 to July 2022 were obtained from ARIA patient management system in the Varian 2300CD Unit at Apeksha Hospital. In order to calculate systematic and random errors, translational errors in all directions were collected utilizing 303 pairs of orthogonal portal images. Moreover, three different algorithms were used to obtain the margin of clinical target volume (CTV) to planning target volume (PTV). The estimated systematic and random errors in the directions of antero-posterior, superior-inferior and medio-lateral are 0.13 cm, 0.10 cm and 0.08 cm, and 0.22 cm, 0.21 cm, and 0.19 cm respectively. Less than 0.5 cm margin were obtained by applying three different algorithms. This study indicates that using a 0.5 cm margin for head and neck cancer patients treating in 2300CD Varian Unit at Apeksha Hospital is safe. Further, this study recommends to developing institutional CTV to PTV margin for all sites of cancer to reduce unnecessary radiation to the surrounding normal healthy tissues.

KEYWORDS: *Radiotherapy, 3-Dimensional conformal radiotherapy, Electronic portal imaging device, Setup error, Clinical target volume, Planning target volume*

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1. INTRODUCTION

According to the GLOBOCAN report, 33243 new cases and 19145 deaths have been reported in 2022 in Sri Lanka (GLOBOCAN 2022). Squamous cell head and neck cancer is the 7th most common cancer worldwide, and it is the most common in men in Sri Lanka (Rupasinghe T., et al., 2021). Head and neck cancers respond to radiotherapy well. Precise delineations of tumour and critical organs are very important in radiotherapy. The International Commission on Radiation Units and Measurements (ICRU) has established different target volumes to account for the microscopic spread of the tumour and all other uncertainties (ICRU, 1999). Underestimation of the variations and uncertainties may lead to failure of tumour coverage and under or overdosage to normal healthy tissues. Image guidance plays a major role in radiotherapy treatment verification. It allows to verifying the patient position by comparing with digitally reconstructed radiograph (DRR). Electronic Portal Imaging Device (EPID) is mostly used in Radiotherapy Units since it can help to identify and fix setup errors quickly.

As setup margins have a direct impact on target volume coverage, they must be optimized to minimize the surrounding normal healthy tissue irradiation. Modern linear accelerators can be used to compare portal images and DRRs to reduce setup uncertainty and variability daily (Ramanathan V. et al., 2022). Therefore, this study aims to evaluate setup errors for head and patients treated with 3-Dimensional Conformal Radiotherapy (3D-CRT) treatment technique in the Varian 2300CD Unit at Apeksha Hospital, Maharagama, Sri Lanka.

2. MATERIALS AND METHODS

In order to assess setup errors, there are two main approaches available as random setup errors and systematic setup errors. When utilizing 3D-CRT, deviations must be assessed in 3 dimensions (Flentje, M. 1997). Portal images are compared with DRRs to identify the variation of isocenter, and the extent of inter-fractional and intra-fractional variations (Cacicedo, J. et al., 2015). References or anatomical markers can be used to match the DRR and portal image. Three formulae are typically used (ICRU report 62, Stroom's formula, and Van Herk's formula) to determine the margins for CTV to PTV (Gupta et al., 2007 and Gizynska et al., 2020).

This descriptive quantitative study (retrospective study) was conducted with 101 head and neck patients treated with 3D-CRT in the Varian 2300CD Unit at Apeksha hospital, Maharagama, Sri Lanka. The data collection period was from July 2021 to July 2022. The age group was 18-80 years. All the data were collected from ARIA patient management system. 303 pairs of orthogonal images were selected to evaluate the transitional set up variations. All the displacements were recorded under specific codes that were assigned for each patient. Three fractions of treatment (first day, second day and randomly selected fractionation) were selected for each patient, and a total number of 606 portal images were analyzed in this study. Each portal image was compared with DRR with the aid of rigid bony anatomical landmarks to assess set up variations as shown in Figure 1 and 2. Set up variations were assessed along three directions Antero posteriorly (AP), Superior-inferiorly (SI) and Medio-laterally (ML). All the displacements were tabulated in Microsoft excel work sheet and data analysis was done by Microsoft excel 2013 version.

In radiotherapy, various error types may be taken into account. Over the course of treatment, systematic error consistently happens in the same direction and is reproducible. By using a permanent shift after a number of observations, it can be found and fixed. Otherwise, the direction and quantity of random errors fluctuate day to day. This study used DRR and portal images to measure the deviation of bony structures relative to the isocenter in order to analyze setup errors. To calculate the systematic error, the mean of the individual patient-shift along a respective axis is firstly calculated. The standard deviation of these individual systematic error values of each patient was calculated to obtain the population systematic error. The random error represents the patient's shifts from fraction to fraction and the random error blurs the dose distribution around the target. To calculate the individual random error, the standard deviation

(SD) of the individual patient shift along a respective axis was calculated. Then the mean value of individual random errors was calculated to obtain the population random error.

In this study, we used Van Herk's formula, Stroom's formula and ICRU 62 recommended formula to estimate CTV- PTV margins for head and neck cancer patients who were treated with 3DCRT technique at Varian 2300CD unit.

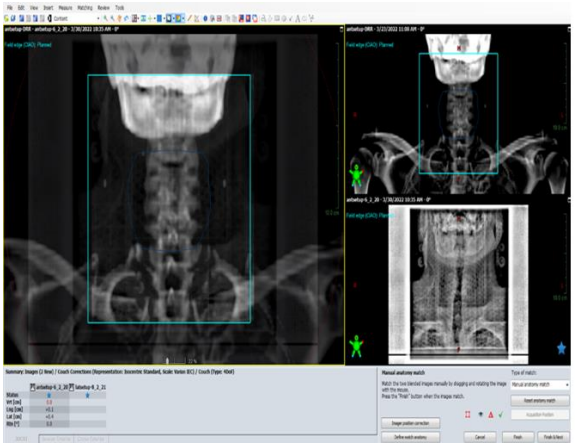

Figure 1: Visual comparison of bony land marks in DRR and EPI (CA Thyroid patient- AP image view).

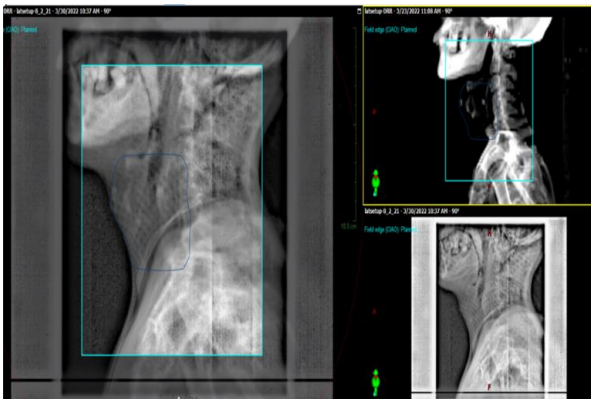

Figure 2: Visual comparison of bony land marks in DRR and EPI (CA Thyroid patient- Lateral view).

3. RESULTS AND DISCUSSION

Figure 3 shows the displacements in all three directions, vertical, longitudinal and lateral. The individual systematic error is calculated from the mean individual deviation and the individual random error is calculated from the standard deviation of individual displacement. The population systematic error is calculated from the standard deviation of all individual systematic errors and population random error is estimated from the mean value of individual random errors. According to the graph, mostly scattered displacements can be observed in vertical direction (anterior-posterior). According to this study population, systematic errors for antero-posterior (AP), medio-lateral (ML) and superior-inferior (SI) directions were 0.13 cm, 0.08 cm and 0.1 cm respectively. In this study, population random errors for AP direction were 0.22 cm, ML direction was 0.19 cm and SI direction was 0.21 cm.

The summary of displacement in all three directions is shown in Table 1. More than 50% of displacements are less than 0.3 cm in all three directions. 0.5 cm is exceeded in less than 30% of displacements. However, greater than 0.5 cm level is higher for longitudinal direction (10.82%) rather than other two directions. Table 2 shows that measured displacements in the displacement category from all dispacements, 96.48% is less than 0.7 cm. 93.08% of displacements are less than or equal to 0.5 cm in all directions. Only 0.16% of displacements exceeded 1 cm.

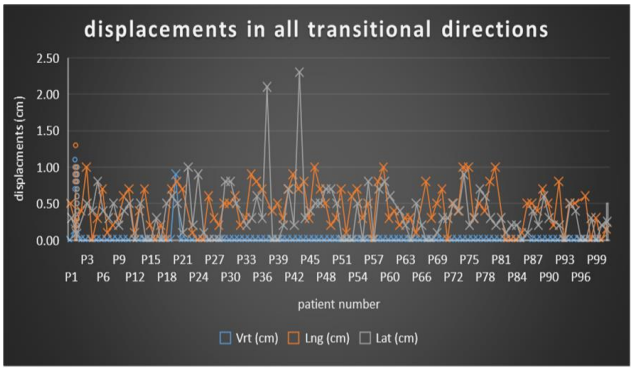

Figure 3: Displacements in all three directions, vertical, longitudinal and lateral.

Table 1: Displacement summary along each direction.

Displacement (d) Category	Vertical	Longitudinal	Lateral
d≤ 0.3 cm	86.92%	70.85%	85.67%
0.3cm<d ≤0.5 cm	8.2%	18.3%	9.3%
0.5cm<d ≤0.7 cm	2.2%	5.9%	2.1%
0.7 cm<d≤1 cm	2.4%	4.7%	2.6%
d>1 cm	0.12%	0.12%	0.24%

Table 2: Displacement summary along all directions.

Displacement (d) Category	In all directions
d≤ 0.3 cm	81.15%
0.3 cm<d≤0.5 cm	11.93%
0.5 cm<d≤0.7 cm	3.4%
0.7 cm<d≤1 cm	3.23%
d>1 cm	0.16%

A similar study was performed by Farajollahi A, et al. (2022) in Iran. The overall mean 3D displacement for head and neck cancer patients treated with 3D-CRT was reported as 0.39 cm. In addition, the maximum values of systematic error and random error were 0.39 cm and 0.27 cm respectively. The results of this study are compatible with those of the present study.

In the present study, CTV to PTV margins were 0.48 cm, 0.40 cm and 0.33 cm in the directions of Antero-posteriorly, Superio-inferiorly and Medio-laterally respectively according to the Van Herk's recipe. From Stroom's formula they were 0.41 cm, 0.35 cm, 0.29 cm, and from ICRU 62 formula they were 0.26 cm, 0.23 cm, 0.21 cm in the directions of Antero-posteriorly, Superio-inferiorly and Medio-laterally. The comparison of CTV to PTV margins calculated from 3 different algorithms (Van Herk, Stroom and ICRU 62) is shown in figure 4. Among all 3 algorithms, ICRU 62 gives a lower margin.

Table 3 : Set-up errors and margins recipes for each direction according to three different formulae.

	Vertical (cm)	Longitudinal (cm)	Lateral (cm)
Population systematic error	0.13	0.10	0.08
Popolation random error	0.22	0.21	0.19
Van Herk's formula	0.48	0.40	0.33
Stroom's formula	0.41	0.35	0.29
ICRU 62	0.26	0.23	0.21

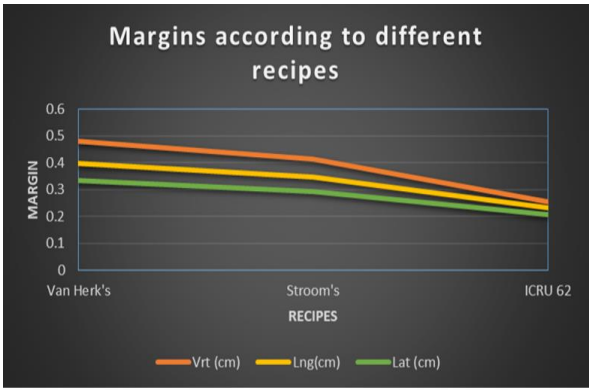

Figure 4: Comparison of margins calculated from three different algorithms.

4. CONCLUSION

It is important to evaluate setup errors in an institute to recognize the errors and to take necessary actions for better treatment delivery and fulfill the goal of

radiotherapy. In addition, it is better to evaluate the CTV-PTV margin for the institute and use the evaluated CTV to PTV margin for head and neck cancer patients who are undergoing 3DCRT technique.

The margins calculated by this study show that 0.5 cm is not exceeded in all directions from ICRU 62 recommended margins. Additionally, the setup error is well within the recommended margin for all cardinal directions. 0.26 cm, 0.23 cm and 0.21cm are the margins calculated from ICRU 62 margin recipe for Antero-posterior, Superio-inferior and Medio-lateral directions. 0.48 cm, 0.40 cm and 0.33 cm margins from Van Herk and 0.41 cm, 0.35 cm, 0.29 cm margins from Stroom's recipe for antero-posterior, superio-inferior and medio-lateral respectively. Portal images matching with DRRs using different anatomical landmarks is a useful tool for clinical practice. Immobilization devices play a major role in head and neck cancer treatment. This study recommends that the effectiveness of immobilization devices should be evaluated throughout the treatment process

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