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CROSS-SECTIONAL CLINICAL STUDY TO EVALUATE THE PTV (PLANNING TARGET VOLUME) MARGIN ERRORS HEAD, NECK, AND BREAST CANCER

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ABSTRACT

Background: To provide quality assurance in patients receiving radiation therapy for different types of cancer, it is critical to accurately assess the setup faults.

Aim: The current cross-sectional clinical study set out to evaluate the PTV (planning target volume) margin errors in individuals with head, neck, and breast cancer in a random and systematic manner.

Methods: A total of 100 participants with breast cancer and 96 subjects with head and neck cancer were evaluated in this study. Treatment setup and radiation were carried out using EPIDs (electronic portal imaging). The treatment's mistakes were evaluated using the Herk formula, and conclusions were drawn.

Results: On the x, y, and z axes, PTV margin shifting error was 1.41, 2.31, and 1.48 mm for breast cancer and 2.77, 1.53, and 4.36 mm for head and neck cancer.For breast cancer, the random error was 0.64, 0.70, and 0.77 mm; for head and neck cancer, it was 0.80, 0.66, and 0.92 mm. On the x, y, and z-axes, the systematic error was, however, 0.87, 0.41, and 1.47 mm for head and neck cancer and 0.37, 0.72, and 0.36 mm for breast cancer.

Conclusion: Based on the study's limitations, it may be concluded that the location of tumors affects the setup mistakes in cancer. The current study highlights the potential benefits of utilising electronic portal imaging equipment to lower setup verification procedure uncertainty.

Keywords: breast cancer, head cancer, neck cancer, planning target volume, shifting margins

INTRODUCTION

Carcinomas are caused by aberrant cell division and development as a result of genetic abnormalities in the cells' DNA. When treating carcinoma, radiation therapy has long been regarded as the gold standard of care. This method typically entails applying high-energy radiation to the tumour in order to destroy the cancer cells.1. Assuring that the maximum radiation dose reaches the PTV (planning target volume) with maximum exposure of radiations to the organs that are at risk—which is the primary goal of radiotherapy—requires positioning the patient appropriately before each fraction of the radiation modality.2

The cochlea, brain stem, and optic nerves are among the critical organs close to head and neck tumours that frequently necessitate strict PTV margins. To get the PTV defects related to beam alignment, patient positioning, and organ motions that indicate internal margin and setup margin, the margin is multiplied by the CTV (clinical target volume). Achieving setup margins is essential to preventing needless radiation exposure.3 Organs at risk (OAR) unintentionally have a major influence on the overall dosage given to the target organ. Random error and systematic error are the two types of faults that might occur in the placing of radiation treatments.4

While systematic mistakes might result in dose distribution that deviates from the intended target region, random errors can cause the cumulative dosage to be displaced from its correct location. Random mistakes are less prevalent than systematic errors, which raise concerns since the former can result in serious organ damage and tumour recurrence, while the latter can be constant across several treatment sessions.5

In order to optimise patient positioning and precision in target localization, 3D conformal radiation planning is typically carried out using EPIDs (electronic portal imaging devices). EPIDs are thought to be useful instruments for assessing and minimising setup mistakes.Six The current clinical investigation evaluated PTV shifts in participants with breast, head, and neck cancer in order to estimate random, systematic PTV (planning target volume) margin errors.

MATERIALS AND METHODS

The current cross-sectional clinical investigation evaluated PTV changes in participants with breast, head, and neck cancer in order to estimate the random, systematic PTV (planning target volume) margin errors. The study was conducted at the institute's Department of Otorhinolaryngology and Head & Neck Surgery. Prior to their involvement in the study, all individuals gave their verbal and written informed consent. All of the individuals had stimulation by computed tomography (CT) for the treated location in order to provide a three-dimensional anatomical picture of the afflicted region. A 5-point thermoplastic mask was utilised to immobilise patients with head and neck tumours, and CT stimulation was performed one week prior to the first radiation dose.

During the CT scan process, the participants were positioned supine with their heads facing front. In order to aid in target localization and proper patient positioning during CT simulation and planning, the thermal guide layer was inserted into a thermoplastic material that included radiopaque markers. The 3 mm slice thickness was visible in the 3D anatomical picture that was obtained after the CT stimulation. The acquired pictures were imported into a treatment planning programme using the 3DCRT approach to recontour.

In order to maximise the radiation dose to the target area and minimise the radiation exposure to healthy surrounding tissue that defines the PTV (planning target volume), the radiation oncologist, a specialist in the field, defined the tumour, also known as GTV-CTV (gross target volume-clinical target volume), along with the organs that were at risk, including the organs nearby and surrounding the tumour. Planning target volumes for head and neck plans were created by adding a 7 mm isotropic margin to the established clinical target volume (CTV). Using a Synergy linear accelerator with photon beam strengths of 10 MV and 6 MV, the patient y=received the recommended dosage.

Accurate positioning devices were used to immobilise the participants before to each therapy session. Mask markings, skin markings, or laser alignment in the treatment region were used to check the subjects' positions. The orthogonal portal pictures were obtained using an amorphous silicon digital portal imaging device with a flat screen and a high resolution of 1024 x 768 pixels. Using the treatment planning software, the acquired images were compared to DRRs (digitally reconstructed radiographs) that were created from orthogonal portal pictures collected at 900 (lateral) and 00 (anterior) TPS. Three translational axes—X, Y, and Z—implying lateral, vertical, and longitudinal axes, respectively, were used to examine the patient setup faults.

Three axes of translational displacement assessment were used to evaluate the random and systematic errors. For head and neck cancer and breast cancer, systematic error was measured as the standard deviation (SD) of all subjects' means for each direction or as the difference between the planned and individual subject positions for each treatment fraction when the planned position differed from the individual subject position. Deviations between various treatment fractions taken weekly during the therapy were referred to as Σ or random errors. The mean root square of each subject's individual standard deviation was computed to evaluate random mistakes.

The magnitude and assessment of the 3D vector lengths were also computed in the study. The standard deviation of the mean value of each unique mean setup error for the lateral, longitudinal, and horizontal directions was added in order to quantify the systematic errors (). The mean root square of each standard deviation in the lateral, longitudinal, and vertical axes was determined for random errors (σ). The PTV margin in the research was determined using the following herk formula: PTV margin = 2.5 ο + 0.7 σ. To determine the margin rules, the formula gives an analytical explanation of how systematic and random geometric deviations affect the target dosage.

RESULTS

The current cross-sectional clinical investigation evaluated PTV changes in participants with breast, head, and neck cancer in order to estimate the random, systematic PTV (planning target volume) margin errors. The mean age of the 96 research participants with head and neck cancer was 49.2±2.22 years, with an age range of 34 to 80 years. Within the head and neck cancer group, there were 70.83% (n=68) men and 29.16% (n=28) females. Stage I, II, III, and IV tumours were observed in 29.16% (n = 28), 20.83% (n = 20), 33.3% (n = 32), and 16.6% (n = 16) of the research participants, in that order. According to Table 1, 25% (n=24) of the study patients did not receive chemotherapy, whereas 75% (n=72) did.

There were 2% (n=2) men and 98% (n=98) female study participants with breast cancer in terms of demographics and illness characteristics. The individuals in this group ranged in age from 31 to 74 years old, with a mean age of 47.4±3.12 years. Stage I, II, III, and IV tumours were observed in 34% (n = 34), 42% (n = 42), 14% (n = 14), and 10% (n = 10) of the research participants, respectively. As shown in Table 2, 84% (n=84) of the individuals with breast cancer received chemotherapy, whereas 16% (n=16) of the subjects did not get chemotherapy. Electronic portal imaging (EPIs) was used to acquire pairs of orthogonal pictures for each patient; a total of 1600 image pairs for breast cancer and 576 image pairs for head and neck cancer were acquired.

The acquired pictures underwent correction and systematic and random error measurement (Table 3). It was shown that in head and neck cancer as well as breast cancer, systematic errors were considerably greater in all directions than random mistakes. Random mistakes were more common than systematic errors in the lateral direction, nonetheless. When comparing head and neck cancer to breast cancer, systematic and random errors were lower in the lateral direction and greater in the longitudinal and vertical directions for head and neck malignancies. For breast cancer, the longitudinal direction showed a less systematic error than the vertical direction.

For both head and neck and breast cancer, the setup error threshold was maintained at 2 mm or more. According to the IEC (International Electrotechnical Commission), 4% of the study participants had no movement of more than 2 mm in any of the three directions examined, while 2% of research participants had motion of more than 2 mm in two directions and less than 2 mm in the third. Subjects with head and neck cancer showed more than 2 mm of movement in longitudinal, lateral, and vertical directions in 0%, 2%, and 4% of cases, respectively. Conversely, a greater proportion of breast cancer patients—2%, 8%, and 6%, respectively—showed displacement of more than 2 mm in longitudinal, lateral, and vertical orientations.

Hank's algorithm was applied to evaluate shifts in PTV margin. The longitudinal or supero-inferior axis showed the most movement in PTV margins in head and neck cancer, measuring 4.36 mm. The vertical (anteroposterior) axis showed the second-greatest shift, measuring 2.77 mm, while the lateral (mediolateral) axis showed the least shift, measuring 1.53 mm. As seen in Table 4, the PTV margin shift in breast cancer patients was largest in the lateral (mediolateral) axis (2.33 mm), lowest in the vertical (anteroposterior) axis (1.43 mm), and longest in the longitudinal (supero-inferior) axis (1.48 mm).

DISCUSSION

The mean age of the 96 research participants with head and neck cancer was 49.2±2.22 years, ranging from 34 to 80 years old. Within the head and neck cancer group, there were 70.83% (n=68) men and 29.16% (n=28) females. Stage I, II, III, and IV tumours were observed in 29.16% (n = 28), 20.83% (n = 20), 33.3% (n = 32), and 16.6% (n = 16) of the research participants, in that order. Of the study individuals, 75% (n = 72) received chemotherapy, whereas 25% (n = 24) did not get it. These findings aligned with those of Menzel HG7 (2010) and Anjanappa M et al. (2017), who evaluated participants whose demographic information was similar to that of the current investigation.

According to the study data, there were 2% (n=2) men and 98% (n=98) females among the study patients with breast cancer in terms of their illness features and demographics. The individuals in this group ranged in age from 31 to 74 years old, with a mean age of 47.4±3.12 years. Stage I, II, III, and IV tumours were observed in 34% (n = 34), 42% (n = 42), 14% (n = 14), and 10% (n = 10) of the research participants, respectively. Chemotherapy was used to treat 84% (n=84) of patients with breast cancer, whereas it was not used to treat 16% (n=16) of participants. These results corroborated the diagnosis of breast cancer in Oh SA et al9 (2016) and Van Herk M10 (2004) in participants with similar demographics.

In this investigation, orthogonal image pairs (EPIs; electronic portal imaging) were acquired for every participant, yielding a total of 1600 image pairs for breast cancer and 576 image pairs for head and neck cancer. The acquired pictures underwent correction and systematic and random error measurement. It was shown that in head and neck cancer as well as breast cancer, systematic errors were considerably greater in all directions than random mistakes. Random mistakes were more common than systematic errors in the lateral direction, nonetheless. When comparing head and neck cancer to breast cancer, systematic and random errors were lower in the lateral direction and greater in the longitudinal and vertical directions for head and neck malignancies.

For breast cancer, the longitudinal direction showed a less systematic error than the vertical direction. These findings aligned with research conducted in 2019 by Kim SH et al. and in 2009 by Pehlivan B et al., whereby the authors documented comparable mistakes in head and neck cancer and breast cancer along the three axes examined in this study. According to the study's findings, the setup error threshold for both breast and head and neck cancer was maintained at 2 mm or more.

According to the IEC (International Electrotechnical Commission), 4% of the study participants had no movement of more than 2 mm in any of the three directions examined, while 2% of research participants had motion of more than 2 mm in two directions and less than 2 mm in the third. Subjects with head and neck cancer showed more than 2 mm of movement in longitudinal, lateral, and vertical directions in 0%, 2%, and 4% of cases, respectively.

Conversely, a greater proportion of breast cancer patients—2%, 8%, and 6%, respectively—showed displacement of more than 2 mm in longitudinal, lateral, and vertical orientations.

These findings corroborated those of research by Rudat V et al. (2011) and Gupta T et al. (2007), whose authors hypothesised that a comparable percentage of participants had movements of more than two millimetres in either direction.
The longitudinal or supero-inferior axis showed the most movement in PTV margins in head and neck cancer, measuring 4.36 mm. The vertical (anteroposterior) axis showed the second-greatest shift, measuring 2.77 mm, while the lateral (mediolateral) axis showed the least shift, measuring 1.53 mm. Nonetheless, in instances of breast cancer, the lateral (mediolateral) axis showed the largest PTV margin movement (2.33 mm), followed by the longitudinal or supero-inferior axis (1.48 mm) and the vertical (anteroposterior) axis (1.43 mm), in that order.

These findings were comparable to the studies of Madlool SA et al[15] in 2020 and Delishaj D et al[16] in 2018 where authors reported comparable PTV margin shifts in head and neck and breast cancer cases in their respective studies.

CONCLUSION

Considering its limitations, the present study concludes that setup errors change in cancer depending on the location of the tumors. The present study points to the potential advantages of using electronic portal imaging devices to reduce the uncertainties for the procedures of setup verifications which can further decrease the complication risks.

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TABLES

S. No	Characteristics	Number (n=96)	Percentage (%)
1.	**Mean age (years)**	49.2±2.22	
2.	**Age range (years)**	34-80	
3.	**Gender**		
a)	Females	28	29.16
b)	Males	68	70.83

4.	**Tumor stage**		
a)	I	28	29.16
b)	II	20	20.83
c)	III	32	33.3
d)	IV	16	16.6
5.	**Chemotherapy**		
a)	Treated	72	75
b)	Not treated	24	25

Table 1: Demographic and disease characteristics of study subjects with head and neck cancer

S. No	Characteristics	Number (n=100)	Percentage (%)
1.	**Mean age (years)**	47.4±3.12	
2.	**Age range (years)**	31-74	
3.	**Gender**		
a)	Females	98	98
b)	Males	2	2
4.	**Tumor stage**		
a)	I	34	34
b)	II	42	42
c)	III	14	14
d)	IV	10	10
5.	**Chemotherapy**		
a)	Treated	84	84
b)	Not treated	16	16

Table 2: Demographic and disease characteristics of study subjects with breast cancer

S. No	Site	Breast			Head and neck		
1.	**Direction**	**longitudinal**	**lateral**	**vertical**	**longitudinal**	**lateral**	**vertical**
2.	**Random error (mm)**	0.77	0.70	0.64	0.92	0.66	0.80
3.	**Systematic error (mm)**	0.36	0.72	0.37	1.47	0.41	0.87

Table 3: Radiotherapy characteristics of study subjects with head and neck and breast cancer

S. No	Direction	Breast	Head and neck
1.	**Longitudinal (supero-inferior)**	1.48	4.36
2.	**Lateral (mediolateral)**	2.33	1.53
3.	**Vertical (anteroposterior)**	1.43	2.77

Table 4: Shifted PTV margins (mm) for head and neck and breast cancer study subjects