ORIGINAL ARTICLE

Analysis of Planning Target Volume Margin on Different Immobilization Devices for Radiotherapy in Carcinoma Breast

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Abstract

Aim This study was conducted to analyze and compare the Planning Target Volume (PTV) margin from different immobilization devices using different formulae in carcinoma breast radiotherapy. **Methodology** patients with carcinoma breast who underwent adjuvant radiotherapy with four different immobilization devices were identified, and positional errors were assessed during pre-radiotherapy verification, using CBCT. Based on these errors, PTV margins were calculated using Van Herk, Stroom and ICRU 62 formulae. **Results** The calculated PTV margin for mould using van Herk, Stroom and ICRU formulae was (9.0, 7.6 and 4.8mm) ML direction, (12.0, 10.0 and 7.0mm) CC direction, (7.7, 6.5 and 4.2mm) AP direction, and for vacloc (9.2,7.8,5.0), (6.5,5.6,3.9) and (8.2,7,4.5) mm for ML, CC, and AP respectively. The lowest margins were noted with ABC (5.5,4.5,3.6) in ML, (7.0,6.0, 4) in CC (5.3,4.4, 2.7) mm in AP. Whereas breast board the margin were little large with (10.6,9.1, 6.1) ML, (12.7,10.8,7.0) CC, and AP (6.3,5.3, 3.3) mm.**Conclusion** It is found that the systematic and random errors are less with gating, so the margin. In all immobilization devices large margin was observed in cranial-caudal direction mm (12.7 max and 6.5 min). Along with Van Herk , Stroom formula also be considered for margin calculation.

Key Words

PTV, Immobilization Devices, CBCT, Ca Breast, Setup errors, Stroom formula, Van Herk formula

Introduction

Breast cancer is considered as the one of the most common cause of cancer death in women worldwide [1], if it is not diagnosed and treated properly. Adjuvant radiotherapy is an important component of multi-disciplinary treatment for breast carcinomas. Radiotherapy treatment delivery requires precision and accuracy in order to maximize its efficacy. One of the key factor in precise and conformal target dose coverage with less radiation toxicities, is to reduce the daily patient's positional errors during the entire course of radiotherapy, and that is done by using immobilization devices.

A geometric expansion of Clinical Target Volume (CTV) to Planning target volume (PTV) margin ensures adequate coverage of the target by accounting for set-up uncertainties. [2] To calculate the appropriate PTV margin, the systematic and random set-up errors of samples must be collected. [3,4] Since PTV margins can vary between departments due to dependence on various treatment planning steps- from immobilization to imaging verification, it is always a good practice to find out the setup margin so as to compute suitable PTV margin individually for each center. There are different formulae for analyzing the PTV margin, but which among them is more

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Manuscript Received: 29.3.2021; **Revision Accepted**: 19.10.2021

Published Online First: 10 April 2022

Open Access at: https://journal.jkscience.org

Cite this article as: Nair SS, Devi VNM, Sharan K , Nagesh J. Analysis of Planning Target Volume margin on different immobilization devices for radiotherapy in carcinoma breast JK Science 2022;24(2):113-117

appropriate is still debatable. Most common formula used for calculating the PTV margin is the Van Herk formula . [5,6]

In this study, we are comparing the set-up accuracy with different immobilization devices, and determining the optimum PTV margin using Van Herk, Stroom and ICRU-62 formulae.

Methods: The study got its approval from Institutional ethics committee and was registered under CTRI. Sixty four patients with breast cancer for adjuvant radiotherapy were enrolled for the study with eligibility criteria listed below.

Inclusion criteria for the study:

"Females

"Age 24<60

"Adjuvant-Radical treatment

"Breast and chest wall

"Supine position

BCS and MRM cases

Selection of particular immobilization devices was based on individual clinical situation, such as movement range of shoulder, patients' comfort, availability, etc. Patients were divided into four groups of 16 patients each, and immobilized either with one of the four immobilization devices: vacuum cushion (vacloc), mould, breast-board and using respiratory gating (Active Breathing Coordinator, ABC). For ABC, patients' ability to execute a Deep Inspiratory Breath Hold was tested prior to enrollment. The four immobilization techniques are shown in *Fig 1*.

Planning CT scan was obtained on Philips brilliance 16 big-bore machine with 3mm slice thickness. Acquired images were pushed to the Monaco (Monaco™ TPS V5.11.02 UK) contouring station for volume delineation. Volume delineation was done according to the RTOG contouring guidelines for breast cancer. Hypofractionated whole breast radiation dose of 42.5 Gy in 16 fractions over 3 weeks, with a planning objective of a minimum of 95% dose coverage to 95% PTV. 3D-CRT plan was done using wedged tangential photon beams. Final plans were evaluated and approved by the treating oncologist. Treatment was delivered on Elekta HD Versa (Stockholm UK) linear accelerator. Cone-beam CT (CBCT) verification system can improve precision and accuracy of treatment by reducing the positional setup errors of the patients [7-9], and was used for all patients. On the first day of treatment, patients were positioned in the same manner as done in planning CT, with the defined immobilization device. The treatment as well as the machine isocentre shifts were applied from the reference fiducial markers on the patient. Following this a volumetric imaging was done with the help of CBCT. The parameters of the CBCT scans are shown in *Table 2*. Set-up verification was repeated for three consecutive days, and thereafter once in every four days of the radiation delivery. A total of 384 CBCTs were taken.

• Acquired reconstructed CBCT were matched with the reference CT images with the help of XVI software algorithm by an experienced oncologist. Visual analyzing was also done in all axial, coronal as well as sagittal planes for ensuring the proper alignment of patient. For all patients, matching was done by a single observer to avoid inter-personal observational errors. Shifts in medio-lateral (ML), anterior-posterior (AP), and cranio-caudal (CC) directions were noted and corrected prior to the radiation delivery. Rotational errors are not applied or corrected in this study. Mean and standard deviations for each patient in all the four groups were calculated. From these readings, systematic errors which are persistent error throughout the entire course, was identified as the mean value of all the errors. Similarly, random errors, which are a result of daily variations, were identified as the standard deviation of all the errors.[5] The systematic error of the population was calculated by taking the standard deviation of mean errors of individual patients, and population random error was calculated as the root mean square of the standard deviation of individual patient errors.[4,10,11] The PTV margins were calculated from this systematic and random errors by using Van Herk formula $(2.5\Sigma+0.7\sigma)$ Stroom formula $(2\Sigma+0.7\sigma)$ and ICRU formula $(\Sigma+0.7\sigma)$, where Σ is systematic and σ is random error [2,6] The analysis of data was done using SPSS software.

Results

The errors, and the resulting PTV margins was found to be more in thermoplastic mould, with 9 mm, 7.6 mm, and 4.8 mm in ML, 12 mm, 10 mm and 7 mm in CC, and 7.7 mm, 6.5 mm and 4.2 mm in AP directions for Van Herk, Stroom and ICRU formulae, respectively The PTV margins for other immobilization devices are given in *Table 3* below.

It was also observed that population random error was always more in CC direction for all immobilization devices, with a maximum error of 5.2 mm in mould, and a minimum error of 1.5 mm with ABC gating apparatus. With gating immobilization, it was noted that the random errors were

1a 1b 1c 1d

Fig. 1 immobilization devices used. 1a: Thermoplastic mould. 1b: Breast-board. 1c: Vacuum cushion. 1d: Active Breathing Coordinator

Table2. The Image Acquisition Parameters of xvi CBCT

KV & MAS	120 & 140
Gantry rotation	Clockwise (36 degree arc)
Collimator	M20
Filter	F1
Frame	660
Reconstruction filter	wiener
XVI software	Version 5.0.3
Nominal scan dose	3.8 mGy

Table 3. Margin Calculated Using Different Formula for Different Immobilization Devices

Devices	Axis	Van Herk (mm)	Stroom (mm)	ICRU (mm)
Thorax mould	ML	9.0	7.6	4.8
	CC	12.0	10.0	7.0
	AP	7.7	6.5	4.2
Vacuum bag	ML	9.2	7.8	5.0
	CC	6.5	5.6	3.9
	AP	8.2	7.0	4.5
Breast board	ML	10.6	9.1	6.1
	CC	12.7	10.8	7.0
	AP	6.3	5.3	3.3
Vacuum bag with ABC gating	ML	5.5	5.3	3.6
	CC	7.0	6.0	4.1
	AP	5.3	4.4	2.7

the lowest. The population systematic as well as the random errors of all immobilization devices are also given in *Fig 2 and 3*

Discussion

A study done on PTV margin on gastric cancer by Leszczyska *et al* states that use of the IGRT system corrects for the motions between fractions and allows reduction in PTV margins and thereby the probability of radiation complications. [12] The most appropriate margin to be utilized can vary between centers, with Van-Herk estimating the largest margins, and the ICRU estimating the smallest. A study by Agnieszka et al on gastric cancer using different PTV margin states that the lowest percentage of shifts that were greater than the calculated margin was observed in the van Herk method, thereby concluding that Van-Herk formula would be most appropriate where daily verification is not possible. [13] Similarly, other researchers have evaluated the inter-fractional PTV margin for different immobilization devices such as mask, knee-fix and feet-fix, wing-board and vac-lok for different sites, and have recommended using Van-Herk formula.[14-19] However, studies on carcinoma breast are few, and there are no publications evaluating different PTV formulae and immobilization devices. The results of our study suggest that Van-Herk formula is the largest estimate, with margins increased by 42-47% compared to ICRU, and 15-16% compared to Stroom formulae, for all devices. For breast due to its pendulous nature, breathing movement, and its close vicinity to the critical organs, a carefully fabricated immobilization system with adequate PTV margin would provide maximum benefit to the patient. From this study it was observed that for Van Herk formula, largest margins are estimated for breast-board and mould. Since selecting the optimum PTV

Fig 2. Population Systematic Errors Using Different Immobilization Devices

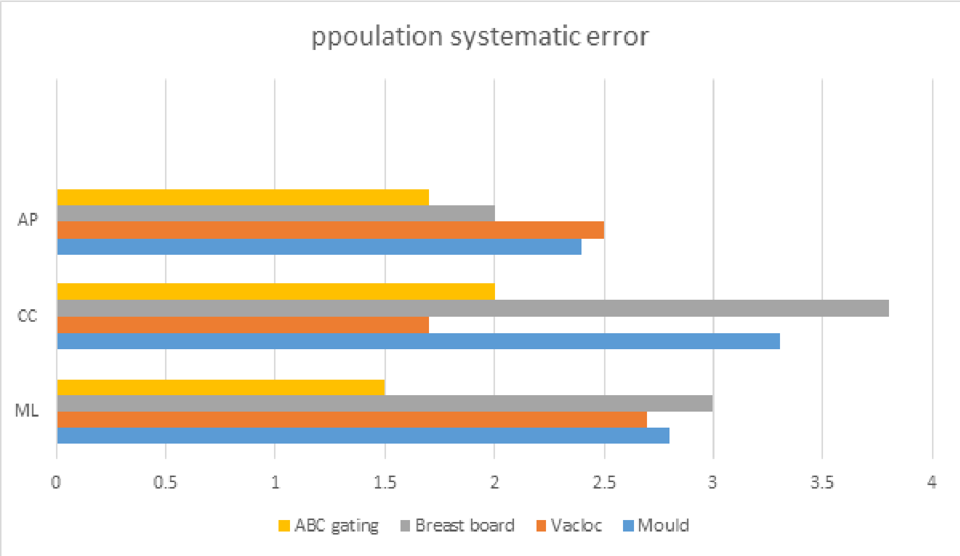
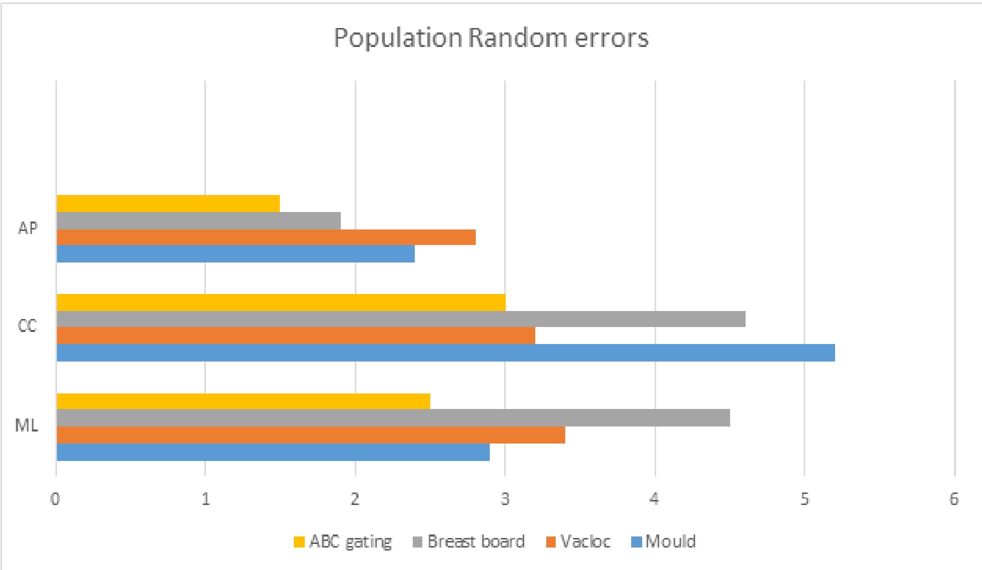


Fig 3. Population Random Errors Using Different Immobilization Devices



margin is one of the prime step in radiotherapy planning, carefully choosing immobilization and set-up margin has to be done. Basaula *et al*. in their article compared the secondary cancer risk in three PTV margin for carcinoma breast cases using the BEIR VII lifetime attributable risk (LAR) model and concluded that smaller PTV margins would result in an overall reduction in secondary cancer risk as well as OAR doses. [20] In our study, smallest margins were observed with ICRU formula for vacloc immobilization using ABC gating. But selecting the ICRU formula for margin estimation is debatable, since lowering the margin will result in geographical error and increased probability of missing CTV. Even though the errors are less in ABC gating, the main problem in gating is the selection of the right participant; thus the choice of ABC gating is always a biased one. Most departments use Van-Herk formula for their margin calculation due to the low-shift errors which may happen from the calculated margin compared with other formulas.

It was also noticed in our study that the errors were maximum in CC direction, irrespective of immobilization device used, but least with vacloc. This may be possibly due to use of a full-body blue bag, with proper folding at cranial and caudal end. Due to the movement in the patient's body itself during inhalation CC directional errors were the largest with ABC. This can be reduced to some extent by proper patient assistance.

In all the immobilization devices both the systematic as well as random errors were found to be the least with ABC gating, with a margin reduction of 39-49% in ML,42-45% in CC and 16-36% in AP axis from other immobilization devices.

Conclusion

We conclude that separate PTV margins have to be calculated for each immobilization devices in individual centers. Even though Van-Herk margin formula is widely used, due to the lesser shift observed from the calculated margin, Stroom formula can also be considered. There is a reduction in margin of 15-16% while considering Stroom formula which could significantly reduce radiation toxicities while retaining adequate coverage. Using a gating along with proper immobilization devices also helps in reducing uncertainty margins.

Financial Support and Sponsorship
Nil.

Conflicts of Interest

There are no conflicts of interest.

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