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**Original Research Article**

# Dosimetric Influence of Normalization Points on Post Mastectomy Chest Wall Teletherapy

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## Abstract

***Background:*** Many advanced radiotherapy techniques had been employed in breast cancer teletherapy, purposely to significantly reduce dose to organs at risk (heart and lungs) with marginal or no compromise in planning target volume (PTV). Majority of used techniques yielded rewarding results in developed countries where facilities, manpower and skills are available. In Nigeria, significant number of post mastectomy breast cancer patients received chest wall irradiation using manual hand planning, therefore, the dose distributions to target volume and organs at risk (OAR) were uncertain. Sokoto centre being the first in the country to use treatment planning system (TPS) focused on identifying planning skills (normalization points) with good 95% dose coverage to PTV, and minimizing dose to OAR. ***Methods:*** Eighteen post mastectomy patients (ten rights and eight lefts chest walls) were simulated via computed tomography scan (CT-scan) in supine position with breast board and fudicial markers to demarcate tumour bed borders. Planning target volume (PTV chest walls) and OAR were contoured from the acquired CT images and bi-tangential portals were applied. The energy used from Elekta précised Linac was 6 MV, and dose of 50Gy in 25# was prescribed to each patient. The Upper 1/3$^{rd}$ normalization point (UNP), Lower 1/3$^{rd}$ (LNP) and Inter-field (INP) were sequentially applied as dose normalization points on each planning CT image, dose to PTV and OAR were evaluated using Clarkson and pencil beam calculation algorithms. Statistical analysis was conducted using SPSS Software to study dose distributions of the normalization points. ***Results:*** Patients simulated were between the ages of 29-56yrs with mean age of 42yrs. The mean percentage doses from normalization points on left chest walls ranged between 81.7-107.7% to PTV, 13.3-17.8% to the lung and 5.5-6.8% to the heart, the reported hot spots were between 110.7 to 141.5%. Similarly, the mean doses from normalization points on the right chest walls ranged between 81.5-108.8% for PTV, 17.8-23.5% to the lung and 2.7-3.7% to the heart, with hot spots of 108.8-137.9%. The statistical differences using independent-t- test for the normalization points on both left and right chest walls shows p-value < 5%**.** ***Conclusion:*** The three normalization points influenced dose distribution to PTV and OAR differently. The UNP and LNP showed a desired dosimetry with marginal compromise in 95% PTV coverage compared to INP.

**Keyword:** Normalization points; Breast cancer; Teletherapy.



## INTRODUCTION

In the early 80's, the incidence of breast cancer in Nigeria was reported second to cervical cancer [1]. Campbell *et al.*, [2] in 1992 reported a contrary finding, where he found breast cancer to be the commonest malignancy, accounting for 23% of 5000 cancer cases seen in radiotherapy centre Ibadan. Since then, local reports in the country had been consistent with his findings [3, 4]. Surgery remains the main stay of breast cancer treatment especially in early stages and some selected locally advanced cases [5, 6]. However, majority of post mastectomy patients (67%) require chest wall irradiation after surgery to reduce local recurrence [4], despite this huge demands, the radiotherapy facilities required to cater for the needs are grossly inadequate in Nigeria. Before the year 2010, there were only two tele-cobalt machines and one non-functioning Linear Accelerator (LINAC) available in the country, serving over 150 million populations. Four new centres emerged in 2010, they were all equipped with Elekta precise linear accelerators, but due to paucity of staffs and frequent break down of the machines, radiotherapy practice in Nigeria remains at status co. Manual hand planning was the commonest planning techniques of breast cancer due to lack of knowledge on how to use TPS, therefore, dose evaluation to chest wall and OAR were impossible in majority of centres due to either limited manpower or lack of facilities in the centres. This is contrary to western world practice where modern radiotherapy facilities and man power were available. Different techniques using TPS were devised in breast cancer teletherapy, this include patients positioning (prone) method, forward-planned IMRT, inverse-planned IMRT, and modulated arc therapies were all explored to obtain dose uniformity to PTV and to reduce dose to OAR. Sokoto state centre where this study was conducted have been equipped with Elekta precise Linear accelerator and computerised TPS, majority of personals to run the centre were trained abroad, hence the reason for being the first to use computerised TPS in the country. Different skills and techniques obtainable in developed nations were also explored locally to achieve similar desired dosimetry in breast cancer teletherapy.

## MATERIALS AND METHODS

Eighteen post mastectomy breast cancer patients (ten rights and eight lefts) were CT simulated between February and August 2016 at Radiotherapy department of Usmanu Danfodiyo University Teaching Hospital (UDUTH) Sokoto, Nigeria. Patients were simulated in supine position with breast board and fudicial markers demarcating tumour bed. PTV chest walls and organs at risk (ipsilateral lung and heart) were contoured from the CT images using the Radiotherapy Oncology Group (RTOG) guide lines. Contoured CT images were subsequently exported from contouring station to the TPS, bi-tangential portal beams were inserted on the planning CT image of each patient, guided by a base line (inter-field line) connecting mid anterior chest wall and mid lateral chest wall fuditial markers. Normalization points were defined along a perpendicular line arising from the mid inter-field line to the outer surface of the chest wall. The perpendicular line was divided into three equal parts, the junction between the upper 1/3$^{rd}$ and middle 1/3$^{rd}$ was defined as upper normalization point (UNP), and for that of the middle 1/3$^{rd}$ and lower 1/3$^{rd}$ was regarded as lower normalization point (LNP), and the last was located at the point of intersection of perpendicular with base line and was referred to as inter-field normalization point (INP). Each time prescriptions were made on those points; dosimetric verifications were also conducted to assess PTV coverage and dose to organs at risk. Dose volume histograms (DVH) of the accepted plans were generated for each normalization point and mean doses to PTV chest wall, lung and heart were extracted from both left and right chest walls.Data obtained were analysed using Statistical Package for Social Sciences version 17.0 (Chicago). Independent-t- test was conducted for significant differences in the mean doses of PTV and OAR. Results obtained were presented in Tables, graphs and charts.

## RESULTS

Eighteen post mastectomy patients were CT simulated, their ages ranged between 20-63 years with mean age of 42 years and SD of ±8.5yrs (figure 1). Majority of UNP normalization points (91.7%) were located on the chest wall except 8.3% that fall inside the lung, the LNP and INP were completely (100%)located inside the lung (table 1). Depending on the normalization point, the dosimetric parameters (mean percentage doses) derived from PTV chest wall, lung, heart and hot spot in a respective manner on the left chest walls were 81.67%, 13.33%, 5.5% and 110.17% using UNP, 82.83%, 13.67%, 5.67% and 111.65% for LNP and 107.67%, 17%, 6.83% and 141.52% for the INP (table 2). Similarly, on the right chest walls the percentage mean doses for PTV chest wall, lung, heart and hot spot were 85.7%, 18.5%, 2.83% and 108.83% for UNP, 81.5%, 17.83%, 2.63% and 103.2% for LNP and 108.8%, 23.5%, 3.67% and 137.88% for INP (table 3) in a respective manner. Independent-t-test conducted for the percentage mean doses of the three normalization points for both left and right chest walls showed a significant differences with p-value < 5% (table 4 and 5).

**Table 1: Location of normalization points on the CT images**

| Sites | U1/3 NP | L 1/3 NP | IFN |
|---|---|---|---|
| R. Chest wall | 5 (83.3%) | 0 | 0 |
| R. Lung | 1 (16.7%) | 6 (100%) | 6 (100%) |
| Heart | 0 | 0 | 0 |

**Table 2: Percentage means doses to PTV and OAR on left chest wall**

| Normalization points (NP) | Contoured structure and their percentage mean doses | | | Hot spots |
|---|---|---|---|---|
| | Chest wall (PTV) | Lung | Heart | |
| UNP | 81.7 | 13.3 | 5.5 | 110.7 |
| LNP | 82.8 | 13.7 | 5.7 | 111.7 |
| INP | 107.7 | 17.8 | 6.8 | 141.5 |

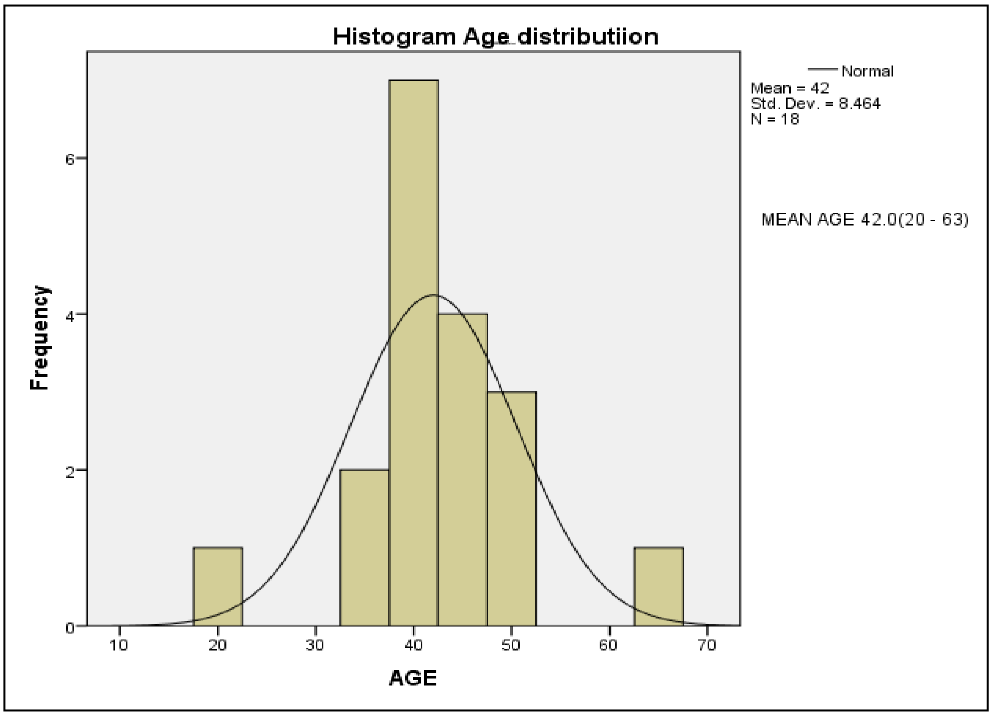


**Figure 1: Age distribution of 18 breast cancer patients displayed in histogram**

**Table 3: Percentage means doses to PTV and OAR on right chest wall**

| Normalization points (NP) | Contoured structure and their percentage mean doses | | | Hot spots |
|---|---|---|---|---|
| | PTV (Chest wall) | Lung | Heart | |
| UNP | 85.7 | 18.5 | 2.8 | 108.8 |
| LNP | 81.5 | 17.8 | 2.7 | 103.2 |
| INP | 108.8 | 23.5 | 3.7 | 137.9 |

**Table 4: Assessment of statistical differences between normalization points on left chest walls using independent-t-test**

| Evaluated parameters | Mean percentage doses from normalization points | | | p-value |
|---|---|---|---|---|
| | UNP | LNP | INP | |
| Chest wall (PTV) | 81.67 | 82.83 | 107.67 | 0.009 |
| Lung | 13.33 | 13.67 | 17.00 | 0.006 |
| Heart | 5.5 | 5.67 | 6.83 | 0.005 |
| Hot spots | 110.17 | 111.65 | 141.52 | 0.007 |

**Table 5: Assessment of statistical differences between normalization points on right chest walls using independent-t- test**

| Evaluated parameters | Mean percentage doses from normalization points | | | p-value |
|---|---|---|---|---|
| | UNP | LNP | INP | |
| Chest wall (PTV) | 85.67 | 81.5 | 108.83 | 0.008 |
| Lung | 18.5 | 17.83 | 23.50 | 0.008 |
| Heart | 2.83 | 2.67 | 3.67 | 0.008 |
| Hot spots | 108.82 | 103.2 | 137.88 | 0.008 |

## DISCUSSION

The evolution of radiotherapy techniques using three-dimensional conformal radiation therapy (3DCRT) started back in 1990s, with desired objectives of minimizing radiation dose to critical organs at risk ( lungs and heart) and achieving 95% PTV coverage in breast cancer teletherapy. The first success recorded using the technique was by reducing the volume of heart covered by 50% isodose charts (approximately 33 cc) [5]. This is synonymous to reduction in heart mean dose from 5.1Gy to 3Gy. (6) Since then, 3DCRT proved to be an effective technique in achieving dose constraint to OAR over 2D [7, 8], this encouraging resulted to further exploration of other techniques with more desired dosimetry in breast cancer teletherapy. Among others include inspiratory breath hold (DIBH) technique, use of prone position and intensity modulated radiotherapy (IMRT) [9-20]. The current study build on the above techniques to introduced new concept of normalization points (UNP, LNP and INP) with similar desired dosimetric objectives in our resource poor environment. The use of UNP and LNP on the left chest wall shows mean heart dose between 2.8 -2.9Gy, this is consistent with the result obtained from DIBH technique with heart mean dose between 2–3 Gy [21-25]. Similarly, a Sweden and Denmark review of 2168 women with risk of ischemic heart disease post breast cancer teletherapy reported a mean heart dose of up to 10Gy on the left chest wall (range of 0.03-27.71Gy), and 1-2Gy on the right chest wall. The reported doses on the left were high than our findings of 2.8Gy-3.4Gy, whereas the mean doses on the right side were consistent with our report of 1.4Gy -1.9Gy. Reasons for the differences in doses between the two studies might be due to variation on contouring, dose calculation algorithms, and planning techniques and in some cases the inclusion of lymph nodes regions in radiation portal [26]. To bias Finazzi *et al.*, in 2019 [40] reported a reduction in heart median dose on left chest wall (4.6Gy vs. 3.3Gy) in favour of IMRT over 3DCRT, the IMRT result shows consistency with our findings of 2.8-3.4Gy using UNP and LNP. A significant variation in heart mean doses exist between right and left chest walls, reasons were strongly attributed to anatomical location of the heart. The heart is more located on the left than on the right chest wall, hence more volume is being exposed to radiation with resultant increase in radiation induced cardiac mortality [27-41].

Similarly, in breast cancer teletherapy, lungs were encompasses within the radiation portals and therefore care has to be taken to minimize their exposure. Finazzi *et al.*, [40] reported his findings on median doses of 14.8 vs. 7.7Gy to the left lung in favour of IMRT over 3DCRT. The IMRT result (7.7Gy) shows consistency with our findings of 6.7Gy and 6.9Gyusing UNP and LNP respectively. The use of advanced techniques like proton beam therapy and lateral decubitus positioning reported lower radiation doses of <2.7Gy and <2.5Gy respectively. However, these techniques and facilities were limited to few countries even in developed world due to their complexity and cost of procurement [42]. Many scholars explained the correlation between total lung volume and heart mean dose by either increasing the lung volume or central long distance (CLD) [43-45]. Previous studies using DIBH method showed an increase in CLD with corresponding reduction in mean heart dose and lung volume [40, 46]. Devising new techniques and improvement in planning skills have significantly reduced dose to critical structures with minimal or no compromise in 95% PTV coverage. This shows that improving planning skills can further reduce radiation dose to critical structures with little or no compromise in 95% PTV coverage. The normalization points used in this study have yielded desired results in term of dose constraint to critical organs except the INP that present with high dose to OAR, hot spots and erratic behaviour. Therefore, the use of INP in breast cancer teletherapy should be discouraged to avoid radiation induced morbidity and mortality. The use of normalization points in this study is time friendly; this is contrary to other techniques that were proven to be time consuming [47-49]. However, results obtained from computerized treatment planning should not be the ultimate criterion in evaluating patient's dosimetric parameters, it required correlation with clinical outcomes of patients.

## CONCLUSION

The use of normalization points in post-mastectomy chest wall teletherapy influenced dosimetry to PTV and OAR differently. The INP shows >100% PTV coverage but with unacceptable high radiation doses to OAR and hot spots. On the contrary, the UNP and LNP showed desired dose constraint to OAR but with marginal compromise in 95% PTV coverage. Therefore, to achieve a near dosimetry in chest wall teletherapy the use of UNP and LNP planning methods are recommended.

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