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Research Paper

Dosimetric Consequences of Using Wedge Angles as Major Determinants of Tumor Dose Homogeneity in Breast Cancer Teletherapy

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Abstract

Advanced radiotherapy techniques such as intensity modulated radiotherapy (IMRT), volumetric modulated arc therapy (VMAT) and proton beam therapy replaced the use of wedge angles in achieving tumor dose homogeneity in developed nations. The availability of such machines is limited in our environment, therefore, wedge angles remains the major alternative beam modifiers to produce dose uniformity to target volumes. This study aimed at evaluating the dosimetric consequences of using wedge angles in achieving tumor dose homogeneity. Twenty Computed Tomography (CT) images of female patients with breast cancer (ten each for left and right side) were reviewed, their mean age was 42 years, Bi-tangential beams were used and dose of 50 Gy in 25 fractions was prescribed to each patient. Three commonly used wedge angles (15°, 30° and 45°) were sequentially inserted across the beams for each plan and tumor dose homogeneity was evaluated using 95% isodose coverage. Hot spot, mean dose, dose rate and monitor units generated were recorded for each wedge angle used. Statistical package for social sciences (SPSS) version 23.0 was used to find overall mean of each parameter. A two ways Analysis of Variance (ANOVA) was conducted to find variation in using different degrees of wedge angles on above stated parameters at 5% α level of significance. Results were presented in tables and bar-chart. After plan evaluation, the overall percentage mean doses were 97.8% for 15°, 97.4% for 30° and 96.4% for 45°. For the hot spot it was 111.7% for 15°, 109.7% for 30° and 108.7% for 45°. Dose rates for medial and lateral fields were (0.5385, 0.6921 cGy/MU) for 15°, (0.3918, 0.5012 cGy/MU) for 30° and (0.2801, 0.3544 cGy/MU) for 45° respectively. Similarly, the corresponding monitor units generated for medial and lateral fields were (78.02, 66.18MU), (170.81, 147.12MU) and (311.86, 269.03MU) according to increasing order of wedge angles. No significant differences seen between the use of different wedge angles and percentage mean doses or hot spots ($p > 0.05$).The use of wedge angles (EDWs) > 15° showed no benefit in improving tumor bed percentage mean dose, but rather it increase number of MUs which prolong treatment time and likelihood of patient movement during treatment.

Keywords: Breast cancer; Teletherapy; Wedge angles; Tumor dose homogeneity

Introduction

In most patients with operable breast cancer, the standard treatment after surgery is radiation therapy to prevent local recurrence [1-4]. In respect to that, the degree of tumor dose homogeneity is very important, because tumor dose inhomogeneity has a significant influence on tumor control and cosmetic outcome [5-7]. To achieve the stated objectives, advanced radiotherapy techniques such as IMRT, VMAT and proton beam therapy are now being used in many centres of developed nations to obtain tumor dose homogeneity. However, in majority of African countries tumor dose homogeneity strongly depends on the application of wedge angles especially on slope surfaces of patients, regions of beams overlap and irregular shaped tumor volumes [8, 9]. The application of such wedge angles were better seen and appreciated in three dimensional conformal radiotherapy (3D CRT), which is only available in three Radiotherapy centres of Nigeria, namely Usmanu Danfodiyo University Teaching Hospital Sokoto, National Hospital Abuja and Lagos University Teaching Hospital. Similarly, there is inadequate knowledge in manipulation of planning parameters to achieve tumor dose homogeneity with less dosimetric consequences, hence the reason for continuous use of wedge angle in modulating the radiation beam intensity, ignoring its dosimetric and clinical implication especially in Nigeria and other African countries with limited radiotherapy facilities [10].

Materials and Methods

Twenty Computed tomography (CT) images of female patients with breast cancer were reviewed, ten each for left and right chest walls. Tumor beds, organs at risk (heart and lungs) were contoured using Radiation Oncology contouring guide lines (RTOG). Bi-tangential opposing fields were used to cover the tumor bed (superior from supra sternal notch, inferiorly two centimetre below the contra lateral mammary fold, medially from the mid sternal line and laterally at the mid axillary line) and dose of 50 Gy in 25 fractions was prescribed for each patient. The photon bean energy used was 6MV in all the fields, three commonly chosen wedge angles (15^{o}, 30^{o} and 45^{o}) from the precise treatment planning system (TPS) were sequentially inserted across the beams for each field and on each patient's plan, followed by dose calculations using pencil beam and clerkson algorithms. Plans were evaluated slice by slice for dose homogeneity (tumor bed percentage mean dose) using 95-100% isodose coverage to planning target volume (PTV chest wall). Hot spot (percentage dose > 110 isodose) tumor bed mean dose (representative percentage dose covering the PTV), dose rate and monitor units produced from each field by using a specified wedge angle were recorded. Statistical package for social sciences (SPSS) version 23.0 was used to find overall mean of each parameter. A two ways Analysis of Variance (ANOVA) was conducted to find statistical differences between the use of wedge angles and changes observed on the above stated parameters at 5% α level of significance. Results were presented in tables and bar-chart.

Results

Twenty female breast cancer patients with mean age of 45.2 years (26 - 80 years) with SD of ± 14.1 were analyzed (Figure 1). The mean inter field distance was 17.4 cm (10.4- 22.8 cm) and SD of ± 3.2 (Figure 2). In table 1, the overall percentage mean doses were 97.8 % for 15^{o}, 97.4 % for 30o and 96.4 % for 45^{o}. For the hot spot it was 111.7 % for 15^{o}, 109.7 % for 30^{o} and 108.7 % for 45^{o}. Dose rates obtained at medial and lateral fields were (0.539, 0.692 cGy/MU) for 15^{o}, (0.392, 0.501 cGy/MU) for 30^{o} and (0.280, 0.354 cGy / MU) for 45^{o} respectively. Similarly, the corresponding monitor units for medial and lateral fields were (78.02, 66.18 MU), (170.81, 147.12 MU) and (311.86, 269.03 MU) according to increasing order of wedge angles. There are no significant differences seen between the use of wedge angles and percentage mean doses or hot spots (p > 0.05). However, dose rates and monitor units generated were statistically significant with differences in wedge angles, p-values < 5% (Table 2).

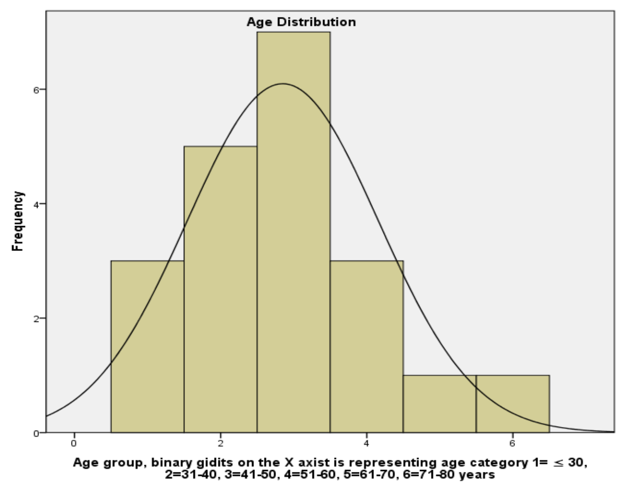

Figure 1. **Age distribution of breast cancer patients treated with Radiotherapy.**

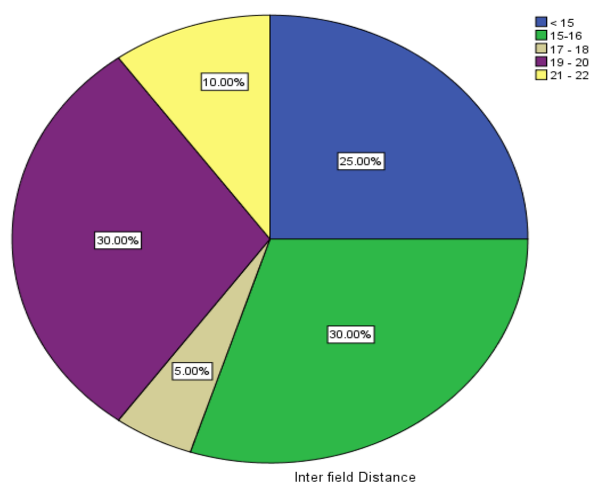

Figure 2. **Distance between the medial and lateral tangential fields (inter fiducial marks distance).**

Table 1. Overall means of dosimetric parameters under three major wedge angles

Dosimetric parameters	Wedge angles 15°	30°	45°
T. percentage mean dose	97.8 %	97.4 %	96.4 %
Percentage hot spot	111.7 %	109.7 %	108.7 %
D. rates M. tangential field (cGy / MU)	0.539	0.392	0.280
D. rates L tangential field (cGy / MU)	0.692	0.501	0.354
MUs M. tangential Field (cGy / MU)	78.02	170.81	311.86
MUs L. tangential field (cGy / MU)	66.18	147.12	269.03

T= Tumor, D= Dose, M= medial, L= lateral, MUs= monitor units

Discussion

Previous report have shown that the use of physical wedge angles have been associated with a lots of demerits which includes limited field sizes and wedge angles, wedge factor that is dependent on beam energy, field size, depth of measurement, and type of accelerator [11]. Misalignment of physical wedge angles in addition to the above stated problems was also reported to impact dosimetric error in treatment delivery [12]. The evolution of modern linear accelerators (LINACs) with enhance dynamic wedge angles (EDWs) gradually replaced the use of physical wedges and provides an alternative options in achieving tumor dose uniformity using computerized treatment planning system (TPS). The emergence of EDWs was thought to bring a tremendous advantage in minimising previously encountered dosimetric errors by using physical wedges, with potential option for any arbitrary wedge angle that can improve target dose distribution and even to reduction of dose to the contralateral breast [13]. However, despite all the stated dosimetric benefits of EDWs in breast cancer teletherapy, this study confirmed other unforeseen disadvantages associated with their use. After careful plan evaluation with other TPS alternative tools (beam weighting, combination of beam energies, mix beams and the use of normalization points) than the use of regular wedge angles alone, it was observed that varying degrees of EDWs played no role in improving percentage mean dose to PTV chest walls and hot spots reduction. Instead, we observed a trend in compromise of 95% mean dose to PTV chest wall when degree of wedge angle increases (>15°). This observed trend might not be restricted to only increasing degree of wedge angles but also related to collimator jaws movements during treatment. Previous reports have shown that collimator movement from cranial to caudal direction results in to PTV under-dosage [14]. It had been debated that the application of modern EDWs is comparative to that of physical wedges in cobalt and other early accelerator machines [15,16] but other authors claimed superiority of EDWs over physical wedges in terms of less MUs generation and safety in clinical practice [17,18-20]. However, this study dwelled on dosimetric differences and implications of varying degrees of EDWs, and the results showed that as degree of EDWs increases especially when >15°, the dose rates decreases and MUs increases. Previous report clearly stated that the introduction of IMRT has made it possible to improve dose homogeneity by moving the MLC either by forward planning or inverse planning rather than the traditional wedge technique, especially in reduction of cold and hot spots in breast cancer radiotherapy [21]. The clinical implication of increase in MU with increasing wedge angles is increase in treatment time and increasing probability of patient movement and target miss during treatment especially in our environment where immobilization devices were not routinely used.

Table 2. An association of dosimetric parameters with three major wedge angles using a two way ANOVA

Dosimetric parameters	Wedge angles			Two way ANOVA		
	15°	30°	45°	M.sq	F	p value
T. % mean dose	97.8 %	97.4 %	96.4 %	9.19	0.18	0.84
Percentage hot spot	111.7 %	109.7 %	108.7 %	44.4	1.20	0.31
D. rates M. tangential field (cGy/MU)	0.539	0.392	0.280	0.33	67.9	0.00
D. rates L tangential field (cGy/MU)	0.692	0.501	0.354	0.56	59.7	0.00
MUs M. tangential field (cGy/MU)	78.02	170.81	311.86	269342	67.79	0.00
MUs L. tangential field (cGy/MU)	66.18	147.12	269.03	202572	43.35	0.00

T= Tumor, D= Dose, M= medial, L= lateral, MUs= monitor units

Conclusions

Changing wedge angles played no significance in improving tumor bed (PTV chest wall) percentage mean dose or eradicating hot/cold spots areas. Similarly, the use of higher wedge angles (≥ 15^o) increase number of MUs resulting to prolong treatment time and likely hood of patient's movement during treatment. Conclusively, this study advises those involved in planning patients to explore other planning tools available inside the TPS in achieving tumor dose uniformity, and whenever necessary, smaller wedge angles ≤ 15^o should be considered to minimize the stated dosimetric disadvantages.

Abbreviations

LINACs: Linear accelerators, TPS: Treatment planning system, PTV: Planning target volume.

Author Contributions

All authors contributed equally to this study and gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

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