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ORIGINAL ARTICLE

Comparative Study of the Simulated and Calculation Gantry Angle Methods in Tangential Breast Irradiation

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Breast irradiation involves a complex geometric and field-matching technique. Simulators are used to obtain the best and accurate patient treatment positioning as well as irradiation geometry for radiation portals. However many centers in developing countries lack this important equipment. The study was designed to determine the accuracy and reliability of the gantry angle calculation method for tangential breast irradiation in comparison with the simulated method. This prospective study was conducted at the National Center for Radiotherapy and Nuclear Medicine, Accra, Ghana between June and October, 2012 with a sample size of 50 breast cancer patients. The simulator method was compared with the calculated method to assess if the two methods can be used interchangeably using Bland-Altman analysis. The sensitivity and specificity values of the calculated formula in estimating accurate gantry angle as well as beta gantry angle were also calculated using Receiver Operator Characteristic. The coefficient of variation (CV) of the results generated by the simulation method (65.18%) was similar to the coefficient of variation of the results generated by the proposed formula (65.30%). The CV of the beta angles results from the breast bridge (13.50%) was also consistent with the calculated formula (14.04%). The sensitivity and specificity of the calculated formula for gantry angle are 100% and 100% respectively. The sensitivity and specificity of the calculated formula for beta angle are 100% and 98% respectively. None of the gantry angle values generated by calculated formula was different from the corresponding value from the simulator by 3 degree or more. Within the limit of this study, the two methods can be used interchangeably without significant variation in treatment plan and outcome.
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INTRODUCTION

Approximately one and half million new breast cancer cases are reported annually worldwide (ACS, 2010; Globocan, 2008; Parkin and Pisani, 2008). In sub-Sahara African countries, it is very difficult to determine the actual incidence of breast cancer due to the absence of a national cancer registry, as cancer receives low priority for health care services (Tannerberger *et al.,* 2004; Parkin and Fernandez, 2006; Jamison *et al.,* 2006). In Ghana, breast cancer is the leading malignancy accounting for 15.4% of all malignancies, and this number increases annually (Clegg-Lamptey and Hodasi, 2007; Stark *et al.,* 2010). Available statistics from the International Agency for Research on Cancer puts the Ghana's 2008 estimates at 25.8 per 100,000 with 2062 recorded cases in Ghana (Globocan, 2008).

Patients who receive breast irradiation represent a significant proportion of the workload in radiotherapy departments across the globe (Bentel, 1996, Bomford and Kunkler, 2003). The rationale for post-mastectomy chest wall irradiation or lumpectomy followed by radiotherapy is to improve overall survival and prevent local recurrence of cancer (Halperin *et al.,* 2008). Radiotherapy is also indicated for locally advanced and metastatic breast cancer

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for palliative intent (Clifford, 1999).

External beam irradiation of the breast involves a complex geometric and field-matching technique, which consists of a supra-clavicular field, a pair of tangential fields to treat the breast or chest wall and sometimes an internal mammary field (Halperin *et al.,* 2008; Clifford *et al.,* 1999, Washington and Leaver, 2000). The supra-clavicular field is used to treat the involved supra-clavicular and/or axillary nodes.

The technical complexity arises from matching the inferior border of the supraclavicular field with the superior borders of the tangential fields to prevent any overdose to the junction of the fields, as well as choosing the right gantry angles for the tangential fields to minimize the volume of lung being irradiated with reference to the posterior edge of the tangential fields (Clifford *et al.,* 1999; Lichter *et al.,* 1998). Shielding (with either lead or Multileaf Collimators) is used to protect the shoulder joint and the apex of the lung to prevent fibrosis of the joint and minimize radiation to the lung respectively. If irradiation of internal mammary chain is intended, then a direct internal mammary field is used (Lotayef *et al.,* 2005; Bomford and Kunkler, 2003).

Simulation helps in target localization and beam placement in the treatment planning for accurate breast irradiation (Lotayef *et al.,* 2005). However, despite the important role of a simulator, many centers in developing countries do not have this equipment. At the centers where they are available, frequent break down and long periods before repair lead to treatment delays with its associated problems. The problem becomes more serious in the tangential fields irradiation of the breast where the gantry angles need to be determined accurately with minimal error margins to spare the lungs from excessive irradiation. Without fluoroscopic guidance with a simulator, the above procedure becomes cumbersome and complicated.

The gantry angles for tangential breast irradiation can, however be calculated with geometric formulas which are based on measurements of the field length, the horizontal distance between midline and mid-axillary line, the vertical distances from the mid axillary line to the inferior and superior beam border and central axis at midline (Clifford *et al.,* 1999; Lichter and Padikal, 1998; Lotayef *et al.,* 2005; Bomford and Kunkler, 2003; Sillanpa *et al.,* 2005; Lederer and Schwendener, 1997, Khan, 2007). This comparative study was conducted to determine the accuracy and reliability of the gantry angle calculation method based on simple geometric formula when compared with angles obtained with a conventional simulator for breast irradiation technique in use at the National Center for Radiotherapy and Nuclear Medicine, Korle-Bu Teaching Hospital (KBTH), Accra, Ghana.

MATERIALS AND METHODS

This prospective study was carried out at the National Center for Radiotherapy and Nuclear Medicine (NCRNM), Korle-Bu Teaching Hospital (KBTH), Accra, Ghana between June and October, 2012. Fifty (50) patients diagnosed with breast cancer and scheduled to undergo radiotherapy were consecutively enrolled into the study after giving informed consent. The study was approved by the management of the NCRNM, Korle-Bu Teaching Hospital and ethical clearance for the study was given by the Ethics and Protocol Review Committee of the School of Allied Health Sciences, University of Ghana.

Convenient sampling was employed in selecting study participants during their simulation appointments at the centre as part of the radiotherapy process. The inclusion criteria included patients having both supra-clavicular and tangential breast field irradiations as well as those treated with only tangential breast fields if the treatment technique required the use of a couch rotation (Neal and Hoskin, 2000). Patients with very large or flaccid breast were excluded from participating in the study. This was based on the assumption that such breasts could not be measured accurately by the breast bridge and also the fact that the breast bridge could not fit well on patients with a big separation (Krystyna, 2007).

Gantry Angle Calculation Technique

Parameters obtained during simulation such as couch rotation(a); separation (s); gantry angles obtained with a simulator (β) and that obtained with a breast bridge (β_b) were considered for each of the study participants. Additional parameters, comprising the treatment depth (H) on the posterior border (P_1) of the medial tangential field in the transverse plane containing the beam central axis was also determined for each study participant. In determining H, the lateral laser was made to coincide with posterior border of the lateral tangential field in the same transverse plane (Chang et al., 2007). Pilot simulation was done on each study participant and this involved taking specific measurements to determine the gantry angles required for simulation and treatment. Individual patient measurements such as skin to lateral laser distance and separation were taken to determine an angle (β) which was then used to calculate the gantry angle (Chang et al., 2007). A breast bridge (MT-BB01; MED-TEC, Orange city, Iowa, USA) was used to determine the angle (β) in order to find the correlation with the calculated (β) (Clifford *et al.,* 1999; Lichter and Padikal, 1998; Lotayef *et al.,* 2005; Bomford and Kunkler, 2003; Sillanpa *et al.,* 2005; Lederer and Schwendener, 1997, Chang *et al.,* 2007). The calculated gantry angle technique was verified fluoroscopically with the conventional simulator to determine the: accuracy of the gantry angle from calculation, coincidence of the posterior borders of the tangential fields and volume of lung in the beam (Lichter and Padikal, 1998; Lotayef *et al.,* 2005). The simulated gantry angles were determined fluoroscopically with the conventional simulator and were considered as the control data (Chang *et al.,* 2007).

Derivation of Gantry Angles from Geometric Formula

A horizontal line was drawn through point P_1 which made an angle of θ with the posterior border of the tangential field. From simple geometry it implies;

$$\sin\theta = \frac{H}{S} \qquad (1)$$

Hence:

$$\theta = \sin^{-1}\frac{H}{S} \qquad (2)$$

Statistical analysis

The simulator method was compared to the formula using Bland-Altman analysis. It is most unlikely that different methods will agree exactly by giving identical results for all individuals. Hence, the need to know by how much the new method (i.e. using the calculated formula) is likely to differ from the conventional and gold standard method (i.e. using simulator): Bland-Altman analysis first calculates the difference in measurement values obtained by the two methods on the subjects. The mean of such difference in a sample of subjects is the estimated bias (difference between method), and the standard deviation (SD) of the difference measure random fluctuation (precision) around this mean. If the "limit of agreement" (mean difference ± SD) between the two methods is not clinically important, both methods could be used interchangeably.

Another essential feature of the analysis is the graphical representation of the data with between-method difference (y axis) plotted against the average (x axis). This allows for evaluation of existing relationships between the error measurement (*difference*) and the assumed true value (*average*). Accuracy is assessed by analyzing how close data points are to the x-axis and the observed trend as the value on the x-axis increases.

The sensitivity and specificity values of the formula in estimating accurate gantry angle as well as beta gantry angle were calculated using Receiver Operator Characteristic (ROC) analysis. In all statistical tests, a value of $p < 0.05$ was considered significant.

RESULTS AND DISCUSSION

A total sample size of 50 breast cancer patients visiting the National Center for Radiotherapy and Nuclear Medicine, Accra, Ghana were enrolled into the study to determine the accuracy and reliability of the gantry angles calculation method for tangential breast irradiation as compared to the simulation method.

Table 1: General characteristic of the studied population

Variables	SGA (°)	CGA (°)	BB (ß) (°)	C (°)	SLLD (cm)	S (cm)	DA (°)
Minimum	52.0	51.0	20.8	20.8	8.0	16.0	1.0
Maximum	309.0	310.0	42.0	42.0	17.0	28.0	5.5
Mean	185.9	185.7	33.0	32.9	11.6	21.3	2.9
Std. Deviation	121.2	121.2	4.4	4.6	2.1	2.8	1.0
SEM	17.1	17.2	0.6	0.7	0.3	0.4	0.1
CV	65.18%	65.30%	13.50%	14.04%	17.80%	13.19%	33.17%

The parameters include; simulated gantry angle (SGA), gantry angle obtained with breast bridge (BB), skin to lateral laser distance (SLLD), calculated angle from the proposed formula (C), couch angle (DA), and calculated gantry angle considering the quadrant of the gantry (CGA).

From the general characteristic of the studied population, the range, mean, SD and SEM of SGA *vs.* CGA as well as BB *vs.* C were comparable as indicated in Table 1. The coefficient of variation of the results generated by the simulation method (65.18%) was also similar to the coefficient of variation of the results generated by the proposed formula (65.30%). The CV of the beta angles results from the breast bridge (13.50%) was also consistent with the CV generated by the beta angles from the proposed formula (Table1).

When the mean values of the simulated gantry angles (SGA) result was compared to the calculated gantry angle from the proposed formula (CGA) using paired *t*-test, there was no significant difference (p = 0.124) in the result as shown in Figure 1. There was also no significant difference (p = 0.581) when results of the beta angle from the breast bridge (BB) was compared to results of the beta angle from the proposed formula (C) (Figure 1).

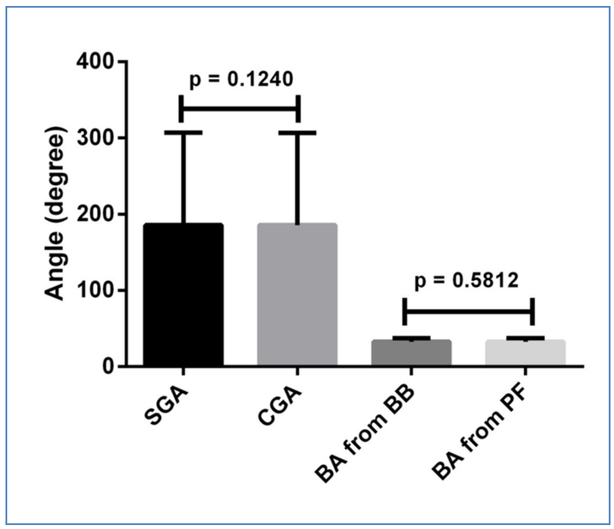

Figure 1: A comparison of SGA *vs.* CGA as well as beta angle (BA) from the breast bridge (BB) *vs.* BA from the proposed formula (PF) using paired *t*-test

From the Bland-Altman analysis in Figure 2, when the reference simulator method was compared to the calculated formula with regards to the gantry angle generated, it indicated that the calculated formula was producing gantry angles very close to the reference method. This finding is in complete agreement with earlier observations made in Table 1 as well as Figure 1. The estimated bias (i.e. mean difference between the two methods) is 0.2; the precision (i.e. standard deviation of the mean difference) for the calculated formula is 0.90 and the 95% limits of agreement ranged from -1.57 to 1.97. From this analysis, only 1 point out of the 50 fell out of the 95% limit of agreement, but this point is however, within the 3° allowable difference between the two methods (Figure 2A).

Method comparison of the beta angle results produced from the breast bridge as well as the calculated formula also indicate good agreement in line with earlier observations made in Table 1 and Figure 1. The estimated bias (i.e. mean difference between the two methods) is 0.1; the precision (i.e. standard deviation of the mean difference) for the calculated formula is 0.90 and the 95% limits of agreement ranged from -1.70 to 1.90. From this analysis, 3 points out of the 50 fell out of the 95% limit of agreement, 2 out of which are within the 3^o allowable difference between the two methods. The other points were 4^o above the corresponding results generated by the breast bridge (Figure 2B).

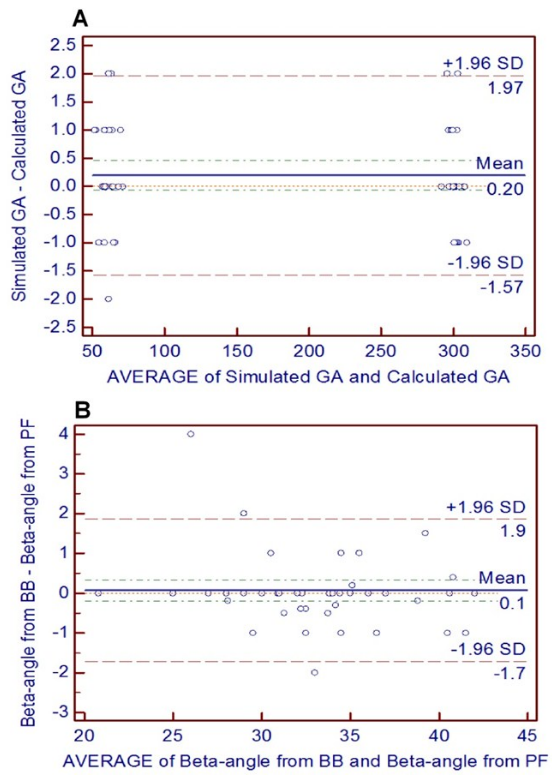

Figure 2: (A) Bland-Altman graph of difference scores for SGA vs. CGA and (B) Bland-Altman graph of beta-angle from Breast Bridge vs. beta-angle from proposed formula

Considering the two methods with regards to gantry angle, none of the gantry angle values generated by the proposed formula was different from the corresponding value from the simulator by 3^o or more. With regards to the beta angle results from the proposed formula only 1 point was differed by 3^o or more (i.e. 4^o) from the beta angle generated by the breast bridge. Further estimations were done on the sensitivity and specificity of the calculated formula with regards to the gantry angle and beta angle at a cut-off of > 3^o (Figure 3). At this cut-off, the sensitivity and specificity of the calculated formula for gantry angle were 100% and 100% respectively with the area under the curve (AUC) being 1.00 ($p < 0.0001$) (Figure 3A). At the same determined cut-off, the sensitivity and specificity of the calculated formula for gantry angle are 100% and 98% respectively with the area under the curve (AUC) being 1.00 ($p < 0.0001$) (Figure 3B).

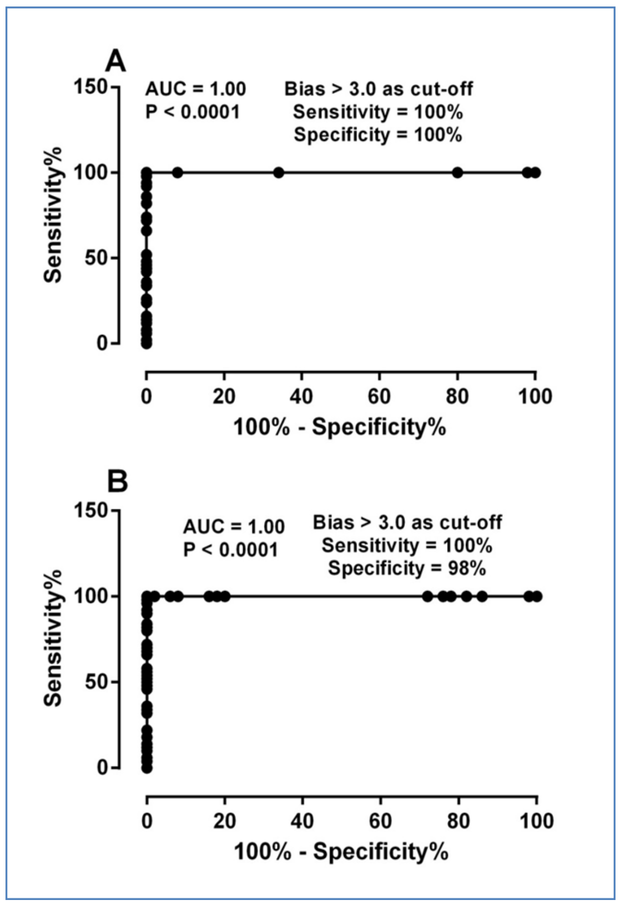

Figure 3: Receiver Operator Characteristic analysis of the proposed formula using the simulator as the reference method with regards to gantry angle (A) and beta angle (B)

CONCLUSION

A fair assessment of the two methods shows that both methods can be utilized interchangeably. Furthermore, none of the gantry angle values generated by the proposed formula was different from the corresponding value from the simulator by 3º or more. In addition the sensitivity and specificity of the proposed formula with regards to the gantry angle and beta angle at a cut-off of > 3º were 100% respectively.

It suffices to note the limitation of the calculated gantry angle method. This limitation is as result of the breast bridge being unsuitable for patients with large or flaccid breasts as it did not fit on them well. Furthermore, patients with a separation of more than 28 centimeters could not be measured accurately with the breast bridge due to the inherent physical limitations of the breast bridge which was utilized for the study (Griffith and Short, 1994, Halperin *et al.,* 2008).

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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