

Radiation doses to contralateral breast during unilateral breast external beam radiotherapy

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Abstract

Introduction: The cost benefit of external beam radiotherapy (EBRT) in the management of patients living with cancer, especially cancer of the breast cannot be over emphasized. It improves 5-year disease free survival, local tumour control and relieves associated pain. However, EBRT for unilateral breast cancer management could predispose contralateral breast (CB), that is outside the treatment volume (TV), to unavoidable scatter radiation doses. This is of great concern in radiation protection because of high radio-sensitivity of breast tissue.

Materials and Methods: Radiation dose to CB of 20 patients, who consented to participate and be managed with EBRT from Tele-Cobalt unit for primary breast cancer were considered. The dose to CB was measured with calibrated Thermoluminescent dosimeters (TLD) placed on CB at three different positions away from the TV.

Results: The scattered radiation dose (Gy) to CB measured at position 5cm (midline), 10cm (nipple) and 15cm away from the TV were 2.515 ± 0.613 ; 1.548 ± 0.578 and 0.780 ± 0.149 respectively. The average dose to CB was 1.601 ± 0.40 Gy per session and this is 43% of the prescribed dose (3.75 Gy). This is a bit higher than result from similar study, where CB was covered with lead shield.

Conclusion: It was observed that the mean scattered radiation doses to three different portions of CB during EBRT varied according to the inverse squared principle, where the portion that is closest to TV got 67% of the prescribed dose followed by 41% and the farthest portion got 21%.

Keywords: Contralateral Breast, External Beam Radiotherapy, Breast Cancer, Scattered radiation doses.

Résumé

Contexte: Le rapport coût-bénéfice de la radiothérapie externe (EBRT) dans la prise en charge des patients atteints de cancer, en particulier le cancer du sein, ne peut être surestimé. Il améliore la survie sans maladie à 5 ans, le contrôle local des tumeurs et soulage la douleur associée. Cependant, l'EBRT pour la prise en charge unilatérale du cancer du sein peut prédisposer le sein controlatéral (BC), c'est-à-dire en dehors du volume de traitement (TV), à des doses de rayonnement diffus inévitables. Ceci est très préoccupant en radioprotection en raison de la radio-sensibilité élevée du tissu mammaire.

Matériel et méthodes: La dose de rayonnement à la C.-B. de 20 patientes, qui ont consenti à participer et à être prises en charge par EBRT de l'unité Tele-Cobalt pour le cancer du sein primaire a été prise en compte. La dose au CB a été mesurée avec des dosimètres thermoluminescents étalonnés (TLD) placés sur CB à trois positions différentes loin du téléviseur.

Résultats: La dose de rayonnement diffusé (Gy) au CB mesurée à la position 5 cm (ligne médiane), 10 cm (mamelon) et 15 cm du téléviseur était de $2,515 \pm 0,613$; $1,548 \pm 0,578$ et $0,780 \pm 0,149$ respectivement. La dose moyenne à CB était de $1,601 \pm 0,40$ Gy par séance et cela correspond à 43% de la dose prescrite (3,75 Gy). C'est un peu plus élevé que le résultat d'une étude similaire, où le disjoncteur était recouvert d'un blindage en plomb.

Conclusion: Il a été observé que les doses moyennes de rayonnement diffusées sur trois parties différentes du CB pendant l'EBRT variaient selon le principe du carré inverse, où la partie la plus proche du VT recevait 67% de la dose prescrite suivie de 41% et la partie la plus éloignée. . obtenu 21%.

Mots clés: Sein controlatéral, radiothérapie externe, cancer du sein, doses de rayonnement diffusées.

Introduction

Cancer is one of the commonest health issues in our contemporary world. It is the second common cause of death in developed countries and among the three leading causes of death in developing countries [1-3]. Female breast cancer is the most frequently

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diagnosed cancer and the leading cause of cancer deaths in female worldwide, accounting for 23% (1.38 million) of the total new cancer cases and 14% (458,400) of the total cancer deaths in 2008 [4 – 5]. According to the World cancer report, the incidence of breast cancer is estimated to increase by 50% (1.5 million) by 2020 [6]

Radiotherapy is one of the most widely used treatment modalities for cancer management. It involves the use of ionizing radiation in its different forms (x-rays, gamma rays and particles) to prevent further growth of tumour and eventual destruction of mutated cells. The sources of radiation used in Radiotherapy could be internal (Brachytherapy) or external (Teletherapy) [7].

Teletherapy is the treatment in which radiation source is at a distance (80 cm or 100 cm) from the body surface. The area of the body to be treated (treatment volume) is irradiated from this source angled at different orientations. This treatment could be delivered by a Cobalt-60 unit, which delivers high energy (1.25 MeV) gamma rays, or a linear accelerator, which delivers high energy (4 – 25 MeV) X-rays and electron beam [7].

The radiation dose is delivered to a tumour volume to achieve a therapeutic benefit within the clinical target volume (CTV) while sparing the healthy tissues. This is achieved through a concerted and dedicated treatment planning system, where different volumes are delineated on the images produced during simulation to ensure that all the cancerous cells are properly captured within the treated volume before the execution of treatment [7].

In a typical external beam radiotherapy that delivers a lethal dose to the tumour, the healthy tissues will inevitably receive radiation due to leakage from collimator and scatter from primary beam. It has been reported that patients who received external beam radiotherapy had significantly higher risk of developing cancer in organs adjacent to the treatment volume (8). Moon *et. al.* [9] also reported cases of male patients, who developed second cancer in the bladder and rectum, five years (latency period) after radiotherapy to the prostate.

It has been reported that incidence of radiation induced breast cancer is a linear function of dose received by the contralateral breast (CB) and the latent period is over 10 years [10]. Several randomized trials, registry-based studies, and hospital-based studies have evaluated the risk of second breast cancer in the CB following RT. Few studies, however, have estimated risk in terms of radiation dose to the CB, and very few reported a significant dose-response relationship. [11].

Although data on radiation doses to critical organs outside primary radiation beams during radiotherapy is sparse in Nigeria, few clinical studies carried out on measurement of scattered radiation dose to critical structures adjacent to the treatment volume have been associated with cardiac toxicity and increased risk of secondary cancer. [8]

This present study is aimed at measuring scatter radiation dose to contralateral breast of patients managed with external beam radiation therapy to the breast using Cobalt-60 machine.

Materials and method

This study was carried out at the University College Hospital, Ibadan, Nigeria following approval of the ethical review committee of the institution.

Twenty patients living with unilateral breast cancer diagnosis who consented to participate were considered in this study. The treatment machine used for their management was Cobalt-60 machine, model Bhabhatron-II. It was manufactured by the Panacea Medical Technologies, India and installed in the year 2012. This machine is a rotational unit without a beam stopper and the treatment head is shielded with Tungsten. The piston within the treatment head moves the source to “on” and “off” positions, electronically. It has a collimator, which shapes the radiation beam to the desired treatment field. The minimum treatment square field size obtainable from the machine is 3 cm x 3 cm while the maximum is 35 cm x 35 cm at source to skin distance (SSD) of 80 cm.

The radioactive Cobalt-60 source at the time (2018) of this study was installed in the year 2013 and its activity at the time of installation (August 2013) was 258 TBq. The radioactive source is encapsulated in a stainless steel and has a square size of 2 cm. The monthly calibration of the source for determination of its dose rate (cGy/min) is based on the International Atomic Energy Agency (IAEA) protocol, TRS 398 (12). The treatment techniques adopted at the centre for patient’s treatment is either SAD or SSD at 80 cm and the daily workload on the machine is about 40 patients.

The calibration of the thermoluminescent dosimeter (TLD) system, the dual channel TLD Reader (Harshaw model 3500, Thermo Electron, USA) and the annealing of the TLD chips used for dose measurements were carried out at the Department of Physics and Engineering Physics Laboratory, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. The TLD reader has an in-built computer system to facilitate accurate dose measurement.

A set of three annealed TLD chips were placed carefully on the CB at 3 different positions away from the irradiated breast namely, medial line 5cm, 10 cm and 15 cm. These chips were labeled according to the position where they would be placed after the patient has been properly set-up for treatment. The TLD chips were fixed at these positions with the help of a paper tape. The TLD chips were immediately removed after each treatment of patient and placed inside a well labeled container prepared for each set of chips.

The exposed TLD chips were thereafter processed with the calibrated TLD system at the Laboratory, Obafemi Awolowo University, Ile-Ife. The radiation dose, D, received by CB with respect to the treatment fields (medial and lateral tangential) was analyzed and presented in tables.

Results

A total number of twenty patients were considered in this study. Their ages ranged from 30 to 79 years and majority (45%) of them were in the age group 40 – 49 years. The weight of these patients ranged from 40 to 119 kg and majority (35%) of them are in the range 50 - 59 kg (Table 1). With respect to the site of treatment, 13 (65%) patients were treated on the left breast while 7 (35%) were treated on the

mastectomy (removal of the diseased breast) and only 1 (5%) had lumpectomy (removal of the lump). The scattered radiation dose to CB at 3 different positions from the treatment site per session (each session comprises of two fields namely, medial and lateral tangential) is presented in Table 3. The mean scattered radiation dose (Gy) to CB at 5cm, 10cm and 15 cm away from the treatment site were 2.52 ± 0.61 , 1.55 ± 0.58 and 0.78 ± 0.15 respectively. These gave an average scattered dose of 1.60 ± 0.4 Gy to CB, which is 43% of the prescribed dose per session given for treatment (Table 3). All patients received prescription dose of 45 Gy in 12 sessions of radiation to the breast tumour (treatment site). The cumulative scattered radiation dose to contralateral breast throughout the entire sessions of treatment was 19.22 ± 4.76 Gy and is presented in Table 4.

Discussion

It has been reported that the scatter radiation dose to CB of patient undergoing radiation therapy should not be ignored, especially in patients younger than 45 years due to high radio sensitivity of breast tissues for carcinogenesis at this age and in fact CB should be regarded as organ at risk for such cohorts of patients [10,1]. As seen in Table 1, the majority of patients considered in this study fell within the age

Table 1: Age and weight of patient

Age group (year)	No of Patient (%)	Weight (kg)	No of Patient (%)
30 - 39	3 (15)	40 - 49	1 (5)
40 - 49	9 (45)	50 - 59	7 (35)
50 - 59	4 (20)	60 - 69	2 (10)
60 - 69	2 (10)	70 - 79	2 (10)
70 - 79	2 (10)	80 - 89	5 (25)
		90 - 99	0 (0)
		100 - 109	2 (10)
		110 - 119	1 (5)

Table 2: Distribution of patients based on the site of treatment and mode of surgery

Parameter	No of Patient	Percentage (%)
<i>Site of Treatment</i>		
Left Breast	13	65
Right Breast	7	35
<i>Mode of Surgery</i>		
Mastectomy	19	95
Lumpectomy (Breast-in-Situ)	1	5

right breast (Table 2). Also presented in Table 2 is the mode of surgery performed on all the patients before radiation therapy, whereas 19 (95%) had

group, where radiation dose to their CB should be monitored to prevent cancer induction in their later years.

Table 3: Scattered radiation dose to contra-lateral breast per treatment session

Patient No.	Dose per fraction given for treatment (Gy)	Dose from 5 cm from the centre of the treatment field (Gy)	Dose from 10 cm from the centre of the treatment field (Gy)	Dose from 15 cm from the centre of the treatment field (Gy)	Average dose to contra-lateral breast (Gy)	% of contra-lateral Breast dose to the prescribed dose
1.	3.768	2.347	1.524	1.194	1.688	45
2.	2.948	2.110	0.915	0.419	1.148	40
3.	3.746	3.097	1.287	0.267	1.548	41
4.	3.750	2.870	1.554	0.869	1.764	47
5.	3.738	2.641	1.500	0.492	1.544	41
6.	3.744	2.740	2.270	0.731	1.914	51
7.	3.760	2.260	0.590	0.264	1.038	28
8.	3.774	1.897	0.330	0.231	0.819	22
9.	3.742	2.670	1.080	0.665	1.468	39
10.	3.822	2.890	1.400	0.537	1.609	42
11.	3.738	2.260	1.500	0.910	1.557	42
12.	3.822	2.740	2.020	1.312	2.024	53
13.	3.810	3.606	2.505	0.670	2.260	59
14.	3.760	2.024	1.581	0.910	1.505	40
15.	3.822	2.787	1.701	1.134	1.874	49
16.	3.754	2.149	1.939	0.404	1.497	40
17.	3.852	3.000	2.450	1.158	2.203	57
18.	3.858	1.523	0.920	0.163	0.869	23
19.	3.806	2.065	1.635	1.132	1.611	42
20.	3.770	3.158	2.261	0.869	2.096	56
Mean	3.739	2.515	1.548	0.784	1.601	43
Std. dev.	1.174	0.613	0.578	0.149	0.400	

Also, the majority of the patients considered in this study, as seen in Table 2, received radiation therapy to their left breast and this usually poses a threat to the heart during irradiation. It has been reported that external beam radiotherapy to the left breast will not only irradiate certain volume of the lung but will also irradiate a significant volume of the heart, especially in a wide margin tangential field [13].

Studies [13,14] have shown that breast cancer patients, whose management regimen involve surgery, such as mastectomy, followed by radiation therapy, have better survival than those without surgery. As seen in Table 2, all patients considered in this study had surgery before radiotherapy, hence they were expected to have better treatment outcome provided that the scattered radiation dose received by the CB was kept minimal (ALARA principle).

It was observed that the mean scattered radiation doses to 3 different portions of the CB during external beam radiation therapy varied according to the inverse square principle. The portion of the CB that was closest (midline/at 5 cm) to the treatment site had the highest (67% of prescribed dose) radiation dose of 2.515 ± 0.613 Gy per fraction, while the

nipple, which is 10 cm away, had 1.548 ± 0.578 Gy (41%) and at 15 cm from the site of treatment had 0.78 ± 0.149 Gy (21%). The mean scattered radiation dose to the contralateral breast was 1.601 ± 0.40 Gy per session and this was 43% of the prescribed dose, which was usually 45 Gy in 12 sessions.

According to the categorization of the amount of scattered radiation dose to organ outside the treatment volume [15], the radiation dose to CB obtained in this study falls in the category of intermediate dose (5 - 50% of the prescription dose).

This result is higher than a similar study conducted by Wahba et al [10], where the dose to CB measured with TLD chips was between 4.5 and 17% of the prescription dose of 50 Gy in 25 fractions. This variation could be due to the use of different treatment regimen such as daily treatment fractionation as against hypo-fractionation treatment applied in this study. Other variations could be in the treatment technique employed in their study which included the use of X-ray photon (4 – 10 MeV) from linear accelerator, and covering of CB with 2 mm lead (Lead shielding of CB) as against the use of

Table 4: Cumulative dose to contra-lateral breast for the whole treatment sessions

Patient No.	Prescribed dose(Gy)	No of fraction	Total dose from 5cm from treatment field (Gy)	Total dose from 10cm from treatment field (Gy)	Total dose from 15cm from treatment field (Gy)	Average dose to contra lateral breast for the whole treatment	% of contra-lateral Breast dose to the prescribed dose
1.	45.000	12	28.164	18.288	14.328	20.256	45
2.	45.000	12	25.320	10.980	5.028	13.776	31
3.	45.000	12	37.164	15.444	3.204	18.576	41
4.	45.000	12	34.440	16.648	10.428	21.168	47
5.	45.000	12	31.692	18.000	5.904	18.528	41
6.	45.000	12	32.880	27.240	8.760	22.968	51
7.	45.000	12	27.120	7.080	3.168	12.456	28
8.	45.000	12	22.764	3.960	2.772	9.828	22
9.	45.000	12	32.040	12.960	7.980	17.616	39
10.	45.000	12	34.680	16.800	6.444	19.308	43
11.	45.000	12	27.120	18.000	10.920	18.684	42
12.	45.000	12	32.880	24.240	15.744	24.288	54
13.	45.000	12	43.272	30.060	8.040	27.120	60
14.	45.000	12	24.288	18.972	10.920	18.060	40
15.	45.000	12	33.444	20.412	13.608	22.488	50
16.	45.000	12	25.788	23.268	4.848	17.964	40
17.	45.000	12	36.000	29.400	13.896	26.436	59
18.	45.000	12	18.276	11.040	1.956	10.428	23
19.	45.000	12	24.780	19.620	13.584	19.332	43
20.	45.000	12	37.896	27.132	10.428	25.152	56
Mean	45.000	12	30.500	19.328	8.598	19.222	43
Std. dev	0	0	5.948	4.01	4.05	4.755	

gamma ray (1.25 MeV) from Telecobalt Unit and no lead shielding of CB employed in this study.

Conclusion

Scatter dose to contralateral breast (CB) during radiation therapy has been measured as part of the quality assurance in radiotherapy facilities. Thermoluminescence dosimetry applied in this study is easy and reasonably accurate method to measure the dose to CB. Although, the scatter dose to CB obtained in this study is in the range of intermediate dose, further reduction is possible by shielding the CB with a layer of 2mm lead absorber.

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