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Determining the contralateral breast dose during radiotherapy of breast cancer using rainbow dosimeter

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ABSTRACT

External beam radiotherapy is being used regularly to treat the breast malignancy post-operatively. The contribution of the collimator leakage and scatter radiation dose to contralateral breast is of concern because of high radio sensitivity of breast tissue for carcinogenesis. This becomes more important when the age of breast cancer breast patient is younger than 45 years and therefore the contralateral breast must be treated as organ at risk. Quantification of contralateral dose during primary breast irradiation is helpful to estimate the risk of radiation induced secondary breast malignancy. In present study contralateral breast dose was measured in forty cancer breast patients undergoing external beam therapy by cobalt-60 teletherapy machine. Post-operative radiotherapy was delivered by medial and lateral tangential fields daily, in addition to supraclavicular field with 200 cGy per fraction to a total dose of 5000 cGy in 25 fractions. The detectors of rainbow dosimeter were employed for these measurements.

The dose at the contralateral breast measured by a rainbow dosimeter for tangential fields was between 5.34–6.40% whereas for supraclavicular field it is 1.2–1.75% of the dose. The contribution due to the medial tangential field is almost twice as that due to lateral tangential field so that maximum dose which contributes contralateral breast dose is due to medial tangential field. The goal of this investigation was to quantify the radiation dose to the contralateral breast after radiotherapy for primary breast cancer. Rainbow dosimetry is easy, accurate and convenient method to measure the contralateral breast dose.

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1. Introduction

Breast cancer is the most common cancer among women, worldwide. It is probably the most feared cancer in women because of its psychological impacts. It affects the perception of sexuality and self image to a degree far greater than any other cancer. It is becoming number one killer in females. Therefore it has become an increasingly important subject of research all over the world. Globally, every 3 minutes a woman is diagnosed with breast cancer, amounting to one million cases annually. According to World Cancer Report, the incidence could go up by 50% to 1.5 million by 2020 (Mahavir & Babita, 2013). In India and other developing countries, breast carcinoma ranks second only to carcinoma of cervix among women, however the incidence of breast cancer is on the rise and may become the number one cancer in females in the near future. It is estimated that at present approximately 80,000 cases occur annually in India and by 2030 the number of new cases of breast cases will approximately be 200,000 per year (Datta, Choudhuri, Guha, & Biswas, 2012; Gupta, Sharma, & Verma, 2002)

Breast cancer is most curable when detected at its earlier stages. Radiotherapy plays an essential role in the management of breast cancer and many studies have shown better survival of patients after mastectomy followed by radiotherapy (Keyvan, Nazli, Shadi, & Alireza, 2013). Although radiation is a cancer healer, but it also carcinogenic, therefore it has been described as a "two edged sword". Women with breast cancer have three-to four-fold increased risk of developing a new primary cancer in the contralateral breast, as compared with the risk of a first primary breast cancer among other women (Adami, Bergstrom, & Hansen, 1985; Harvey & Brinton, 1985). In general, Radiotherapy for breast cancer after mastectomy and breast-conserving surgery include chest wall and for patients with regional lymph node involvement, the supraclavicular region should be regularly irradiated (Fisher et al., 2002). For patients receiving irradiation to both the chest wall and supraclavicular area, the irradiation field area is generally divided into two groups by the baseline of the lower edge of the subclavian head: one pair of tangential beams to cover the chest wall and interior beam to cover the upper supraclavicular area as shown in Fig. 1. During external beam therapy of malignant breast, the contralateral breast receives radiation due to leakage from collimator and scatter from primary beam. Breast is highly radiosensitive tissue for radiation induced second malignancy and is of more concern for female younger than 45 years of age receiving radiotherapy for breast malignancy. Boice, Land, Shore, Norman, and Tokunaga (1979) have reported that incidence of dose received by the contralateral breast and the latent period is over 10 years. Several investigators (Frass, Roberson, & Lichter, 1985; Kelly, Wang, Chu, & Hartselle, 1996; Muller & Kalokhe, 1990) have measured the contralateral breast dose on Anderson female phantom/Rando phantom observed that the scatter dose to contralateral breast during medial tangential and supraclavicular field is quite high and some times of the order of 500 cGy for 5000 cGy primary breast dose. The quantification of the contralateral breast especially during treatment of diseased breast by external beam is very important, as the scatter contribution will be more.

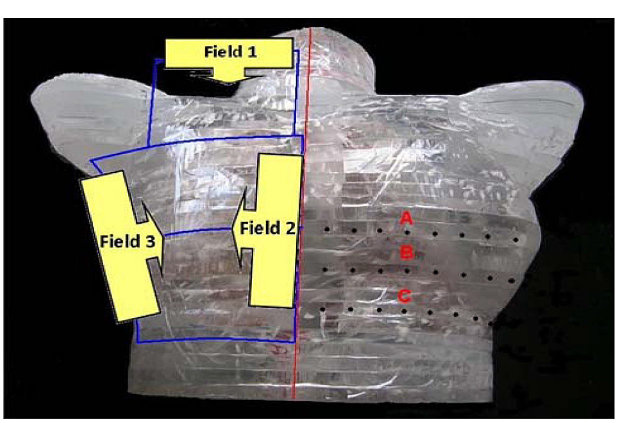

Fig. 1 – Anterior view of treatment fields of the patient positions.

In the present study, measurement of contralateral breast dose is done by using rainbow dosimeter with solid state detectors because of small size, high sensitive ability to record very small doses and energy independent response. The detectors of rainbow dosimeter were employed for the measurement of radiation doses to contralateral breast. The dosimeter has applications for relatively low doses and dose-rate independent up to 10^{-8} Gy s^{-1}. The system is also independent of relative humidity and can be used over a broad temperature (0 to 5 °C). The integrated radiation effect that is used for the measurement is the shift in threshold voltage due to trapped charge in the multilayered device. This threshold voltage is evaluated in the measurement of the channel (drain) current as a function of gate voltage at a constant supply voltage to the device.

2. Materials and methods

In present study contralateral breast dose was measured in forty breast cancer patients undergoing external beam therapy by cobalt-60 teletherapy machine. In radiotherapy for breast cancer, the chest wall was treated with medial and lateral tangential fields daily. Total Dose of 5000 cGy is given in 25 fractions to the chest wall with a dose of 200 cGy per fraction. Patients are usually placed in the supine position on an angled breast board with one or both arms stretched above the head. The position of the patient is kept similar in treatment and simulation. The patient is placed on an angled breast board because the sternum slope and chest wall slope is modified. Tangential fields must cover the breast and edges of the field are shaped based on patients' anatomy. In addition to these tangential fields, a supraclavicular field is also given with radiation dose of 5000 cGy and fraction dose of 200 cGy in 25 fractions.

Three detectors were put on the surface of the skin of contralateral breast, one at the level of nipple and two other detectors were placed 3 cm away from the nipple on both sides along the middle line for each field as shown in Fig. 2.The most widely accepted technique for whole-breast irradiation is the tangential field technique, in which the entire breast and chest wall, with a small portion of lung, is included in the irradiated

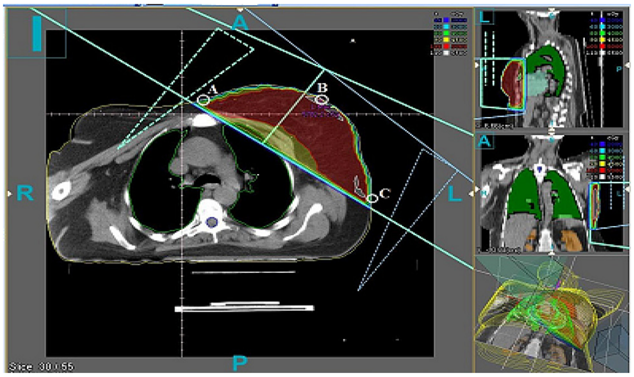

Fig.2 – Schematic representation of the detector during breast treatment at 'A', 'B' and 'C'.

volume. For simple, 2-dimensional planning, the best predictor of the percentage of ipsilateral lung volume treated by the tangential fields is central lung distance (CLD), which is defined as the perpendicular distance from the posterior tangential edge to the posterior part of the anterior chest wall at the center of the field. A CLD of 1.5 cm predicts that approximately 6% of the lung is in the irradiation field; when CLD is increased to 3.5 cm, approximately 26% of the lung is included, which may augment the risk of developing pneumonitis. When the CLD is >3 cm, particularly in the left breast, a significant volume of the heart will be irradiated as well. The most common schedule for breast irradiation is to deliver 50 Gy to the whole breast over 5 to 6 weeks with daily doses of 1.8 to 2 Gy. Radiotherapy should be initiated without a long delay after surgery if chemotherapy is not delivered. A delay longer than 3 months has been associated with decreased survival.

3. Results

The goal of this investigation was to quantify the radiation dose to the contralateral breast after radiotherapy for primary breast cancer. The contribution of contralateral breast dose because of various treatment fields is given in Table 1. It is observed that the contribution to contralateral breast dose due to for tangential fields is between 5.34–6.40% whereas for supraclavicular field it is 1.2–1.75% of the dose as shown in Fig. 3. The contribution due to the medial tangential field is almost twice as that due to lateral tangential field. The lateral tangential field enters laterally and may be contributing to internal scatter, which is very difficult whereas the medial tangential field is close to the contralateral breast and hence the scatter and the collimator contribution is more. Age, type and mode of the surgery of different breast cancer patients are mentioned in Table 2.

4. Discussion

Among the 40 patients in our study, the surface doses recorded at the contralateral breast in the range for tangential fields between 5.34–6.40% whereas for supraclavicular field it is 1.2–1.75% of the dose. We found that the following factors are likely to increase the dose to the contralateral breast:

- A short perpendicular distance from the contralateral breast surface to the geometric beam edge increases the dose at the surface. A short perpendicular distance can be caused by a shallow medial gantry angle or a large, protruding breast. A combination of both is the least favourable.
- It is observed that the contribution to contralateral breast dose due to all the fields. The contribution due to the medial tangential field is almost twice as that due to lateral tangential field. The lateral tangential fields enter laterally and may be contributing to internal scatter, which is very difficult whereas the medial tangential field is close to the contralateral breast and hence the scatter and the collimator contribution is more.

Dose to contralateral breast as a result of radiotherapy of breast should not be ignored in radiotherapy and more so in patients younger than 45 years. The breast tissue is highly sensitive and therefore the contralateral breast must be regarded as organ at risk while planning for radiotherapy. Radiation carcinogenesis is stochastic process where probability of cancer induction increases with dose and there is no threshold dose (Hall & Giaccia, 2006). Many researchers have reported the contralateral breast dose; some reported results of direct measurement on patients, some reported measurements on phantom and some gave the figures from calculation.

Gao, Fisher, and Emami (2003) found a relative risk of 1.32 and 1.15, respectively, for second cancer induction in the contralateral breast of women patients whose ages were below 45 years and over 55 years at the time of diagnosis. In a 15-year follow-up, Obedian, Fischer, and Haffty (2000) reported a 10% increase in contralateral breast cancer rate in patients who had radical mastectomy under the age of 45 and received a total dose of 46–54 Gy to the involved breast. This increase was small compared to a 7% increase in breast cancer in the control unirradiated group.

Boice, Harvey, Blettner, Storall, and Flannery (1992) have conducted case control study in cohort of 41,109 women diagnosed with breast cancer and analyzed the records. They found mean contralateral breast to be 282 cGy with maximum of 710 cGy and relative overall increase in risk of contralateral breast malignancy due to treatment of primary by radiation to be 1.19. However, the risk of second malignancy in the contralateral breast was 1.59, significantly high, in patients who underwent radiotherapy at younger age then 45 years for primary breast malignancy. This indicates high risk for younger patients. Muller and Kalokhe (1994) have advocated covering of contralateral breast with thin lead sheet to reduce the scattered contribution to contralateral breast skin though little can be done to reduce the dose from the lateral tangential field as the dose is caused by internal body scatter. They used 4 mm thick commercially available vinyl coated flexible lead shield containing lead powder of 1 mm equivalent lead density to cover the contralateral breast and found that the contralateral dose is reduced by 3 fold from 15% to 5%. Kelly et al. (1996) reported a study of evaluation of four different breast treatment techniques with 6 MV linac beam to compare the radiation dose to the contralateral breast. They have done the dose measurement of Rando Phantom using TLD and used four different techniques of half beam with custom blocks, half beam using

Table 1 – Contralateral breast dose because of various treatment fields.

S. No	Dose to contralateral breast (cGy)							
	Lateral tangential field	Medial tangential field	Total	Percentage (%)	Standard error	Supraclavicular axial	Percentage (%)	Standard error
1.	4.1	8.3	12.4	6.20	±2.49	3.0	1.50	±1.22
2.	4.2	8.5	12.7	6.35	±2.52	3.1	1.55	±1.24
3.	3.9	8.0	11.9	5.95.	±2.44	2.8	1.40	±1.18
4.	4.0	8.1	12.1	6.05	±2.46	2.9	1.45	±1.20
5.	3.7	7.8	11.5	5.75	±2.39	2.7	1.35	±1.16
6.	4.2	8.5	12.7	6.35	±2.52	3.0	1.50	±1.22
7.	4.1	8.2	12.3	6.15	±2.48	2.9	1.45	±1.20
8.	3.8	7.9	11.6	5.80	±2.40	2.8	1.40	±1.18
9.	4.0	8.1	12.1	6.05	±2.45	3.0	1.50	±1.22
10.	3.9	8.0	11.9	5.95	±2.43	2.9	1.45	±1.20
11.	4.3	8.5	12.8	6.40	±2.53	3.4	1.70	±1.30
12.	4.1	8.2	12.3	6.15	±2.48	3.1	1.55	±1.24
13.	4.2	8.3	12.5	6.25	±2.50	3.2	1.60	±1.26
14.	3.8	7.9	11.7	5.85	±2.41	2.9	1.45	±1.20
15.	3.5	7.6	11.1	5.55	±2.35	2.5	1.25	±1.12
16.	4.0	8.1	12.1	6.05	±2.46	2.9	1.45	±1.20
17.	3.7	7.7	11.4	5.70	±2.38	2.5	1.25	±1.12
18.	4.1	8.3	12.4	6.20	±2.49	2.7	1.35	±1.16
19.	3.9	8.0	11.9	5.95	±2.44	2.8	1.40	±1.18
20.	4.2	8.6	12.8	6.40	±2.53	2.9	1.45	±1.20
21.	4.1	8.3	12.4	6.20	±2.49	3.1	1.55	±1.24
22.	3.8	7.8	11.6	5.80	±2.40	2.8	1.40	±1.18
23.	4.3	8.4	12.7	6.35	±2.52	3.2	1.60	±1.26
24.	4.0	8.1	12.1	6.05	±2.46	2.8	1.40	±1.18
25.	3.5	7.2	10.7	6.35	±2.52	2.4	1.20	±1.09
26.	4.2	8.4	12.6	6.30	±2.51	3.1	1.55	±1.24
27.	4.1	8.3	12.4	6.20	±2.49	2.8	1.40	±1.18
28.	3.9	8.0	12.9	5.95	±2.44	3.1	1.55	±1.24
29.	3.8	7.9	11.7	5.85	±2.41	2.7	1.35	±1.16
30.	4.1	8.2	12.3	6.15	±2.48	3.2	1.60	±1.26
31.	4.2	8.5	12.7	6.35	±2.52	2.8	1.40	±1.18
32.	3.7	7.7	11.4	5.70	±2.38	3.0	1.50	±1.22
33.	3.9	7.9	11.8	5.90	±2.43	3.1	1.55	±1.24
34.	4.1	8.1	12.2	6.10	±2.47	3.2	1.60	±1.26
35.	4.2	8.3	12.5	6.25	±2.50	3.5	1.75	±1.32
36.	3.8	7.8	11.6	5.80	±2.40	2.8	1.40	±1.18
37.	3.9	8.0	11.9	5.95	±2.44	3.0	1.50	±1.22
38.	3.7	7.6	11.3	5.65	±2.37	2.7	1.35	±1.16
39.	4.0	8.1	12.1	6.05	±2.46	2.9	1.45	±1.20
40.	4.2	8.3	12.5	6.25	±2.50	3.1	1.55	±1.24

asymmetric collimator jaw, half beam using asymmetric collimator jaws with custom blocks and isocentric technique with non-divergent posterior border. They observed higher contralateral breast dose during medial field with wedge and lowest dose with asymmetric jaws and no medial wedge or block. Bhatnagar, Heron, Deutch, Brandner, and Kalnicki (2006) reported comparison of contralateral breast dose during primary breast irradiation using intensity modulated radiotherapy (IMRT) and conventional tangential field technique. They have treated 36 patients of breast malignancy with IMRT and 8 with 3-D technique using tangential field with wedge and measured contralateral breast dose during treatment using TLD. They observed the contralateral breast dose of 7.74 ± 2.35% of primary breast dose (5000 cGy) in IMRT treatment planning and 9.74 ± 2.04% of primary breast dose during conventional tangential field technique i.e., about 20% reduction in contralateral breast dose with IMRT as compared to conventional tangential treatment with wedge. Chougule (2007) suggested that use TLD discs to measure the contralateral breast dose during half beam block for patients treated with primary breast irradiation on teletherapy unit.

Bhatnager et al. (2004) have studied the effect of breast size on scatter dose to contralateral breast. They have treated 65 patients of breast cancer using 6 MV photon with IMRT technique and measured contralateral breast dose using TLD. The primary breast size volume was calculated by planning system from CT slices. They found the mean contralateral dose of 7.2% of primary breast dose (5000 cGy) and found that the contribution to contralateral breast dose is strongly dependent on primary breast size of the patient. Therefore it became of more concern in young breast cancer patients with bulky protuberant breast.

Wahaba and Reham (2009) proposed to use 2-mm lead shield during breast radiation therapy in order to achieve an effective reduction in contralateral breast dose. Hooning et al. (2008) reported that young patients with breast cancer irradiated with breast tangential experience increased risk of

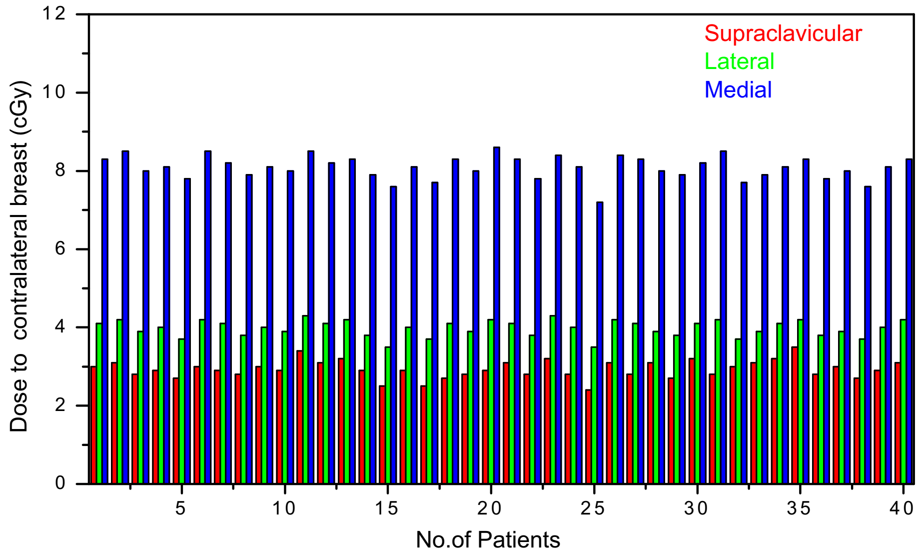

Fig. 3 – Dose calculation for different patients at various geometries.

Table 2 – Age, type and mode of surgery of different breast cancer patients.

S. No	Age of the patient	Prescribed dose (Gy)	Type of the cancer	Mode of the surgery
1.	58	50	Invasive ductal carcinoma	Mastectomy
2.	39	50	Invasive ductal carcinoma	Radical mastectomy
3.	65	50	Invasive ductal carcinoma	Mastectomy
4	62	50	Invasive ductal carcinoma	Mastectomy
5	67	50	Invasive ductal carcinoma	Mastectomy
6	37	50	Invasive ductal carcinoma	Radical mastectomy
7.	60	50	Invasive ductal carcinoma	Mastectomy
8.	66	50	Invasive ductal carcinoma	Mastectomy
9.	61	50	Invasive ductal carcinoma	Mastectomy
10.	60	50	Invasive ductal carcinoma	Mastectomy
11.	38	50	Invasive ductal carcinoma	Radical mastectomy
12.	62	50	Invasive ductal carcinoma	Mastectomy
13.	59	50	Invasive ductal carcinoma	Mastectomy
14.	66	50	Invasive ductal carcinoma	Mastectomy
15	64	50	Invasive ductal carcinoma	Mastectomy
16	60	50	Invasive ductal carcinoma	Mastectomy
17	65	50	Invasive ductal carcinoma	Mastectomy
18	58	50	Invasive ductal carcinoma	Mastectomy
19	64	50	Invasive ductal carcinoma	Mastectomy
20	37	50	Invasive ductal carcinoma	Radical mastectomy
21	60	50	Invasive ductal carcinoma	Mastectomy
22	66	50	Ductal carcinoma	Mastectomy
23	35	50	Invasive ductal carcinoma	Radical mastectomy
24	59	50	Invasive ductal carcinoma	Mastectomy
25	67	50	Invasive ductal carcinoma	Mastectomy
26	36	50	Invasive ductal carcinoma	Radical mastectomy
27	50	50	Invasive ductal carcinoma	Mastectomy
28	58	50	Invasive ductal carcinoma	Mastectomy
29	63	50	Invasive ductal carcinoma	Mastectomy
30	59	50	Invasive ductal carcinoma	Mastectomy
31	37	50	Invasive ductal carcinoma	Mastectomy
32	63	50	Invasive ductal carcinoma	Mastectomy
33	65	50	Ductal carcinoma	Mastectomy
34	60	50	Invasive ductal carcinoma	Mastectomy
35	57	50	Invasive ductal carcinoma	Mastectomy
36	66	50	Invasive ductal carcinoma	Mastectomy
37	65	50	Invasive ductal carcinoma	Mastectomy
38	63	50	Invasive ductal carcinoma	Mastectomy
39	61	50	Invasive ductal carcinoma	Mastectomy
40	59	50	Ductal carcinoma	Mastectomy

contralateral breast cancer, especially in those with positive family in story of breast cancer. Alzoubi, Kandaiya, Shukri, and Elsherbieny (2010) found that breast and chest wall radiotherapy treatment using 6-MV photons and measured contralateral breast dose at the surface fell sharply with distance from the field edge. The average ratio of the measurement to the calculated contralateral breast dose using the pencil beam algorithm at surface was approximately 53%.

5. Conclusion

Rainbow dosimetry is very easy, most convenient and reasonably accurate method to measure the dose to contralateral breast. Dose to the contralateral breast as a result of radiotherapy of breast should not be ignored in radiotherapy and more so in patients younger than 45 years. Contralateral breast dose increases with increase in size/area of the primary breast to be treated as well as the patient thickness. The contralateral breast doses to patients with lumpectomy are much higher than those with mastectomy for the same lateral separation.

The use of half beam block instead of asymmetric collimator in Co-60 machine increases the dose to contralateral breast dose. The half beam blocker lies comparatively close to the patient and thereby increases dose to the contralateral breast. The dose to the contralateral breast is mainly due to scatter and transmission of radiation through half beam blocker. The scatter dose received by the contralateral breast can be reduced by strapping the contralateral breast with paper tape. In addition to this the dose due to transmission can be also reduced by strapping the contralateral breast away from the collimated beam, this can be done mainly if the patient has pendulum breast.

In case of the left breast, a significant volume of the heart will be irradiated as well. The amount of the heart volume in the tangential field associated with the development of cardiovascular disease, techniques like the addition of a medial portal with the use of electrons should be considered, especially in patients with wide tangential fields and with an increased central lung distance because of large breasts. A significant dose inhomogeneity is predictable, which could result in less satisfactory cosmetic outcomes. To minimize this problem, 10–15 megavolt (MV), high-energy X-rays may be needed. The breast tissue is highly sensitive and therefore the contralateral breast must be regarded as organ at risk (sensitive organ) while planning for radiotherapy.

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