A comparison between skin dose of breast cancer patients at the breast region, measured by thermoluminescent dosimeter in the presence and absence of bolus

ABSTRACT

Aim: The aim of this study was to measure entrance skin dose (ESD) on the breast of patients who had undergone radiotherapy following surgery, in the presence and absence of bolus.

Materials and Methods: In this study, the ESD on the breast of 22 female patients was measured using thermoluminescent dosimeter-100 chips. For each patient, the ESD was measured 3 times (once without bolus and twice using bolus). The bolus types used in this study include super flab and wax.

Results: The average ESDs on the breast of patients (from both medial and lateral tangential fields) in the presence of the super flab bolus and absence of bolus were 225.8 and 148.17 cGy, respectively, that when using the bolus, around 52% increasing in ESD was observed. The results showed a significant relationship between the ESD on the breast of patients and bolus types ($P = 0.002$); in addition, correlation coefficient between the two boluses (super flab and wax) was 0.615 ($r = 0.615$).

Conclusion: When using the bolus in postmastectomy irradiation, it is noted that in dose delivery to the chest wall, surgical scar or skin of the treated region should be considered. The use of the bolus as a substance that increases of the skin dose can sometimes cause an excessive increase in skin dose that may cause severe skin reactions and underdosing of underlying tissues. Furthermore, using wax bolus in regions that do not require a lot of shaping of bolus is affordable.

KEY WORDS: Bolus, breast cancer, radiotherapy, skin dose

INTRODUCTION

Breast cancer is the most prevalent cancer and the second most lethal cancer (after lung cancer) among women in the United States.$^{[1,2]}$ Treatments for breast cancer include surgery, radiation therapy, chemotherapy, and hormone therapy. The sequence of these modalities is important and has a significant impact on the outcome of the patient treatment.$^{[3-5]}$ Effective factors in the selection of treatment modalities include tumors size, patient’s age, menopausal status, estrogen or progesterone receptors, tumor marker, lymph node status,$^{[6]}$ and side effects of selected modalities.$^{[7]}$ The first treatment choice for patients is surgery (except in advanced diseases)$^{[8]}$ that can be carried out as modified radical mastectomy or breast-conserving surgery.$^{[9]}$ In some cases, patients undergo radiotherapy following mastectomy (that is called postmastectomy radiotherapy [PMRT]) that include (1) patients with 4 or more metastatic axillary lymph nodes; (2) T3/T4 tumors with positive axillary nodes and patients with operable stage-3 tumors; and (3) positive margins or gross (>2 mm) extranodal extension. In addition, PMRT may be carried out for patients with some of the following features: (1) tumor is located in the central or inner quadrant and associated with positive axillary nodes; (2) lymphatic vascular space invasion; and (3) 1–3 metastatic axillary lymph nodes.$^{[7]}$

PMRT improves local control and survival in patients with high-risk breast malignancy.$^{[10,11]}$ Treatment guidelines for PMRT in 2001 were

Cite this article as: Farhood B, Bahreyni Toossi M, Ghatel N, Mohamadian N, Mozaffari A, Knaup C. A comparison between skin dose of breast cancer patients at the breast region, measured by thermoluminescent dosimeter in the presence and absence of bolus. J Can Res Ther 2018;14:1214-9.
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published by the American Society of Clinical Oncology. These guidelines explained that the chest wall should be treated adequately.\footnote{12} The chest wall is the most common site of recurrence, and delivering enough radiation dose to the chest wall is very important in reducing the risk of treatment failure.\footnote{13} Determination of surface and superficial chest wall doses give valuable information to avoid near-surface recurrences and to limit severe early and late skin reactions.\footnote{14} Providing the adequate dose to the chest wall, while keeping radiation-induced side effects as low as possible, remains a challenge.\footnote{15,16}

PMRT is usually carried out using low-energy photon beams (usually 6 MV) in combination with boluses made from tissue-equivalent material.\footnote{17} In addition to being tissue equivalent, the bolus material must also be sufficiently flexible to conform to surface contours, nontoxic, easily procured or fabricated, durable, cost-effective, and approved by the Food and Drug Administration.\footnote{18} Various materials commercially available as a bolus include paraffin wax, polystyrene, lucite, super staff, super flab,\footnote{19} and gel-elastic.\footnote{20} The bolus should be thick adequate to provide an enough dose buildup in the superficial chest wall while keeping the dose of the skin as low as possible.\footnote{17}

Due to the poor calculations in the buildup region, it will affect the doses given to near-surface tumors and the normal skin tissues. Hence, it is of significant interest to measure the dose delivered to the skin and also near-surface tumors. Therefore, the purpose of this research was to measure entrance skin dose (ESD) on the breast of mastectomy patients who had undergone radiotherapy in the presence and absence of bolus types (super flab and wax).

**MATERIALS AND METHODS**

**Patient selection**

In this study, 22 female patients with breast cancer who had undergone PMRT with bolus technique were evaluated. Furthermore, patients for whom bolus was used to get a sufficient dose in the area of the surgical scar were excluded from the study.

**Bolus types used**

The bolus types used include super flab and wax as these boluses are commonly used in the hospitals of Mashhad (Mashhad, Iran). The thicknesses of super flab and wax boluses were 5 and 10 mm, respectively which were considered equivalent. Given that there is no compromise on the bolus thicknesses used,\footnote{21,22} the selection of these thicknesses was based on the previous studies available in this field.\footnote{21-23} The use of these thicknesses can provide the desired dose distribution, in other words, with these boluses it is possible to deliver a dose in the range of 90–95% relative to the prescribed dose to the chest wall.

It can be noted that before applying these bolus types for the patients, measurements in the gantry angle of 0° have been carried out in the commissioning process. The measurements were performed in a slab phantom while the bolus was positioned on the surface of the phantom. The aim of this work is to evaluate whether increasing the surface dose by various bolus types is sufficient or not.

**Radiation techniques**

In this research, the patients were treated by 6 MV photon beams, delivered from Siemens (Siemens AG, Erlangen, Germany) and Varian Clinac 600 (Varian, Palo Alto, CA, USA) linear accelerators. All patients were treated with standard fractionation (200 cGy per fraction) and treatments were performed 5 days a week. In most patients, half of the fractions were treated with bolus and the rest without it in a way that bolus was used either for every other fraction (i.e., a fraction with bolus and the next without it) or first half of the fractions with the bolus and the second half without it.

**Data collection**

In this study, the ESD on the breast of 22 patients was measured by thermoluminescent dosimeter (TLD-100) chips. The TLD-100 chips used in this research were produced by Harshaw Company and were made from LiF: Mg, Ti with the 3 mm × 3 mm size, and thickness of 0.9 mm. Because of the energy-dependent response of TLD-100 chips, they were calibrated with 6 MV photon beams. Before the radiation of tangential field, three TLD-100 chips were placed under the bolus so that one of the TLD chips was placed at central axis (in the point is determined surface to skin distance [SSD]) and two TLD chips were placed 4 cm on either side of the central TLD chip (one on the left and other on the right of central TLD chip). It is noted that the TLD chips on both sides of the central TLD chip were not in the penumbra regions. Then, ESD on the breast of patients was measured in the presence and absence of bolus types. For each patient, measurements of ESD were performed 3 times so that first, second, and third measurements were related to without bolus, super flab, and wax boluses, respectively. Considering the different patient sizes and geometries, the field size and beam angle is different from one patient to other so to reduce confounding factors such as geometric characteristics of the patient, field size and beam angle; both bolus types was used for each patient. In other words, the measurement was performed in the same conditions for both with bolus and without bolus so that one can compare ESDs obtained from bolus types. It is notable that in this study there was no intervention in the treatment protocol and ESDs were measured only 3 times during the treatment time. Finally, the ESD on the breast of patients in the presence and absence of bolus types was measured and compared. It should be noted that due to the rigidity of wax bolus, measurements related to wax bolus were only carried out for medial tangential field.
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Analysis of data
The results were analyzed by paired t-test using SPSS 11.5 software (SPSS, Chicago, IL, USA). $P \leq 0.05$ was considered statistically significant.

RESULTS
In this study, the average age of the patients was 52 ± 9 years and the minimum and maximum of age were 36 and 82 years, respectively.

In the absence of bolus, for medial tangential field, the average ESD of breast region of patients obtained was $74.21 \pm 10.49$ cGy which was in the range of 50.2 and 98.5 cGy, and for lateral tangential field, the average ESD of breast region of patients obtained was $73.96 \pm 12.46$ cGy which was in the range of 51.2 and 98.2 cGy. In total, the average ESD of breast region of patients (from both medial and lateral tangential fields) was 148.17 cGy.

Table 1 shows ESD of breast region of patients from medial and lateral tangential fields in absence of bolus.

When using super flab bolus, for medial tangential field, the average ESDs of breast region of patients were obtained 111.4 ± 17.61 cGy that was in the range of 70.24 and 162.7 cGy, and for lateral tangential field the average ESD obtained was $114.34 \pm 15.65$ cGy which was in the range of 50.2 and 98.5 cGy. In total, the average ESD of patient’s breast region (medial and lateral tangential fields) was 225.8 cGy.

To compare the average ESD of breast region of patients when using the various boluses, the paired samples t-test was used. The results showed that there is a significant relationship between the ESD on the breast of patients and bolus types ($P = 0.002$); also, correlation coefficient between the two boluses (super flab and wax) was 0.615 ($r = 0.615$).

DISCUSSION
In some cases, patients undergo radiation therapy following surgery of breast cancer. Radiotherapy plays a significant role in the multimodality treatment of breast cancer. It has been shown in several studies that radiotherapy eventually improves survival and reduces locoregional recurrence and ultimately improves survival.\(^{[24-27]}\) It is commonly accepted that the surgical scar should be covered by enough dose to remove seeding of malignant cells, thereby reducing recurrence in chest wall treatment of patients after mastectomy, and margin around the scar surgical even in breast conservation therapy. In addition, coverage of superficial dose is important if the tumor has extension near to skin although the skin dose is of concern for the cosmetic outcome.\(^{[28]}\) Surface dose is dependent on several factors including beam energy, bolus or beam spoiler, beam angle, source to skin distance, wedge, and treatment techniques.\(^{[29-33]}\) In clinical radiation therapy,
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Table 2: Entrance skin dose of breast region of patients from medial and lateral tangential fields in the presence of super flab bolus

| Number of patients | ESD of patients from medial tangential field (cGy) | ESD of patients from lateral tangential field (cGy) |
|--------------------|-----------------------------------------------|-----------------------------------------------|
|                    | TLD 1 | TLD 2 | TLD 3 | average | TLD 1 | TLD 2 | TLD 3 | Average |
| 1                  | 116.30 | 105.10 | 100.40 | 107.27 |
| 2                  | 95.27  | 107.30 | 83.24  | 95.27  |
| 3                  | 119.10 | 136.70 | 88.96  | 114.92 |
| 4                  | 96.87  | 96.00  | 97.74  | 96.87  |
| 5                  | 108.50 | 101.40 | 94.30  | 101.40 |
| 6                  | 89.46  | 96.97  | 104.30 | 96.91  |
| 7                  | 110.80 | 103.70 | 81.94  | 98.81  |
| 8                  | 68.37  | 61.86  | 80.49  | 70.24  |
| 9                  | 128.90 | 120.00 | 119.00 | 122.63 |
| 10                 | 127.70 | 134.90 | 120.50 | 127.70 |
| 11                 | 101.00 | 110.10 | 91.01  | 100.70 |
| 12                 | 114.30 | 116.30 | 118.30 | 116.30 |
| 13                 | 154.20 | 181.50 | 152.40 | 162.70 |
| 14                 | 120.30 | 124.30 | 113.80 | 119.47 |
| 15                 | 119.80 | 121.90 | 76.07  | 105.92 |
| 16                 | 124.90 | 119.30 | 114.00 | 119.40 |
| 17                 | 117.20 | 117.80 | 96.42  | 110.47 |
| 18                 | 126.60 | 124.80 | 130.90 | 127.43 |
| 19                 | 101.90 | 124.90 | 103.30 | 110.03 |
| 20                 | 142.30 | 110.60 | 126.37 | 126.42 |
| 21                 | 110.12 | 106.52 | 103.02 | 106.56 |
| 22                 | 112.10 | 112.80 | 125.90 | 116.93 |

ESD=Entrance skin dose, TLD=Thermoluminescent dosimeter

Table 3: Entrance skin dose of breast region of patients from medial tangential fields in the presence of wax bolus

| Number of patients | ESD of patients from medial tangential field (cGy) |
|--------------------|-----------------------------------------------|
|                    | TLD 1 | TLD 2 | TLD 3 | Average |
| 1                  | 114.90 | 101.20 | 100.30 | 104.67 |
| 2                  | 103.89 | 122.60 | 85.19  | 103.89 |
| 3                  | 82.66  | 119.50 | 105.50 | 102.55 |
| 4                  | 113.70 | 119.70 | 116.70 | 116.70 |
| 5                  | 81.40  | 87.09  | 73.04  | 80.51  |
| 6                  | 83.84  | 91.62  | 95.50  | 90.32  |
| 7                  | 104.70 | 94.05  | 83.94  | 94.23  |
| 8                  | 88.25  | 110.60 | 116.40 | 105.08 |
| 9                  | 86.18  | 100.00 | 119.00 | 101.73 |
| 10                 | 116.30 | 137.20 | 137.30 | 130.27 |
| 11                 | 105.00 | 114.40 | 98.14  | 105.85 |
| 12                 | 123.90 | 126.10 | 139.80 | 129.93 |
| 13                 | 116.20 | 160.50 | 121.20 | 132.63 |
| 14                 | 114.50 | 123.40 | 136.20 | 124.70 |
| 15                 | 109.80 | 122.50 | 77.11  | 103.14 |
| 16                 | 125.20 | 119.90 | 116.00 | 120.37 |
| 17                 | 89.97  | 115.30 | 112.10 | 105.79 |
| 18                 | 144.40 | 135.60 | 120.30 | 133.43 |
| 19                 | 101.60 | 122.90 | 103.10 | 109.20 |
| 20                 | 140.80 | 124.90 | 112.80 | 126.17 |
| 21                 | 100.60 | 118.10 | 134.50 | 117.73 |
| 22                 | 122.80 | 140.30 | 139.60 | 134.23 |

ESD=Entrance skin dose, TLD=Thermoluminescent dosimeter

most patients with breast cancer have different degrees of skin reactions. Several studies have evaluated the skin complications of radiotherapy in breast cancer patients.

One of the treatment techniques in postmastectomy irradiation is using bolus to get a sufficient dose to the chest wall or surgical scar. Boluses of tissue-equivalent materials, which are adequately thick to provide enough dose in the superficial chest wall and skin, are commonly applied during PMRT. Although the use of the bolus could increase dose, in some cases, the dose increase can be excessive. In the present study, using the bolus increased the average ESD of breast region of patients, around 52% (so that the average ESD of breast region of patients was reached from 74% [in absence of bolus] to 112.9% [in the presence of super flab bolus]). Several studies have been performed to assess the effect of bolus on skin dose of breast region of patients (with breast cancer) who had undergone radiotherapy. For example, Hsu et al. evaluated skin dose on the breast for bolus types. They showed that the surface dose increase to up 82% using 2 mm fine mesh Aquaplast. In another study, Quach et al. indicated that the surface dose increased 112% when using 1 cm bolus compared to without bolus. Because of using various boluses with different thicknesses as well as different treatment geometry in the above-mentioned studies with our study, we cannot compare our results with their results. However, it should be noted that an excessive increase of skin dose may cause severe reactions of the skin and under dose of underlying tissues. One solution to prevent excessive increase in skin dose is to use an appropriate thickness of the bolus and/or low use of bolus in the duration of treatment time. The treatment guidelines for PMRT in 2001 that were published by the American Society of Clinical Oncology highlighted the lack of evidence to guide physician in bolus practice: "Whether it is necessary to use bolus every day, less frequently, or at all is uncertain."

Other result of this study was about the comparison between the average ESD of breast region of patients when using...
boluses of the super flab and wax. The results showed that there is a significant relationship between the ESD of breast region of patients and bolus types. These differences could be due to difference in material and thicknesses of bolus types. In other words, difference in the thickness and material of bolus can cause changing in the skin dose. Considering the low cost of wax bolus, it can be used instead of super flab for cases that do not require a lot of shaping of the bolus, because wax bolus is less flexible than super flab. In other words, using the bolus of wax in regions that do not require a lot of shaping of bolus is affordable.

It is notable that since the beam’s angle and source to skin distance (SSD) vary for each of the three TLDs, the dose received by these TLDs are different. The differences in the TLD readings can be explained by the inverse square distance law and the secondary electrons contribution produced by a pencil beam of photons interacting with the medium, etc.

There is a relationship between the skin dose with increasing the gantry angle. This issue is also related to the concept of electron range surface (ERS). The ERS is a three-dimensional representation of secondary electrons’ range and distribution produced by a pencil beam of photons interacting with the medium. Electrons generated inside the ERS volume reach the phantom surface and contribute to the surface dose. On the other hand, those electrons which are generated outside this volume, due to their short range, make no contribution. In addition, considering that there is relationship between increasing the skin dose with increasing the field size, the relationship between the skin dose with changing the field size was evaluated in this study. As the field dimensions are increased, the dose in the skin region increases. This increase in the skin dose can be related to the increased electron contamination in the larger field sizes.

In this study, the ESDs of the patients were measured once for each of the three conditions (once without bolus and twice using bolus). As a future work and to rule out of the statistical variations, it is suggested that the ESDs of patients are measured 3 times for each case. Furthermore, evaluation of the effect of variation of linac’s output, patient setup during various therapeutic sessions, TLD responses, etc., on the total random uncertainty can be interesting in this field.

CONCLUSION

In this study, ESDs on the breast of patients who had undergone PMRT with bolus technique were measured in the presence and absence of two bolus types. The results showed that using bolus in PMRT can cause excessive increase of skin dose on the breast of patients; hence, it is concluded that when using bolus one should estimate the skin dose. Furthermore, it is recommended that using the bolus of wax in regions that do not require a lot of shaping of bolus is affordable.

Acknowledgment

The authors would like to thank the student research committee of Mashhad University of Medical Sciences for financial support of this work. Moreover, the authors are thankful to the staff of the “Omid and Imam Reza” radiotherapy departments (Mashhad, Iran), who had participated sincerely in this project.

Financial support and sponsorship

The Student Research Committee of Mashhad University of Medical Sciences (Mashhad, Iran) has financially supported the work.

Conflicts of interest

There are no conflicts of interest.

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