Point dose verification in breast cancer radiotherapy: comparison between 3D conformal and IMRT technique

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Abstract. The aim of this work was to verify multi point dose of the 3D-CRT and IMRT in the case of breast cancer. The experiment was performed at Siloam Hospital using Linac Trilogy and TPS Eclipse ver. 11. For measurements, Gafchromic film EBT3 was employed in this work in which the EBT3 film was distributed at 5 different points (trachea, axilla, and mammari interna, nipple, mamme inferior). Then, the statistical comparison between the dose measurement between 3D-CRT and IMRT techniques was evaluated. Moreover, the comparison of dose measurement between the non mastectomy and mastectomy group was also carried out. The result of differences in dose shows the trachea dose in the 3D-CRT is smaller than the IMRT in both the non mastectomy and mastectomy patients. The dose at the axilla, internal mammary, nipple, and inferior mammae are greater in the 3D-CRT than IMRT techniques in both non mastectomy and mastectomy patients. The dosage difference between TPS and EBT3 film in the range of from 0.66\% to 5.67\% (3D-CRT) and -0.67\% to -7.57\% (IMRT). The statistical test showed there was no difference of mean dose (sig 2 tailed > 0.025) between non mastectomy and mastectomy patients group and 3D-CRT and IMRT.

1. Introduction
Breast cancer is the most common cancer found among women worldwide in addition to cervical cancer. Based on Globocan estimation, the International Agency for Research on Cancer (IARC) in 2012 stated that 40 breast cancer incidence per 100,000 women in the world \cite{1}. Radiotherapy is very common technique which is used after surgery for most women diagnosed with early-stage breast cancer \cite{2}. The purpose of radiotherapy is to kill the tumor cell as target volume and minimize the risk of complications in healthy organs. Radiotherapy has the effect of reducing 70\% the locoregional region and raising the cure rate by 85-90\% \cite{3}. Conventional 3D-CRT techniques have become one of the breast cancer treatment solutions by using tangential beam technique to achieve low doses in the lung and heart areas \cite{4}. A number of studies on 3D homogenous dose distribution for tangential irradiation in the breast was depend on the variation of the output beam, the photon energy and the use of the wedge. Along with technological developments, higher conformal radiotherapy techniques such as Intensity Modulated Radiotherapy (IMRT) has been used for the treatment of breast cancer. IMRT employ a number of radiation field by utilizing a modulated radiation beam with a computer system, Multileaf Collimator.
EBT3 film, and using a fixed gantry angle so that the dose distribution and local tumor can be improved by adjusting the external beam into a specific tumor.

Several study have been conducted to verify the radiation dose distribution in the case of breast cancer radiotherapy. Baird's research explains that the verification of the radiation dose distribution in the midplane phantom of the breast using radiographic film and the results indicates 3% accuracy for dose distribution [5]. Liu also explained that the 3D-CRT technique has a good dose for contralateral lung and liver (P <0.05) and IMRT techniques for both contralateral breast and IMRT have better conformity [6].

In order to elaborate the previous work, this study was to verify multi point dose of the 3D-CRT and IMRT for non mastectomy and mastectomy breast cancer patients.

2. Experimental method

This study has evaluated and measured the dose distribution of 31 breast cancer patients for non mastectomy and mastectomy and has been endorsed by clinical ethics committee No. 17-04-0396. We have evaluated 25 patients who were treated with 3D-CRT irradiation technique and 6 patients who treated with IMRT irradiation technique. The experiment was performed at Siloam Hospital using Linac Trilogy and TPS Eclipse ver. 11. For the measurements, Gafchomic film EBT3 were employed in this work.

Prior to the measurement, EBT3 films with size of size 4 × 4 cm² was calibrated using 6 MV photon beams and radiation field size of 10 x 10 cm² with dose variation in the range of 0 to - 260 cGy. The irradiated EBT3 film was scanned using an Epson V700 flatbed scanner to evaluate the pixel value. The calculation and plot between netOD and dose was used to obtain the calibration curve which will be used to calculate radiation dose measurement for patients. Figure 1 shows EBT3 film placed horizontally on a phantom slab with an area of 10 cm × 10 cm irradiation and SAD 100 cm.

Before dispensing treatment to the patient, a computerized dose planning has been performed using Eclipse planning system ver.11. The dose planning used a criteria based on ICRU no.50 which is covered at least 95% by the PTV and 100% of GTV which receives 95% of prescription dose, and no more than 5% PTV will receive 107% of the prescription dose. In IMRT technique, the planning has been performed using inverse planning dose calculation mode and 7 field irradiation whereas the 3D-CRT technique used the calculation mode of supraclav and chestwall dose and 4 field irradiation.

Prescribed dose on IMRT and 3D-CRT techniques were 5000 cGy for 25 fractions (200 cGy per fraction) and there were also patients with 4160 cGy prescription doses given for 16 fractions (260 cGy). For dose verification measurements with IMRT and 3D-CRT, EBT3 film (2 cm × 2 cm) were distributed at 5 points (trachea, axilla, and mammari interna, nipple, mamme inferior) as shown in Figure 2(a) and attached to the mask used by the patient during the irradiation as shown in Figure 2(b).

Figure 1. Illustration of calibration of EBT3 film.

An analysis of EBT3 film dosimeters that have been scanned and stored in digital form using imageJ. In order to calculate point dose, calibration curve were plotted between netOD and dose. NetOD were calculated using following the equation [7]:

$$\text{NetOD} = \frac{\text{OD}_{\text{irradiated}} - \text{OD}_{\text{background}}}{\text{OD}_{\text{reference}}}$$
\[ netOD = \log_{10} \left( \frac{PV_{un}}{PV_{ex}} \right) \]  

(1)

where \( PV_{un} \) is the average pixel value of film before exposure and \( PV_{ex} \) is the average pixel value of the film after exposure.

\[ (\Delta \%) = 100 \times \left( \frac{D_{\text{meas}} - D_{\text{plan}}}{D_{\text{prescription}}} \right) \]  

(2)

where \( D_{\text{meas}} \) is radiation dose measurement, \( D_{\text{plan}} \) is the dose value of TPS, and \( D_{\text{prescription}} \) is the dose prescription. Furthermore, the statistical analysis has been conducted using SPSS 15.00 between the group before and after breast surgery for 3DCRT and IMRT techniques.

3. Results and discussion

The EBT3 films were scanned and saved in .TIFF format and then read on the red channel using ImageJ software to obtain pixel values. The average pixel value was obtained by making the ROI at the center of the image of EBT3 film, it was done to avoid any impact due to cutting on the edge of the film. Furthermore, it is also assumed that the more homogeneous dosage value is at the center of the radiation beam. The dose value and the netOD value are plotted and obtained by linear interpolation technique as shown in Figure 3. From the curve, the authors interpolated between netOD and dose utilizing the following equation,

\[ Y = -16493X^3 + 7957X^2 + 296.9X + 5.667 \]  

(3)

where \( Y \) is the dose value (cGy) and \( X \) is the netOD value.

Point dose measurements between 3D-CRT and IMRT techniques are shown in table 1. Table 1 explains that the dose difference of PTV50 between EBT3 film measurement and the calculated TPS on 3D-CRT technique was not significant. The smallest dose difference was at the axillary point of 0.30% whereas the largest was at the inferior mammary point of 3.51%. Furthermore, the smallest dose
difference was found at the nipple point of 1.12% while the largest was at 8.81% of the internal mammary point for the measurement of EBT3 films via the IMRT techniques.

Comparative analysis point dose results was done by grouping patients based on non mastectomy and mastectomy. In 3D-CRT technique there are 20 mastectomy patients and 5 non mastectomy patients. For the IMRT technique evaluation, four mastectomy patients and two non mastectomy patients were selected. Table 2 and Table 3 shows point dose measurements of film EBT3 using the 3D-CRT and IMRT technique in the patient group non mastectomy and mastectomy. In the group of non mastectomy, the highest percentage difference between the planning dose and the measurement dose was at the trachea point of -2.56% (3D-CRT) and at the inferior mammary point of -11.80% (IMRT) while the lowest was at the nipple point of -0.22% (3D-CRT) and -1.06% (IMRT). Similarly, in the group of mastectomy, the highest percentage difference was at the trachea point of 12.60% (3D-CRT) and at mammaria interna point at -4.85% (IMRT) and the lowest at the nipple point of 1.51% (3D-CRT) and -0.23% (IMRT). Table 4 shows the comparison of mean dose between 3D-CRT and IMRT techniques. In the IMRT procedure, the trachea received a higher dose in comparison with same area with 3D-CRT. In contrast, the axillary, internal mammary, nipple, and inferior mammae point, the 3D-CRT technique received a higher dose than the IMRT technique for both the group of non-mastectomy and mastectomy.

![Figure 3. Curve of the relationship between dose values and netOD values of EBT3 film calibration.](image)

The result showed the trachea dose in the 3D-CRT is smaller than the IMRT in both patients non mastectomy and mastectomy. The dose at the axilla, internal mammary, nipple, and inferior mammam are greater in the 3D-CRT than IMRT techniques in both non mastectomy and mastectomy patients. Therefore, using the 3D-CRT is a better treatment option than IMRT to protect trachea as OAR but IMRT is a better treatment option for multi point target tumor of breast cancer than 3D-CRT technique. The percentage of dose difference was relatively higher when compared to the study of Selvaraj [8] and Andrea. In Andrea's study [9], the mean dose of trachea was 48 cGy in both 3D-CRT and IMRT techniques, while the results showed the dose in the range of 40.33 cGy to 68.90 cGy. Although the trachea dose as OAR in this study was higher than Andrea’s work, the dose was still within the tolerance limit in accordance with the ICRU report 83 in which the acceptable dose limit of trachea for the average dose was 5 Gy. However, the target is still below tolerance limit which is stated in the ICRU recommendation.
Table 1. Comparison of dose point measurements in 3D-CRT and IMRT techniques of EBT3 film.

| Points | Measurement (cGy) | TPS (cGy) | Diff* (cGy) | Error (%) | Measurement (cGy) | TPS (cGy) | Diff* (cGy) | Error (%) |
|--------|------------------|-----------|-------------|-----------|------------------|-----------|-------------|-----------|
| Trachea | 34.21 | 35.40 | 1.19 | 3.36 | 63.03 | 66.7 | 3.67 | 5.50 |
| Axilla | 118.74 | 119.10 | 0.36 | 0.30 | 155.11 | 157.3 | 2.19 | 1.39 |
| MI | 22.48 | 22.20 | -0.28 | -1.24 | 33.01 | 36.2 | 3.19 | 8.81 |
| Nipple | 141.91 | 140.90 | -0.72 | - | 117.70 | 116.4 | -1.30 | -1.12 |
| MI | 47.86 | 49.60 | 1.74 | 3.51 | 27.86 | 29.4 | 1.54 | 5.25 |

*Diff = different dose between measurements and TPS
MI = Mammaria Interna
MI = Mammae Inferior

Table 2. Average point dose measurement of EBT3 film using 3D-CRT technique.

| Points | Measurement ± SD (cGy) | TPS (cGy) | Error (%)* |
|--------|-------------------------|-----------|------------|
| Non mastectomy | Mastectomy | Non mastectomy | Mastectomy |
| Trachea | 41.90 ± 12.89 | 57.46 ± 30.15 | 43.00 | 51.04 |
| Axilla | 111.72 ± 31.44 | 138.87 ± 31.60 | 112.08 | 145.75 |
| MI | 92.00 ± 45.59 | 95.26 ± 31.60 | 92.74 | 97.92 |
| Nipple | 167.20 ± 67.18 | 176.89 ± 60.07 | 167.58 | 174.25 |
| MI | 53.40 ± 17.33 | 78.72 ± 60.07 | 40.08 | 82.81 |

*Diff = different dose between measurements and TPS
MI = Mammaria Interna
MI = Mammae Inferior

Table 3. Average point dose measurement of EBT3 film using IMRT technique.

| Points | Measurement ± SD (cGy) | TPS (cGy) | Error (%)* |
|--------|-------------------------|-----------|------------|
| Non mastectomy | Mastectomy | Non mastectomy | Mastectomy |
| Trachea | 78.25 ± 76.93 | 64.22 ± 14.27 | 80.15 | 66.25 |
| Axilla | 89.18 ± 21.86 | 114.53 ± 30.76 | 93.65 | 116.47 |
| MI | 95.40 ± 6.72 | 68.28 ± 30.43 | 96.95 | 71.76 |
| Nipple | 106.11 ± 3.85 | 96.75 ± 15.28 | 107.25 | 96.98 |
| MI | 53.40 ± 5.75 | 60.22 ± 30.68 | 60.55 | 62.37 |

*Diff = different dose between measurements and TPS
MI = Mammaria Interna
MI = Mammae Inferior
### Table 4. Value of point average dose calculation of EBT3 film on 3D-CRT and IMRT technique.

| Technique | Points | Measurement (cGy) | TPS (cGy) | Error (%)* |
|-----------|--------|-------------------|-----------|------------|
|           |        | Non mastectomy EBT3 film | Mastectomy EBT3 film | Non mastectomy Mastectomy EBT3 film | Mastectomy EBT3 film |
| 3D-CRT    | Trachea | 41.9 | 57.46 | 43 | 51.04 | -2.56 | 12.6 |
|           | Axilla | 111.72 | 138.87 | 112.08 | 145.75 | -0.32 | 4.72 |
|           | MI | 92 | 95.26 | 92.74 | 97.92 | -0.79 | 2.71 |
|           | Nipple | 167.2 | 176.89 | 167.58 | 174.25 | -0.22 | 1.51 |
|           | MI | 39.24 | 78.72 | 40.08 | 82.81 | -2.09 | 4.93 |
| IMRT      | Trachea | 78.25 | 64.22 | 80.15 | 66.25 | -2.37 | 3.06 |
|           | Axilla | 89.18 | 114.53 | 93.65 | 116.47 | -4.77 | -1.66 |
|           | MI | 95.4 | 68.28 | 96.95 | 71.76 | -1.6 | -4.85 |
|           | Nipple | 106.11 | 96.75 | 107.25 | 96.98 | -1.06 | -0.23 |
|           | MI | 53.4 | 60.22 | 60.55 | 62.37 | -11.8 | -3.46 |

*Error for average value MI = Mammaria Interna MI = Mammae Inferior

### Table 5. Point dose measurement of EBT3 film between groups of patients non mastectomy and mastectomy.

| Points | Sig (2-tailed) EBT3 film  |
|--------|---------------------------|
| Trachea | 0.077                     |
| Axilla | 0.317                     |
| MI     | 0.891                     |
| Nipple | 0.357                     |
| MI     | 0.934                     |

(a) 3D-CRT

| Points | Sig (2-tailed) EBT3 film  |
|--------|---------------------------|
| Trachea | 0.517                   |
| Axilla | 0.370                     |
| MI     | 0.719                     |
| Nipple | 0.551                     |
| MI     | 0.623                     |

(b) IMRT

### Table 6. Point dose measurement of EBT3 film between IMRT and 3D-CRT technique.

| Points | Sig (2-tailed)  |
|--------|-----------------|
| Trachea | 0.285 | 0.431 |
| Axilla | 0.407 | 0.091 |
| MI | 0.925 | 0.336 |
| Nipple | 0.279 | 0.000 |
| MI | 0.331 | 0.508 |

MI = Mammaria Interna MI = Mammae Inferior

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The statistical analysis has been conducted using the independent sample T-test. Results presented in Table 5 (a) and 5 (b) show that there is no difference of mean dose between groups of non mastectomy and mastectomy patients based on the 3D-CRT and IMRT techniques (sig-2 tailed > 0.025). Table 6 shows that there is no difference of mean dose between the 3D-CRT and the IMRT technique using EBT3 film (sig-2 tailed > 0.025) but in the axilla and nipple points of the mastectomy group showed there is a difference of mean dose between the 3D-CRT and IMRT technique (sig 2 tailed < 0.025).

4. Conclusion
The use of EBT3 film on point dose verification of breast cancer patients was successfully implemented in this study. The measurement dose in the group of mastectomy patient is greater than in the non mastectomy group at the point of trachea, axilla, internal mammary, nipple, and inferior mamma. The trachea dose in the 3D-CRT is smaller than the IMRT in both the non mastectomy and mastectomy patients. The doses received at the axilla, internal mammary, nipple, and inferior mamma are greater in the 3D-CRT technique in both non mastectomy and mastectomy patients.

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