**ORIGINAL ARTICLE**

# An Investigation into the Surface Dose Using Eclipse Treatment Planning System and Film Dosimetry for Treatment of Breast Cancer

**Nooshin Sheykholeslami [1], Wrya Parwaie [2], Mostafa Farzin [3], Vahid Vaezzadeh [4], Mahbod Esfahani [4], Ghazale Geraily [1, 4*]**

[1] *Department of Medical Physics and Biomedical Engineering, School of Medicine, Tehran University of Medical Sciences, Tehran, Iran*

[2] *Department of Laboratory Sciences, School of Allied Medical Sciences, Ilam University of Medical sciences, Ilam, Iran*

[3] *Brain and Spinal Cord Injury Research Center, Neuroscience Institute, Tehran University of Medical Sciences, Tehran, Iran*

[4] *Radiation Oncology Research Center, Cancer Institute, Tehran University of Medical Sciences, Tehran, Iran*

*Corresponding Author: Ghazale Geraily
Email: gh-geraily@sina.tums.ac.ir

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## Abstract

**Purpose:** Accurate knowledge about surface dose distribution is a critical issue in skin irradiation. This study was conducted to investigate the surface dose using the Eclipse Treatment Planning System (TPS) calculation and GAF chromic film measurement for breast cancer treatment.

**Materials and Methods:** An inhomogeneous chest phantom was used in the present study. Irradiations were done with a 6 MV energy beam of a linear accelerator (Varian 2100C/D). TPS calculations and film measurements were compared for surface dose estimations.

**Results:** The average difference between film measurements and TPS calculations was 7.1%. Surface doses were lower in TPS calculations in comparison with film measurements.

**Conclusion:** TPS plays a significant role in radiotherapy. However, they have many errors in measuring surface doses. Because of the inaccuracy of the majority of treatment planning systems in calculating the surface dose, the need for practical measurements is essential.

**Keywords:** Film Dosimetry; Surface Dose; Treatment Planning System.


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## 1. Introduction

Accurate knowledge of surface dose distribution is a significant issue in skin irradiation. Skin dose evaluation is critical for chest radiotherapy to determine a sufficient dose for the target volume without causing excessive skin reactions [1].

Toxicity due to overdose in radiation therapy occurs on natural tissues such as the skin and mucous membranes. Acute toxicity occurs during or shortly after the end of radiation therapy, while late toxicity lasts from weeks to years after treatment. Acute skin reactions to radiation are prevalent. In about 80% of the cases, these reactions occur accompanied by symptoms such as pain, itching, and infection, and, in the worst case scenario, can result in treatment discontinuation [2].

Treatment Planning Systems (TPSs) play a vital role in radiotherapy. However, because of the inaccuracy of the majority of treatment planning systems in calculating the dose distribution of superficial tissues, practical measurements are needed to evaluate and confirm the skin dose. On average, treatment planning systems are 25% inaccurate for skin doses estimations. Peacock, Pinnacle, and Corvus treatment planning systems have many errors in calculating the surface dose distribution [3].

Mutic *et al.* used Thermoluminescent dosimeter (TLD) to determine the surface dose distribution and compared it with the Peacock treatment planning system calculations. According to TLD measurements, the total dose volume was transmitted in 3 mm and slightly beyond, while Peacock's treatment planning system calculated a dose transfer of 15% in the first 3-6 mm [4]. Chung *et al.* compared surface dose measurements with radiochromic film and Pinnacle and Corvus treatment planning systems from 400 to 1000 cGy and found a difference of 7.4-18.5% [5].

The film is a powerful two-dimensional dosimetry tool to confirm radiation therapy. Radiochromic film is one of the new films in radiation therapy dosimetry. The most common radiochromic films are EBT3 GAFchromic films. The main advantages of these films in dosimetry are their texture equivalence, high resolution, high dynamic range, relatively low sensitivity, lack of sensitivity to visible light, and lack of a need for chemical processing. Film dosimetry is a simple way to determine a set of isodose curves on a film screen. The film also has the highest spatial resolution compared to other dosimeters [6, 7-9]. This study was conducted to estimate Eclipse TPS inaccuracy for surface dose determination using film dosimetry measurements for breast radiotherapy treatment.

## 2. Materials and Methods

### 2.1. GAFchromic EBT3 Film

In this study, 8″ × 10″ sheets of GAFchromic EBT3 films were used. The samples were cut into 5 × 5 $cm^2$ pieces before irradiation. Plastic gloves were used during cutting to prevent contamination and error.

### 2.2. Inhomogeneous Chest Phantom

An inhomogeneous chest phantom, including lung inhomogeneity, was used in this study. The constituents of the phantom were according to International Commission on Radiation Units (ICRU) No. 44 [10]. The breast was made of transparent plexiglass with a density of 1.01 g/$cm^3$, and the lung was made of cork with a density of 0.23 g/$cm^3$.

### 2.3. CT Scan

The chest phantom was placed on the breast board, and imaging was performed with a slice thickness of 5 mm using a multi-slice Computed Tomography (CT) scanner (Siemens Somatom Scope) (Figure 1).

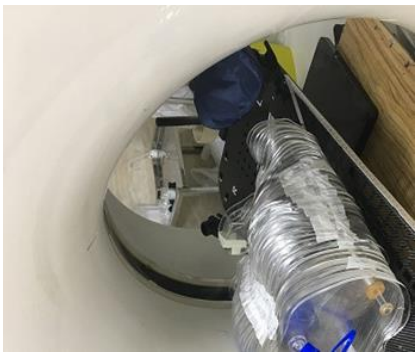

**Figure 1.** CT scan imaging of inhomogeneous chest phantom

### 2.4. Treatment Planning

CT scan images were entered into the Eclipse treatment planning system. A one-centimeter thick bolus was added to the surface of the chest. The treatment planning was performed using two tangential radiation fields that

delivered a total dose of 2 Gy to the target volume. The 6 MV photon mode was selected for irradiation.

### 2.5. Film Calibration

To obtain the calibration curve of the film dosimeter, seven perspex layers with a thickness of 1 cm were used under the films to collect the scattered electrons. To create a build-up condition, five layers with a thickness of 1 cm were placed on the films.

Film dosimeters were irradiated to the doses of 25, 50, 75, 100, 125, 150, 175, 200, 225, and 250 cGy using a 6 MV energy beam of linear accelerator (Varian 2100C/D). Irradiation was performed with a field size of 15 × 15 $cm^2$, a depth of 5 cm, a source-to-surface distance of 100 cm, and a dose rate of 200 cGy/min. The irradiations were repeated three times for each dose level. After irradiation, the films were placed in a darkened envelope for 48 hours.

### 2.6. Irradiation Procedure

The phantom was placed on the breast board, and the film pieces were pasted on it at the radiation entry point for lateral and medial fields. The sides of the film were marked so that their intersection was where the rays entered the film. Then, a Super flab clinical bolus (30×30 $cm^2$, ρ=1.02 $g/cm^3$, thickness=1 cm) was placed on the films. Irradiation was performed using two medial and lateral fields with 6 MV photons. To reduce the measurement error, all measurements were repeated three times (Figure 2).

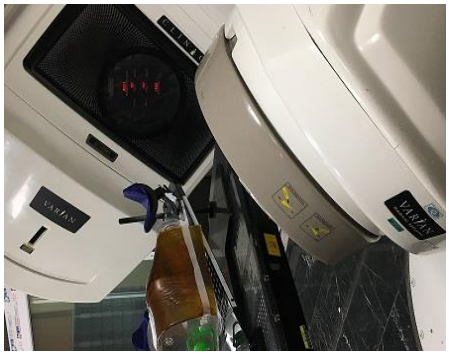

**Figure 2.** Irradiation of film dosimeters with 6 MV photons

### 2.7. Scan Analysis

The film pieces were placed in the center of the Microtek 9800XL scanner. The films were digitized in 150 dpi spatial resolution in RBG mode, and the digitized images were saved in the TIFF format. To measure the optical density of the background, the control film (not irradiated) was also scanned along with the irradiated films.

The ImageJ software was used to analyze the films. First, an average filter with a radius of 2 cm was applied to the films. Then, the film's green, blue and red color channels were extracted. The EBT3 GAFchromic film has the highest light absorption at 633 nm, which is related to red color, and the radiation dose ranged between 0 and 250 cGy in this study. As a result, the red channel was used to analyze the images. The central areas of the film were considered for analysis. Then, the net optical density was calculated with the use of the pixel values from the scanned images according to the following formula (Equation 1):

$$Net\ OD = log\left(\frac{I_{unexp}}{I_{exp}}\right) \quad (1)$$

Where $I_{unexp}$ and $I_{exp}$ are the mean pixel values of the reflected intensities through nonirradiated and irradiated films, respectively [11-13].

Then a curve was fitted to the plotted data and, a calibration curve of the used film dosimeter was obtained.

### 2.8. TPS Calculation

This study used the Eclipse treatment planning system for dose calculation. This treatment planning system uses a convolution-based three-dimensional photon dose calculation algorithm. In this step, the surface dose values in the treatment planning system were read at the radiation entry points.

## 3. Results and Discussion

In the sensitive layer of GAFchromic films, monomers polymerize after irradiation. This process creates a blue color in the film. The amount of color change is proportional to the amount of radiation dose of the film. Figure 3 shows the calibration curve of the GAFchromic EBT3 film in the dose range of 0 to 250 cGy.

Using the film dosimeter calibration curve, the surface dose in the medial and lateral parts of the breast were measured and compared with values in the treatment planning system (Table 1). Comparison between measured and calculated results was reported as a percentage difference.

The obtained calibration curve was a quadratic polynomial function with an R2 value of 0.99. According to the diagram, the values of optical density increased with an increase in the absorbed dose. The results were consistent with the results of a study by Farah *et al.* [14].

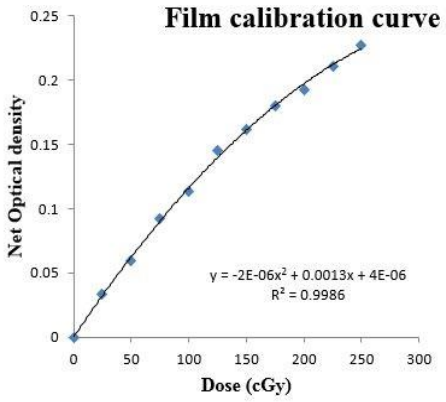


**Figure 3.** Dose response of EBT3 Gafchromic film irradiated with 6 MV photons

Treatment planning systems do not accurately estimate dose distribution in high-dose gradient areas, like near-surface buildup regions. The reason is the error in modeling the dose distribution in the dose calculation algorithms. Therefore, practical measurements in these areas are necessary and can not be satisfied with the results of the treatment planning systems. Accurate knowledge of the surface dose distribution helps to make clinical decisions such as determining the prescribed dose, especially for the treatment of superficial tumors. Acute toxicity can be prevented by avoiding skin over-irradiation.

In this study, the values of surface dose in the specified areas (medial and lateral parts of the breast) were compared using a film dosimeter and treatment planning system. Due to high spatial resolution, measurement of the two-dimensional dose distribution in a beam, the possibility of cutting to fit the phantom, very low energy dependence, low dose sensitivity, and surface dose measurement with accuracy, film dosimeters are considered the gold standard for surface dosimetry [15,16].

The surface dose values measured with the treatment planning system differed from the values measured with the film in the medial and lateral parts by 8% and 6.2%, respectively. In this study, surface doses were lower in TPS calculations in comparison with film measurements. This is because of the inaccuracy of the majority of treatment planning systems in calculating the dose distribution of superficial tissues. The interaction between the pixel location and size, exact phantom (or patient) location, contour grid, and dose calculation grid in CT scan images are factors that have a great impact on dose calculations. This interaction improves the accuracy of dose calculations in treatment planning systems, and the lack of interaction between the above parameters causes erroneous dose calculations.

The difference between the measured and calculated doses indicates that special dosimetric measurements are needed to confirm the surface doses.

## 4. Conclusion

TPSs play a significant role in radiotherapy. However, they have many errors in surface dose calculation. Treatment planning systems cause errors by underestimating or overestimating dose calculations. In the present study, which was carried out to measure the error of the Eclipse treatment planning system in calculating the surface dose, the TPS calculations and film measurements were compared. The results showed that the Eclipse treatment planning system had an average error of 7.1% in calculating the surface dose. As a result, considering the inaccuracy of the majority of treatment planning systems in calculating the surface dose, there is an essential need for practical measurements.

**Table 1.** Values of surface dose measured with film dosimeter and calculated with the treatment planning system

| Surface dose value | Medial part of breast | Lateral part of breast |
|---|---|---|
| **Film dosimeter** | 1.87 ± 0.01 Gy | 1.91 ± 0.01 Gy |
| **Treatment planning system** | 2.02 Gy | 2.03 Gy |
| **Difference (%)*** | 8% | 6.2% |

*Difference (%) = (Measurement with film dosimeter – Calculation with treatment planning system) / Measurement with film dosimeter ×100

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## References

1- Shu-Hui Hsu, Peter L Roberson, Yu Chen, Robin B Marsh, Lori J Pierce, and Jean M Moran, "Assessment of skin dose for breast chest wall radiotherapy as a function of bolus material." *Physics in Medicine & Biology*, Vol. 53 (No. 10), p. 2593, (2008).

2- Horatiu Muresan *et al.*, "Impact of evolving radiation therapy techniques on implant-based breast reconstruction." *Plastic and Reconstructive Surgery*, Vol. 139 (No. 6), pp. 1232e-39e, (2017).

3- MM Eyadeh, M Wierzbicki, and KR Diamond, "Measurements of superficial dose distributions in radiation therapy using translucent cryogel dosimeters." in *Journal of Physics: Conference Series*, (2017), Vol. 847 (No. 1): *IOP Publishing*, p. 012035.

4- Sasa Mutic and Daniel A Low, "Superficial doses from serial tomotherapy delivery." *Medical physics*, Vol. 27 (No. 1), pp. 163-65, (2000).

5- Heeteak Chung *et al.*, "Evaluation of surface and build-up region dose for intensity-modulated radiation therapy in head and neck cancer." *Medical physics*, Vol. 32 (No. 8), pp. 2682-89, (2005).

6- Faiz M Khan and John P Gibbons, Khan's the physics of radiation therapy. *Lippincott Williams & Wilkins*, (2014).

7- Alexandra Rink, I Alex Vitkin, and David A Jaffray, "Energy dependence (to) of radiochromic films assessed using a real-time optical dosimeter." *Medical physics*, Vol. 34 (No. 2), pp. 458-63, (2007).

8- MC Saylor, TT Tamargo, William L McLaughlin, HM Khan, Dave F Lewis, and RD Schenfele, "A thin film recording medium for use in food irradiation." *International Journal of Radiation Applications and Instrumentation. Part C. Radiation Physics and Chemistry*, Vol. 31 (No. 4-6), pp. 529-36, (1988).

9- Valeria Casanova Borca *et al.*, "Dosimetric characterization and use of GAFCHROMIC EBT3 film for IMRT dose verification." *Journal of applied clinical medical physics*, Vol. 14 (No. 2), pp. 158-71, (2013).

10- Murat Kurudirek, "Effective atomic numbers and electron densities of some human tissues and dosimetric materials for mean energies of various radiation sources relevant to radiotherapy and medical applications." *Radiation Physics and Chemistry*, Vol. 102pp. 139-46, (2014).

11- M Vadrucci *et al.*, "Calibration of GafChromic EBT3 for absorbed dose measurements in 5 MeV proton beam and 60Co γ-rays." *Medical physics*, Vol. 42 (No. 8), pp. 4678-84, (2015).

12- AC Sparavigna, "On the use of ImageJ segmentation." *Zenodo Repos*, Vol. 1p. e11, (2020).

13- Uğur AKBAŞ, Nazmiye DÖNMEZ KESEN, Canan KÖKSAL, Kübra ÖZKAYA, Musa Altun, and Hatice Bilge, "Investigation of surface dose using film dosimetry and commercial treatment planning system for larynx cancer treatment with intensity-modulated radiotherapy and volumetric modulated arc therapy." *Turkish Journal of Oncology*, Vol. 33 (No. 1), (2018).

14- Nicolas Farah, Ziad Francis, and Marie Abboud, "Analysis of the EBT3 Gafchromic film irradiated with 6 MV photons and 6 MeV electrons using reflective mode scanners." *Physica Medica*, Vol. 30 (No. 6), pp. 708-12, (2014).

15- Hatice Bilge, Aydın Cakir, Murat Okutan, and Hilal Acar, "Surface dose measurements with GafChromic EBT film for 6 and 18 MV photon beams." *Physica Medica*, Vol. 25 (No. 2), pp. 101-04, (2009).

16- Slobodan Devic *et al.*, "Accurate skin dose measurements using radiochromic film in clinical applications." *Medical physics*, Vol. 33 (No. 4), pp. 1116-24, (2006).