X Congreso Regional Latinoamericano IRPA de Protección y Seguridad Radiológica
"Radioprotección: Nuevos Desafíos para un Mundo en Evolución"
Buenos Aires, 12 al 17 de abril, 2015
SOCIEDAD ARGENTINA DE RADIOPROTECCIÓN

BREAST DOSIMETRIC EVALUATION USING PHYSICAL THORACIC PHANTOM

Silva, S.D.[1], Nogueira, L.B.[2], Oliveira, M.A. [3], Dias, H.G. [3] y Campos, T.P.R.[1]

[1] Nuclear Engineering Department, Federal University of Minas Gerais, Belo Horizonte, Brazil,
[2] Anatomy and Imaging Department, Federal University of Minas Gerais, Belo Horizonte, Brazil
[3] Uberlandia's Cancer Hospital, Uberlândia, Brazil

ABSTRACT

According to the World Health Organization, breast neoplasia is the main cause of death by cancer in women worldwide. The major challenge of radiotherapy is to deposit the entire prescribed dose homogeneously into the target volume, sparing the surrounding tissue. In this context, this paper aims to reproduce opposite parallel fields applied to breast tumors in a thoracic phantom in order to estimate experimentally the spatial dose distribution. The simulator with synthetic breast, composed of equivalent tissue material (TE), was previously developed by the NRI Research Group (UFMG). The phantom was scanned on a computer tomography (CT) previously. The radiotherapy planning systems (TPS) in the thoracic phantom was performed in the ECLIPSE system of Varian Medical Systems. The irradiation was reproduced in the Varian Linear accelerator, model SL – 20 Precise, 6 MV energy. The experimental dosimetric distribution was generated through radiochromic films positioned within the glandular equivalent tissue of thoracic phantom. The dosimetric results measured in the film were compared to those predicted by the treatment planning system. The findings suggested a non-uniform distribution in the breast due to its anatomy and the presence of risk organs in the neighborhood. However, the doses reached the recommended value of 180 cGy with variations between 180 up to 220 cGy.

1. INTRODUCTION

According to the World Health Organization (2014), breast cancer is the main cause of death induced by this disease in women worldwide [1]. However, it has a good prognosis if it is associated with early detection and proper treatment [2]. Radiotherapy is one of the therapeutic modalities for the treatment of this neoplasia.

The breast radiotherapy can be curative or palliative. The planning in radiotherapy involves a series of procedures, aiming the location of the tumor volume, target volume and the homogeneous quantification of the prescribed dose in the treated volume [3].

The principal challenge of radiotherapy in cancer is to deposit the entire prescribed dose homogeneously in the target volume, sparing the surrounding tissue. Due to the anatomy of the chest wall, breast radiotherapy is particularly challenging because it is difficult to achieve a homogeneous prescribed dose distribution on the completely glandular tissue. In addition, there are organs at risk in their surroundings, such as the lungs, heart and the contralateral breast. Indeed, those organs should receive doses as low as possible to avoid early and late complications [4].

[1] Author's email. sadonatosilva@hotmail.com

Technological imaging advances have improved the diagnosis. However, despite the numerous benefits obtained by the new technologies, the equipment used must pass a strict quality control.

Hence, the dosimetry in breast and surrounding organs exposed in radiotherapy is of paramount importance. In addition, the knowledge of the doses is required for dosimetric validation on the radiotherapy planning and in the dose fractions achieved on the irradiation sections. Physical simulators can help in this validation process. Therefore, materials that absorb and spread to ionizing radiation similar to the human body, named phantom, may become important tools in radiotherapy validation process [5].

Radiochromic films have also been employed for mapping dose in patients. Such films have a composition which polymers change color according to the radiation dose received [6].

The aim of this paper was to reproduce two opposite parallel fields used in the breast radiotherapy in a thoracic phantom in order to evaluate the spatial dose distribution, comparing to a therapy planning system (TPS).

2. MATERIALS AND METHODS

2.1. Thoracic phantom

The phantom used in this experiment was previously developed by the research group NRI [7, 8, 9], depicted on Figure 1. This phantom shows metrics shapes and chemical compositions similar to a human body, whose composition was prepared based on the ICRU report No. 44 [5].

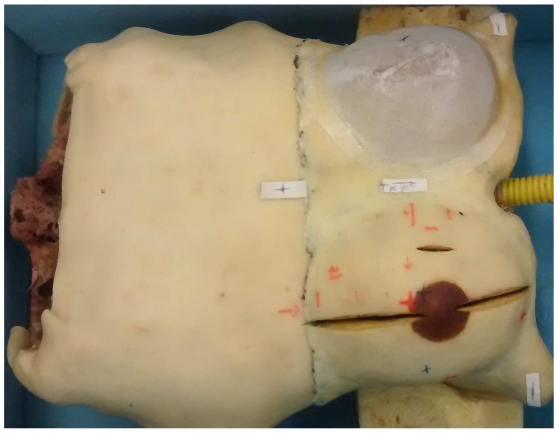

Figure 1. Thoracic phantom.

2.2. EBT2 film calibration

The Gafchromic EBT2 film is an inexpensive tool designed to be used in dosimetry applied to radiotherapy and diagnostic radiology. Developed by International Specialty Producct (ISP), EBT2 film can be used in most existing technologies in radiotherapy, and can be used to measure a wide dose range from 1 cGy to 40 Gy [6]. In order to achieve its proper use, both EBT2 films as other detectors must be calibrated. This process allows to find the relationship between the absorbed dose imparted on the film and its optical density. This relationship can be plotted as a curve, called calibration curve [10].

For the calibration process, a group of ten segments of the film EBT2 was irradiated (3.0 x 3.0 cm^2) in a 6 MV linear accelerator from Varian (Varian SL - Precise 20). The irradiation was performed on a water phantom. The films were placed at depths of 9.5 and 19.5 cm, with a source surface distance (SSD) of 100 cm in a 10 x 10 cm field, as shown in Figure 2.

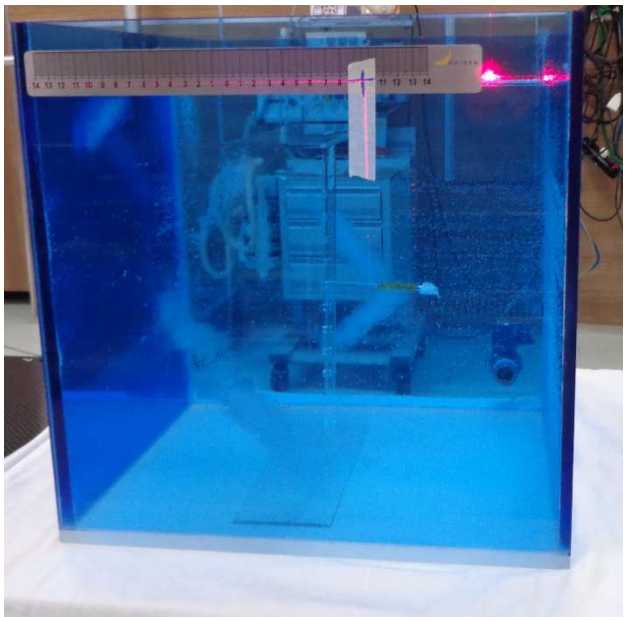

Figure 2. Water phantom and support used in the calibration of the films.

The absorbed doses measured by the radiochromic film in the depths of 9.5 cm and 19.5 cm were calculated by multiplying monitor units by the percentage depth dose. It ranged from 0 up to 499, 7 cGy.

After irradiation, the films exposed in the water phantom were digitalized. The reading of EBT2 films was held at the HP Scanjet G4050 scanner operating in transmission mode. The Scanned films were separated into RGB channels using the software Image J. Since the absorbance spectra of the active component of gafchromic EBT2 has peaks at 636 nm, the

films has the sensitivity maximized by measurement with red color channel [6]. The mean intensity of each irradiated film was measured in the red color channel and the optical density was associated with absorbed dose. The Equation 1 defines the optical density.

$$DO = \log (I_0/I) \quad (1)$$

Where I_0 is the intensity in RGB in the film not irradiated, and I is the intensity in the irradiated film.

2.3. Simulation and phantom irradiation

The Eclipse Varian's software from Varian Medical Systems was used to carry out the radiotherapy planning in the phantom. This planning was based on the protocol suggested by the radiation oncology group of the Uberlandia Hospital (Uberlandia, MG).

The Computed Tomography (CT) images, saved in DICOM format, previously generated were used for feeding of radiotherapy planning system. The total area scanned was 184.5 cm², with slices of 2.00 mm thick, totaling 91 slices [9]. The volume to be irradiated and the prescribed dose were defined, which was determined by applying a dose of 180 cGy in tumor volume, in which 100% of the dose filled the planned target volume (PTV) with a normalization to the dose curve 100 % in the isocenter. Then, two film segments were partially inserted into of the thorcacic phantom which shall receive a single fraction dose of 180 cGy from target volume. The selected target percentage was 100 %.The left breast was the interest organ in the planning system. Two opposite parallel fields were used, both measuring 16 x 8 cm delivered a dose of 90 cGy each.

3. RESULTS AND DISCUSSION

3.1. Film calibration curve and dosimetric analysis

After dose and optical density evaluation for the ten calibration films, one calibration curve was performed and the values were mathematically adjusted by a second-degree polynomial function, Eq. (2). The adjustment provides coefficients to obtain an equation that relates the absorbed dose to the optical density of the calibration films.

$$y = \text{Intercept} + B_1 x + B_2 x^2 \quad (2)$$

Figure 3 presents the graphic representation of equation 2, showing their coefficients.

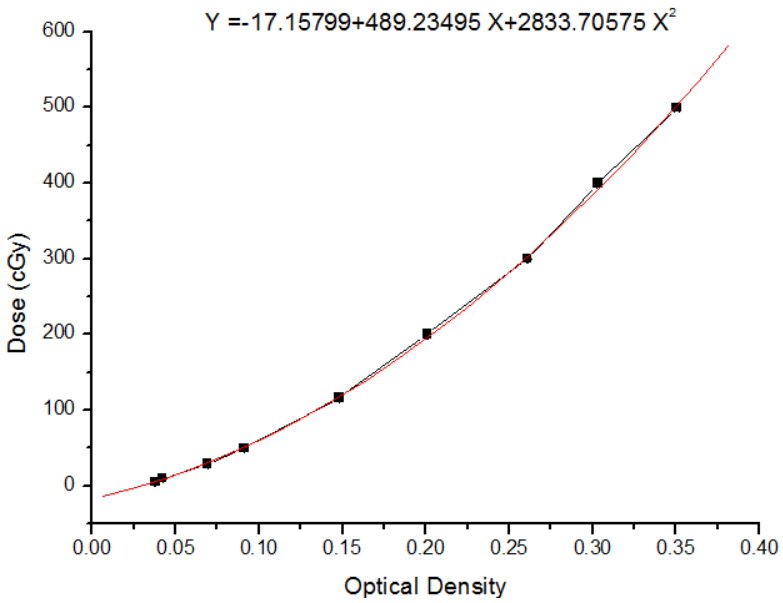

Figure 3: Calibration curve obtained in the red channel.

Later, the radiochromic films placed onto the breast were evaluated. The optical densities were converted to dose and the spatial dose distributions were plotted (Figures 4 and 5).

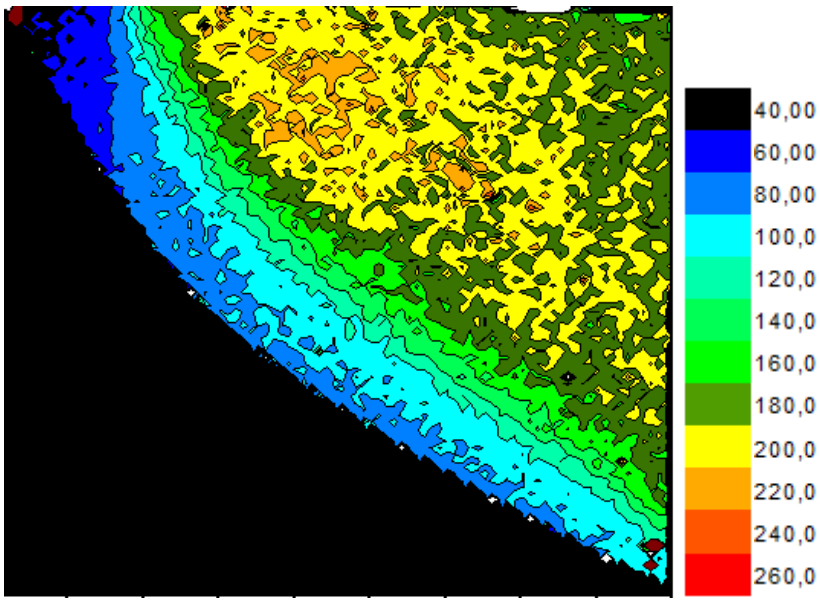

Figure 4: EBT2 film dosimetric distribution in cGy.

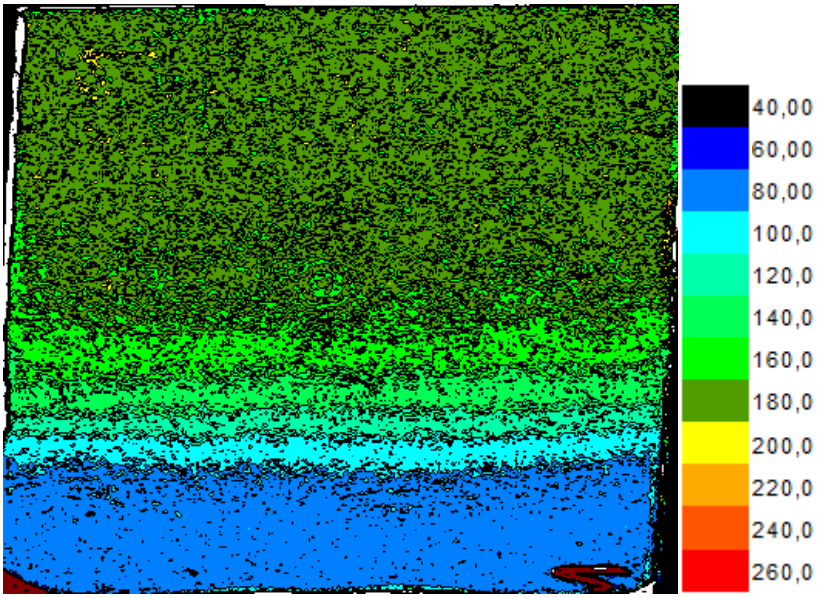

Figure 5: EBT2 film dosimetric distribution in cGy.

The radiotherapy planning was performed in order to deliver the most homogeneous dose as possible in the target volume defined on the TPS, with a recommended value of 180 cGy achieved in a irradiation dose fraction. However, the figures 4 and 5 show a dose range to the full extent of the film of 60 cGy to 220 cGy. Nevertheless, we must consider that one part of the film was inserted into the glandular tissue and another was placed out. The equivalent skin tissue is the separation border of the glandular tissue and the air. In air, the film received 40 cGy up to 160 cGy of dose, and glandular tissue received a dose ranging of 180 cGy up to 220 cGy. A hot spot higher than 260 cGy is observed into the glandular tissue.

Borges C. et al. [4] qualifies breast radiotherapy as particularly challenging, because the anatomy of the chest wall and the existence of organs at risk in its surroundings make difficult to obtain a homogeneous dose. This was confirmed by the spatial dose distribution found in the films of this experiment.

Portions of the films placed outside of the phantom had lower doses. This effect can be explained by the build-up effect, in which high-energy beams exhibit the maximum dose in a point deeper into the tissue, or in this case in the phantom. The region between the surface and the point of maximum dose is called *dose build-up region*. This effect is clinically known as *skin-sparing effect*. For high voltage beam, dose on the surface is much lower than the maximum level in the tissue, which is beneficial effect; it saves the skin surface of the patient [11].

Both films showed hot spots, at doses higher than 260 cGy. Butson *et al.* [12] describes that microscopic and macroscopic changes may occur in the uniformity of the film due to several factors. Microscopic variations can affect the spatial resolution. This is a determining factor in the exhibition or not of the nonuniform points. For example, at high spatial resolutions defective points that would not be noted at low resolutions end up being evident. This effect in our experiment may have caused the expression of hot spots in the film. Devic S. *et al.*

[13] recommends applying a correction in these "bad" pixels. Thompson [14] has chosen to present these points in their work and discuss them.

3. CONCLUSION

The generation of a homogeneous dose in the breast is a difficult task due to its anatomy and the presence of risk organs in the neighborhood. It has been shown that breast doses had variations between 180 up to 220 cGy, when compared to the recommended planning of 180 cGy at 100 %. Furthermore, hot spots were found in the film, which can be explained by differences in uniformity on the film. A larger and more accurate study is being conducted in the definition of uncertainties, in relation to those hot spots and the doses received in the skin.

4. REFERENCES

1. "World Health Organization. Women's health" http://www.who.int/mediacentre/factsheets/fs334/en/ (2014).
2. INCA. Instituto Nacional do Cancer. Controle de Cancer de Mama: Documento de Consenso. Rio de Janeiro – Brasil (2004).
3. Scaff, L. Fisica na Radioterapia a Base Analógica de uma Era Digital. Editora Projeto Saber, São Paulo - Brasil, **v.2** (2010).
4. Borges C. *et al*. *Comparison of different breast planning techniques and algorithms for radiation therapy treatment*, Physica Medica, v. XXX pp 1-11 (2013).
5. ICRU. International commission on radiation units and measurements. *Tissue substitutes in radiation dosimetry and measurement* – ICRU REPORT 44. Maryland – United States (1989).
6. "Gatchromic self-developing dosimetry films | EBT2 | EBT 3 | Cyberknife | HD-V2 | MD-V3 | RTQA2 Ashland Inc." www.ashland.com
7. Maia, M. *Fantoma antropomórfico antropométrico de tórax para fins de radioproteção e dosimetria*. (2004).
8. Schettini, M. P. *Avanços no desenvolvimento de um fantoma antropomórfico e antropométrico de tórax humano e avaliação dosimétrica em modelo de voxel de tórax na radioterapia de tumores do terço médio do esófago.* Universidade Federal de Minas Gerais, Belo Horizonte – Brasil (2006).
9. Nogueira, Luciana Batista. *Síntese, caracterização e dosimetria de sementes radioativas de Ho e HoZr para tratamento de câncer de mama*. Universidade Federal de Minas Gerais, Belo Horizonte – Brasil (2012).
10. AAPM. American Association of Physics in Medicine. Radiochromic Film Dosimetry. Report No. 63. (1998)
11. Faiz M. Khan. *The Physics of Radiation Therapy*. Lippincott Williams & Wilkins, ed. 3 Philadelphia (2003).
12. Butson M. J. *et al. Radiochromic film for medical radiation dosimetry,* Materials Science and Engineering, pp 61-120 (2003).

13. Devic, S. *et al. Precise radiochromic film dosimetry using a flat-bed document scanner*. Med Phy, **v. 32**, n. 7, p. 2245–2253 (2005).
14. Thompson, Larissa; Dias, Galvão Humberto; Campos, Tarcísio Passos Ribeiro. *Dosimetry in brain tumor phantom at 15 MV 3D conformal radiation therapy*. Radiation Oncology (2013).