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Evaluation of Gafchromic EBT2 film for the measurement of anisotropy function for high-dose-rate ^{192}Ir brachytherapy source with respect to thermoluminescent dosimetry

Satish C. Uniyal[a,*], Umesh C. Naithani[b], Sunil D. Sharma[c]

[a] Department of Radiology, Himalayan Institute of Medical Sciences, Jolly Grant, Dehradun 248140, India
[b] Department of Physics, H N B Garhwal Central University, Campus Pauri, Pauri (Garhwal), Uttarakhand 246001, India
[c] Radiological Physics & Advisory Division, Bhabha Atomic Research Centre, CT & CRS Building, Anushaktinagar, Mumbai 400094, India

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ABSTRACT

Aim: The aim of this work was to assess the suitability of the use of a Gafchromic EBT2 film for the measurement of anisotropy function for microSelectron HDR ^{192}Ir (classic) source with a comparative dosimetry method using a Gafchromic EBT2 film and thermoluminescence dosimeters (TLDs).

Background: Sealed linear radiation sources are commonly used for high dose rate (HDR) brachytherapy treatments. Due to self-absorption and oblique filtration of radiation in the source capsule material, an inherent anisotropy is present in the dose distribution around the source which can be described by a measurable two-dimensional anisotropy function, $F(r, \theta)$.

Materials and methods: Measurements were carried out in a specially designed and locally fabricated PMMA phantom with provisions to accommodate miniature LiF TLD rods and EBT2 film dosimeters at identical radial distances with respect to the ^{192}Ir source.

Results: The data of anisotropy function generated by the use of the Gafchromic EBT2 film method are in agreement with their TLD measured values within 4%. The produced data are also consistent with their experimental and Monte Carlo calculated results for this source available in the literature.

Conclusion: Gafchromic EBT2 film was found to be a feasible dosimeter in determining anisotropy in the dose distribution of ^{192}Ir source. It offers high resolution and is a viable alternative to TLD dosimetry at discrete points. The method described in this paper is useful for comparing the performances of detectors and can be applied for other brachytherapy sources as well.

1. Background

High dose rate ^{192}Ir sources are commonly used in brachytherapy by most of the radiotherapy centers. Ideally, a treatment source would be a point source, but in reality the geometry is

* Corresponding author.
E-mail address: uniyal.satish@rediffmail.com (S.C. Uniyal).

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more complex. In remote afterloading High Dose Rate (HDR) brachytherapy the ^{192}Ir source is normally cylindrical, made of high-Z elements and encapsulated in stainless steel. Due to self-absorption and oblique filtration of radiation in the capsule material, the dose distribution is inherently anisotropic around the HDR ^{192}Ir source. According to the dose calculation model as recommended by American Association of Physicists in Medicine (AAPM), Task Group No. 43 reports TG-43U1,[1,2] a two-dimensional angular anisotropy function, $F(r, \theta)$ accounts for anisotropic dose distribution around brachytherapy sources.

Previous studies using different detectors such as TLDs, radiochromic film, diodes and ionization chambers have measured anisotropy function for HDR ^{192}Ir source at various radial distances through a range of polar angles.[3–12] Most of them have used either a single detector or different detectors in separate experimental settings for dosimetric characterization of the source. Employing different detectors in a single experimental set up may provide a faithful comparison between performances of detectors. A reliable comparative dosimetry data is of significant importance for the purpose of clinical quality control.

Lithium fluoride (LiF) thermoluminescence dosimetry (TLD) is the recommended method for experimental determination of dose around brachytherapy sources because it offers best compromise between relatively small size, flat energy response and high sensitivity. However, it has many associated artifacts such as volume averaging, inter-detector and self attenuation, positioning errors at short distances and higher total uncertainty in dose determination. The recently introduced Gafchromic EBT2 film has been mainly targeted towards application in external beam radiotherapy and found less application in brachytherapy dosimetry. However, due to its high resolution and other favorable properties, the EBT2 film promises to be a suitable detector for point dose measurement in brachytherapy.

2. Aim

The present work was aimed to evaluate the feasibility of radiochromic film dosimetry using Gafchromic EBT2 model in determining the anisotropy function for microSelectron ^{192}Ir HDR source with respect to the validated method of thermoluminescence dosimetry. It was also intended to device a dosimetry technique to use both detectors simultaneously in identical conditions of phantom material and their spatial geometry with respect to the source for a reliable comparison.

3. Materials and methods

3.1. *microSelectron HDR ^{192}Ir source and dosimeters*

Measurement of the anisotropy function was carried out for microSelectron HDR ^{192}Ir source (classic/old source) which has an active length of 3.5 mm and active diameter of 0.6 mm. It is encapsulated in a cylindrical stainless steel capsule with an outer diameter of 1.1 mm and length of 5.0 mm. It is not completely symmetrical with respect to its transverse axis and has one end welded to a stainless steel drive cable, which is connected to stepping motors that can precisely position the source into the required applicator.[13]

Thermoluminescent dosimeters [LiF:Mg, Ti (TLD-100)] in the form of cylindrical rods with a length of 6 mm and diameter of 1 mm were used for the measurement of anisotropy in the dose distribution around the source. The TLD rods were stored in aluminum trays and were numbered to their corresponding position in the phantom for identification purpose in the course of annealing and reading. A batch of 70 fresh TLD rods was used in this measurement. Before each exposure, TLD rods were annealed in groups using a thermal cycle: 400 °C for 1 h, fast cooling for 6 min followed by 100 °C for 2 h. For the readout of TLD rods, a TLD reader model UL-320 (Rexon) was used with a purified N_2 atmosphere. Readings were taken after 24 h of irradiation. The dose response of TLD rods was obtained by exposing them to a ^{60}Co gamma rays beam (Bhabhatron-II, BARC, Mumbai/PMT, Bangalore, India). From TL (thermoluminescent) outputs, the individual calibration factors for TLD rods were determined in terms of nC/cGy to be used to evaluate absorbed doses from their TL outputs in subsequent measurements.

The Gafchromic EBT2 dosimetry film (ISP Technologies, Lot Number F020609) used in our work is a recently introduced high spatial resolution and high sensitive dosimetry film which can be used in the dose range 0.01–40 Gy. The active part of the film is a single sensitive layer about 30 μm in thickness with a thin topcoat made on a clear 175 μm thick polyester substrate. Coated to the active layer is polyester over-laminate (50 μm thick) with a pressure-sensitive adhesive layer with thickness of 25 μm. The film is near tissue equivalent with $Z_{eff} = 6.84$, which is also very close to the effective atomic number of PMMA ($Z_{eff} = 6.5$). In comparison to earlier radiochromic film models, EBT2 film shows less energy dependency. In addition, it develops in real time with density changes stabilizing rapidly after exposure. For calibration, EBT2 film samples of size 3 cm × 3 cm were placed in a full scatter PMMA phantom and irradiated in a ^{60}Co γ-ray beam (Bhabhatron-II, BARC, Mumbai/PMT, Bangalore) in the dose range 25–800 cGy. One such sample was left unexposed but kept with other samples for background optical density. After 24 h of irradiation, each sample was scanned in landscape orientation and in a red color channel mode of a flatbed scanner Epson Expression 10000 XL. The optical density (OD) of each pixel in the central 1 cm × 1 cm region of the calibration film was measured from the corresponding scan value and the film background scan value. Mean optical density (MOD) for each calibration film was then calculated. A curve between MOD and corresponding dose for the EBT2 film was plotted (Fig. 1) and a fit equation (Eq. (1)) was obtained for determination of the dose from the measured optical density in the subsequent experiment.

$$y = 1897x^2 + 696.3x \quad (1)$$

where x is the optical density and y is the dose in cGy.

3.2. *Experimental technique*

A precisely machined polymethyl methacrylate PMMA phantom was used for the measurement of anisotropy function for