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Evaluation of dosimetric functions for Ir-192 source using radiochromic film

P. Sellakumar [a,*], A. Sathish Kumar [b], Sanjay S. Supe [c], M.R. Anand [a], K. Nithya [a], S. Sajitha [a]

[a] Department of Radiation Oncology, Bangalore Institute of Oncology, 44-45/2, II Cross, RRMR Extension, Bangalore – 560 027, India
[b] Department of Physics, Bharathiar University, Coimbatore – 641 046, India
[c] Department of Radiation Physics, Kidwai Memorial Institute of Oncology, Bangalore – 560 027, India

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ABSTRACT

Ir-192 source is widely used in high dose rate brachytherapy. The aim of this study was to derive the brachytherapy dosimetric functions described in AAPM TG-43 to characterize the dosimetric properties of commercially available microselectron HDR Ir-192 source. All the measurements were carried out with GAFCHROMIC EBT radiochromic film in water equivalent solid phantom and the grey values were analyzed using Omnipro IMRT film dosimetry software with Vidar VXR-16 scanner. Optical density of the film was converted to dose using calibration film established in this study. Measurements were carried out by measuring the dose at radial distances from 0.5 cm to 5.0 cm with interval of 0.5 cm and at polar angle 0°–180° in 10° intervals. Dosimetric functions such as dose rate constant, radial dose functions and anisotropy of the dose distribution were found to be in good agreement with Monte Carlo calculations. This study confirms the feasibility of radiochromic EBT film dosimetry in characterization of the TG-43 parameters for Ir-192 HDR source.

1. Introduction

Ir-192 source is the most commonly used radioactive source in all kinds of high dose rate (HDR) brachytherapy applications [1–3]. Since currently varieties of Ir-192 sources are commercially available with different core dimensions and different encapsulation dimensions, accurate dosimetry in mm distance range in the proximity of the sources are required. The dose distribution produced by the high dose rate Ir-192 source is inherently anisotropic. This anisotropy property depends on source construction and geometry and also depends on self-filtration, oblique filtration of primary photons through the encapsulating material [4–7]. So, it would be of great interest to investigate their dosimetric characteristics using dosimetric formalism proposed in American Association of Physicist in Medicine (AAPM) Task Group (TG)-43 [8–11]. Several investigators have investigated the dosimetric characteristics of different brachytherapy sources using ion chambers, semiconductors, thermoluminescent dosimeters (TLD) and Monte Carlo calculations [5,12–17]. Because of the detector size and measurement geometry it is very difficult to analyze the dose distribution within a millimeter from radioactive sources accurately. Currently as we know MOSFET detector is the only real time dosimeter which allow measurements very close to the source due to submicron size of the sensitive volume of the dosimeter [18,19]. Recently radiochromic film is widely used to evaluate in the area of medical dosimetry. The sensitivity of the radiochromic film is less compared to other detectors makes them ideal to determine the brachytherapy dosimetric functions very close to source [20–26]. In this paper, we have evaluated the dosimetric functions for Ir-192 brachytherapy source using GAFCHROMIC EBT film based on AAPM TG-43 recommendation and compared with the data calculated using benchmark Monte Carlo photon-transport (MCPT) code [16]. The MCPT algorithm has been described in detail elsewhere [13,27–30] and briefly reviewed here. This code simulates photo-electric absorption followed by emission of K and L shell characteristic X-rays, pair production followed by emission of annihilation photons, and coherent and incoherent scattering. The photon cross section library, DLC-99 (HUGO) distributed by Radiation Shielding Information Center was used [31]. The primary photon spectrum for Ir-192 was that of Glasgow and Dillman [32].

2. Materials and methods

2.1. Experimental setup

2.1.1. Description of source

The radiation source used in this investigation was a high dose rate Ir-192 source V2, from Nucletron microselectron HDR unit with an initial apparent activity of 370 GBq. The source consists

* Corresponding author. Tel.: +91 80 4020 6535; fax: +91 80 2222 2146.
E-mail address: psellakumar@rediffmail.com (P. Sellakumar).

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of a core of 0.65 mm diameter and length 3.6 mm encapsulated in a cylindrical stainless steel capsule of 0.9 mm diameter and 4.5 mm length. The proximal end of the source is laser welded to the drive cable.

2.1.2. Phantom design

To comply with TG-43 brachytherapy dosimetry protocol, measurements were performed in a water equivalent RW3 solid phantom. The phantom was modified in such a way that to accommodate interstitial nylon catheter at the center of $30 \times 30 \times 30\,cm^3$ phantom. The Ir-192 source was positioned inside the interstitial nylon catheter at 1 cm from the plane of detector and the schematic diagram of phantom used in this study was shown in Fig. 1.

2.1.3. Radiochromic film

In this study, we have used GAFCHROMIC EBT (Lot No. 47261-07I; ISP Technologies) to measure the dose distribution around the source followed by calculation of radial and geometrical functions for Ir-192 source as described in the TG-43 protocol. The film is made by laminating two film coatings each having an active layer approximately 17 μm thick and a surface layer approximately 3 μm thick. The coatings are applied to clear, transparent ~97 μm polyester. The product is formed by laminating the two pieces of coated film by a proprietary technique requiring no intermediate adhesive layer. The colorless, transparent film responds to ionizing radiation by turning blue, which depend on the absorbed dose. The radiation-induced color change is formed directly without thermal, optical, or chemical development and the original blue image is stable at room temperatures. The radiation-induced color changes were read with broadband fluorescent light from Vidar VXR-16 medical scanner and recommendations [20–26,33,34] described in AAPM TG-55 for radiochromic film dosimetry were followed through out this study and all the films used in study were from the same pack.

2.1.4. Calibration film

For film calibration a set of GAFCHROMIC EBT films from the same pack (Lot No. 47261-071) were cut into 16 film pieces of size approximately $3 \times 4\,cm^2$ and the orientation on each film was marked. Each film pieces were placed at 1.0 cm from the interstitial nylon catheter, in which an Ir-192 HDR source was driven to the pre determined position i.e. center of a solid water phantom and each film was separately exposed, with exposure ranging from 25 cGy to 3500 cGy and one film piece was left unirradiated. Optical density (OD) values were measured at the center of the each film piece. The same procedure was repeated twice to reduce the uncertainty during the calibration and mean OD value from these three films were considered in this experiment.

2.1.5. Experimental film

To calculate the brachytherapy dosimetric functions two sets of GAFCHROMIC EBT film (Lot No. 47261-07I) of size $25 \times 20\,cm^2$ were considered. Each set consists of three films and exposed to dose of 400 cGy and 800 cGy at 1.0 cm from center of the source respectively. These two dose values were considered to keep the resultant OD in the calibrated dose range. OD values were mea-

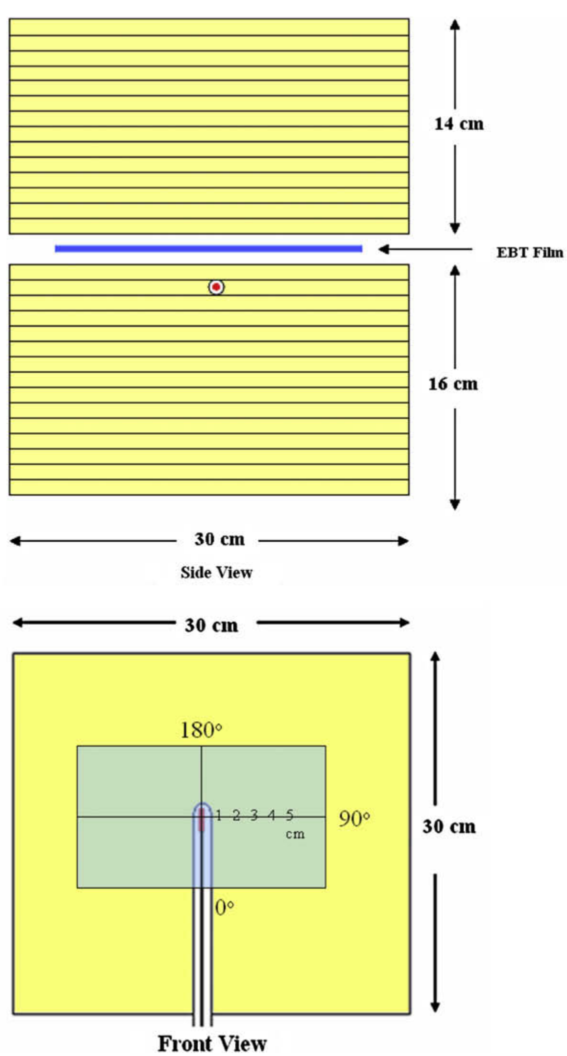

Fig. 1. Schematic diagram of phantom containing source and radiochromic film.

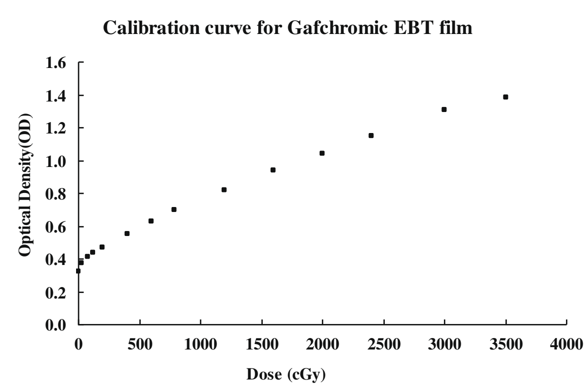

Fig. 2. Calibration curve for Gafchromic EBT film.

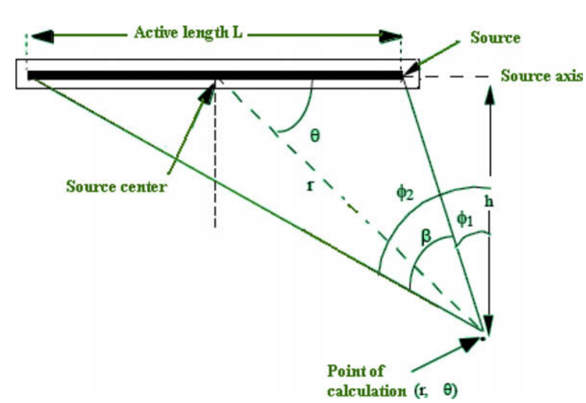

Fig. 3. Schematic representation of polar coordinates.