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Dose distribution verification for GYN brachytherapy using EBT Gafchromic film and TG-43 calculation

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ABSTRACT

Aim: Verification of dose distributions for gynecological (GYN) brachytherapy implants using EBT Gafchromic film.

Background: One major challenge in brachytherapy is to verify the accuracy of dose distributions calculated by a treatment planning system.

Materials and methods: A new phantom was designed and fabricated using 90 slabs of 18 cm × 16 cm × 0.2 cm Perspex to accommodate a tandem and Ovoid assembly, which is normally used for GYN brachytherapy treatment. This phantom design allows the use of EBT Gafchromic films for dosimetric verification of GYN implants with a cobalt-60 HDR system or a LDR Cs-137 system. Gafchromic films were exposed using a plan that was designed to deliver 1.5 Gy of dose to 0.5 cm distance from the lateral surface of ovoids from a pair of ovoid assembly that was used for treatment vaginal cuff. For a quantitative analysis of the results for both LDR and HDR systems, the measured dose values at several points of interests were compared with the calculated data from a commercially available treatment planning system. This planning system was utilizing the TG-43 formalism and parameters for calculation of dose distributions around a brachytherapy implant.

Results: The results of these investigations indicated that the differences between the calculated and measured data at different points were ranging from 2.4% to 3.8% for the LDR Cs-137 and HDR Co-60 systems, respectively.

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Conclusion: The EBT Gafchromic films combined with the newly designed phantom could be utilized for verification of the dose distributions around different GYN implants treated with either LDR or HDR brachytherapy procedures.

1. Background

As radiation therapy techniques become more complex, the quality assurance (QA) techniques have to be changed to provide a sound and practical method of verification of treatment delivery in order to reduce errors during radiation therapy.[1] A QA progress needs to be adopted for complex brachytherapy treatment techniques, particularly when it involves treatment with a complex gynecologic (GYN) system.

GYN brachytherapy treatments for the cervix, vaginal and endometrial cancers have been commonly used for over 100 years.[2] Accuracy of dose calculation plays a vital role in the brachytherapy treatment planning. Experimental verification of dose accuracy is one of possible QA procedures for determination of over-dose or under-dose area in the brachytherapy planning volume. However, this technique faces several challenges related to the measurements of dose distributions in a high-gradient region. One of the important criteria for these experimental setups is to have a dosimeter with high spatial resolution such as Gafchromic films. Gafchromic films are being used as 2D dosimeters by several investigators in various types of applications.[3]

Different investigators had demonstrated the usefulness of the EBT Gafchromic films for brachytherapy source dosimetry.[4] These films require no chemical processing and they are insensitive to ambient light. Therefore, they can be cut to the shape of the experimental geometry for the best representation of a dosimetric setup.

2. Aim

Verification of dose distributions for gynecological (GYN) brachytherapy implants using EBT Gafchromic film.

3. Materials and methods

EBT Gafchoromic film dosimetry for two different brachytherapy systems for GYN treatment were considered in this study: the GZP6 high dose rate (HDR) ^{60}Co brachytherapy unit that was introduced by Nuclear Power Institute of China for brachytherapy procedures,[5] and the Selectron low-dose-rate (LDR) ^{137}Cs remote afterloading system distributed by Nucletron (Nucletron BV, Veenendaal, The Netherlands).[6]

3.1. GZP6 HDR system

GZP6 afterloading unit (Nuclear Power Institute of China) with HDR ^{60}Co sources has one stepping source and five non-stepping source-braids.[7] The GZP6 treatment planning system is able to produce dose distributions in the transverse and longitudinal planes. It calculates dose using the superposition dose calculation technique. This system could be used for intracavitary treatment of cervical, vaginal, endometrial, rectal, esophageal and nasopharyngeal malignancies. The sources in this system were consisted of ^{60}Co active pellets (3.5 mm long and 1.5 mm diameter) sealed by titanium capsules and spherical stainless steel inactive pellets (1.5 mm diameter) which were covered by a steel spring.[8] TG-43 recommended dosimetric characteristics of the sources in this system have been evaluated by several different investigators.[7–9]

In this study channels 3 and 4 of GZP6 HDR system were utilized to deliver 1.5 Gy dose to 0.5 cm distance from the lateral surface of ovoids within 4.62 min. Each of the channels 3 and 4 contains one stationary active pellet (they are nearly identical in their source strength and geometry) and they can be used in the ovoids.

3.2. Selectron LDR system

Selectron Cs-137 LDR system has some active pellet spherical sources (supplied by Amersham Corporation, Louisville, CO) and inactive or dummy pellets in an applicator set.[10] Different combinations of active and inactive pellets are used for GYN cancer. The Nucletron PLATO treatment planning system (TPS) calculates the dose delivered by the unit at the point of interest.[10] The TPS determines the dose distribution around different combinations of sources and spacers by assuming each active pellet as a point source, using the superposition dose calculation technique.

The Selectron unit consists of spherical Cs-137 pellets composed of 1.5 mm active source core of ceramic, encapsulated in 0.5 mm steel, with a total diameter of 2.5 mm.[11] In addition, this system contains some non-active pellets as a dummy, with the same dimensions and chemical composition as the active pellets.[6] Liu et al. have published the TG-43 recommended dosimetric characteristics of the sources in this system.[12]

In this study, from a set of 8 pellets, numbers 2–7 are considered active, and the remainders are non-active, in order to deliver 1.5 Gy of dose to 0.5 cm distance from the lateral surface of ovoids within 1.01 h.

3.3. EBT Gafchromic film dosimetry

The new phantom was designed and fabricated from 90 slabs of 18 cm × 16 cm × 0.2 cm Perspex to accommodate GYN applicators (tandem and ovoid). The composition of the Perspex taken to be H, 8%; C, 60%; O, 32%, with a density of 1.18 g/cm^3.[13] This configuration enables us to verify the dose distributions around the applicator with a high spatial resolution. Fig. 1 shows the schematic diagram of this phantom with its layers and the ovoid applicator which is placed in the phantom.