

ROPES eye plaque dosimetry: commissioning and verification of an ophthalmic brachytherapy treatment planning system

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Abstract. In this study, the Plaque Simulator™ eye plaque brachytherapy planning system was commissioned for ROPES eye plaques and Amersham Health model 6711 Iodine 125 seeds, using TG43-UI data. The brachytherapy module of the RADCALC® independent checking program was configured to allow verification of the accuracy of the dose calculated by Plaque Simulator™. Central axis depth dose distributions were compared and observed to agree to within 2% for all ROPES plaque models and depths of interest. Experimental measurements were performed with a customized PRESAGE™ 3-D type dosimeter to validate the calculated depth dose distributions. Preliminary results have shown the effect of the stainless steel plaque backing decreases the measured fluorescence intensity by up to 25%, and 40% for the 15 mm and 10 mm diameter ROPES plaques respectively. This effect, once fully quantified should be accounted for in the Plaque Simulator™ eye plaque brachytherapy planning system.

1. Introduction

Choroidal melanoma is the most common primary intraocular malignancy [1] and is commonly treated using plaque brachytherapy, external beam charged particle therapy, surgical resection or enucleation. The Collaborative Ocular Melanoma Study (COMS) trial began in 1986 [2], comparing enucleation against a minimum of 100 Gy I-125 plaque radiation therapy for medium-sized choroidal melanomas. With 12 years follow up, no significant difference in survival was found, establishing eye plaque brachytherapy as an effective treatment modality for choroidal melanoma [3].

Following the publication of AAPM TG-43 report in 1995 providing a dose calculation formalism for Ir-192, I-125 and Pd-103 sources [4], the dose prescription of 100 Gy was lowered to 85 Gy [5]. A TG-43 report update was released in 2004 (TG43-UI [6]) to include new brachytherapy sources and critically reassessed some published brachytherapy dosimetry data, however both the TG-43 and TG43-UI reports assume a full water scattering medium around the sources.

I-125 seeds have been the subject of extensive dosimetric studies using LiF thermoluminescent dosimeters (TLD), diodes, scintillators, Gafchromic film and polymer gels [6]. LiF TLD remains the method of choice recommended in the AAPM TG43-UI report [6], and Monte Carlo codes are often used as benchmarks for any experimental measurements [7].

Whilst the dosimetric studies of model 6711 I-125 seeds are extensive, many of these are limited to the study of the seeds in conjunction with COMS plaques [8]. To date, only one group has published a Monte Carlo study of the dose distributions produced by Radiation Oncology Physics and Engineering Services Australia (ROPES) type eye plaques with model 6711 I-125 seeds [9] and to the best of our knowledge, limited experimental data have been reported.



The Plaque SimulatorTM eye plaque brachytherapy planning system (BEBIG, Germany) was recently commissioned in our institution using TG43-UI data for model 6711 Amersham Health (London, UK) I-125 seeds in association with ROPES eye plaques. The brachytherapy module of RADCALC[®] independent checking program (Lifeline Software, Inc. USA) was used to separately model the ROPES eye plaques loaded with model 6711 I-125 seeds and verify the resulting treatment time calculation accuracy. Central axis eye plaque depth dose distributions, as calculated by Plaque SimulatorTM and RADCALC[®], are compared for different ROPES eye plaque seed configurations. PRESAGE[®] is a radiochromic solid dosimeter 3-D dosimeter [10, 11]. Preliminary results obtained using customized PRESAGE^m 3-D dosimeter for central axis fluorescence intensity measurements are also presented with an experimental assessment of the effect of the plaque backing on the distribution.

2. Materials & Methods

2.1. ROPES Eye Plaques loaded with I-125 Seeds (Amersham Health type 6711)

The ROPES eye plaques consist of an acrylic carrier with holes for the I-125 seeds combined with a stainless steel backing shield to place the acrylic insert in. Available plaque diameters are 11, 15 and 18 mm with 4, 9 or 10, and 14 seeds, respectively. The stainless steel backing and the acrylic insert are portion of a spherical shell that offsets the radioactive seeds by approximately 1 mm from the sclera of the eye [9]. The Amersham Health type 6711 I-125 seed is a cylindrically shaped and silver rod on which I-125 has been coated onto the surface. It emits photons with a weighted mean energy of 28.37 keV [7].

2.2. Dose calculations with Plaque SimulatorTM and RADCALC[®]

The Plaque SimulatorTM v5.63 software (BEBIG Germany) supports dose calculations for a variety of eye plaques, radioactive nuclides and seed models. The dose calculations are performed three-dimensionally with an algorithm based on the superposition principle, using TG43-UI data and formalism [12].

RADCALC[®] v6.1 (Lifeline Software, Inc. USA) is a versatile program designed to independently check radiation therapy treatment doses. The brachytherapy module allows dose calculations to points of interest for various brachytherapy sources whose data and model/approximation are user defined. The 3D I-125 seeds geometries were defined in Radcalc[®] for every ROPES eye plaque type available.

The line-source approximation for the geometry function and 2D anisotropy corrections were used for the I-125 sources in both software systems and lead to single seed dose comparison of difference less than 1% at distances up to 1 cm from the seed centre.

The plaques were loaded with 9.93 U sources and treatment times calculated in Plaque SimulatorTM to deliver 85 Gy to a depth of 5 mm. Corresponding treatment times were entered into RADCALC[®], taking into account that RADCALC[®] does not account for the decay of the sources during treatment. Central axis depth dose distributions were then compared for each of the ROPES eye plaques.

2.3. 3-D PRESAGE^m Phantom/Dosimeter and irradiation protocols

Customized 3-D PRESAGE^m phantoms/dosimeters were shaped in hemispheres to match eye ball geometry and fit ROPES eye plaques internal curvature. The following fractional atomic-mass composition optimized water equivalence for low-energy photons with a resulting mass-density of 1.06 g/cm³ (at room temperature) and Z_{eff}=7.46: C (64.086%); N (5.083%); H (9.379%); O (20.922%); Sn (0.011%); Br (0.518%) [13].

Plaque SimulatorTM was used to calculate the time needed to deliver a dose of 3 Gy to 5 mm depth. ROPES plaques loaded with model 6711 I-125 seeds were then placed over the hemispherical 3-D PRESAGE^m phantoms/dosimeters, and bound together using film wrap. The arrangement was then submerged in a water tank, in order to provide full scatter conditions, and left for the calculated treatment time. Experiments were repeated for each plaque configuration both with and without the stainless steel backing, in order to quantify its contribution to the central axis fluorescence signal.

Fluorescence intensities obtained with the 3-D PRESAGE^m dosimeters were read using a laser type confocal microscope as described elsewhere [14].

3. Results

3.1. ROPES Eye Plaques Dose Calculation Comparison

Figure 1 presents the calculated percentage difference in the central axis depth dose curves between Plaque SimulatorTM and RADCALC[®] for all ROPES plaque models. Agreement better than 2% between the two programs is observed for depths of 1 – 8 mm, except for the 18 mm diameter eye plaque (14 seed insert) at a depth of 1 mm.

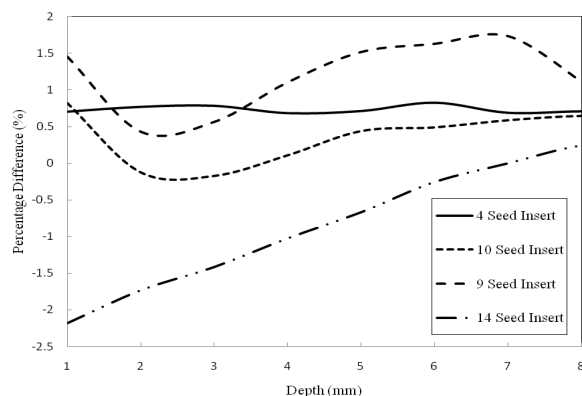


Figure 1: Percentage different between Plaque SimulatorTM and RADCALC[®] for ROPES eye plaque central axis depth dose curves.

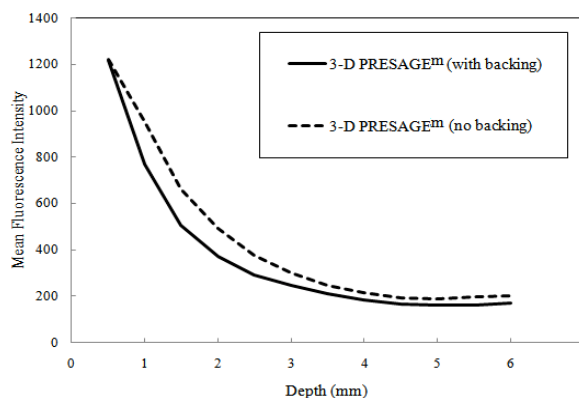


Figure 2: Central axis fluorescence intensity measurements for the 15 mm diameter (10 seeds insert) ROPES plaque.

3.2. 3-D PRESAGE^m Central Axis Measurements

Figure 2 shows the eye plaque central axis fluorescence intensity curves measured by the gel dosimeters for the 15 mm diameter plaque (10 seeds), both with and without the plaque stainless steel backing. The effect of the plaque backing is observed to result in a decrease in signal when compared to the measurements in which the plaque backing was removed, with a maximum difference of -25% occurring at 2 mm depth. The 10 mm plaque (4 seeds) resulted in similar signal decrease, with a maximum of -40% also occurring at 2 mm depth.

4. Discussion and Conclusion

The Plaque SimulatorTM eye plaque brachytherapy planning system was commissioned following TG43-UI data and formalism for use with ROPES eye plaques and Amersham Health model 6711 I-125 seeds. The 3D geometries for these plaques loaded with their I-125 seeds were simulated in the RADCALC[®] independent checking program to allow verification of the doses calculated by Plaque SimulatorTM. Central axis depth dose comparisons agreed to within 2% for all ROPES plaques seed configurations, except for the 18 mm diameter (14 seeds) eye plaque where a discrepancy of 2.2% is found at 1 mm depth. At this point, there is a superposition of a large number of sources at a short distance, corresponding to a region of large uncertainty in the dosimetric data. Further comparison of the two programs is planned in order to compare off-axis profiles at several depths of interest. Using these off-axis profiles, three-dimensional dose distributions can be obtained. Precise calculations of these dose distributions are necessary in order for Plaque SimulatorTM to accurately determine the dose to the sclera of the eye and other organs at risk (lens, macula, etc.).

Preliminary central axis fluorescence intensity curves have been measured using 3-D PRESAGE^m dosimeters. The effect of the eye plaque stainless steel backing on the shape of the curve was

investigated. The effect of the stainless steel plaque backing was observed to decrease the measured fluorescence intensity by up to 25% and 40% for the 15 mm and 10 mm diameter ROPES plaques respectively, and was not predicted by any of the dose calculation software systems that use water full scatter conditions. Granero et al. [9] have shown through Monte Carlo simulation, an average decrease in dose due to the stainless steel backing of the 15 mm diameter (4 seeds) eye plaque of 4%.

Future measurements using the 3-D PRESAGE[™] dosimeters should be performed with a calibration of the gels to correlate the fluorescence intensity with dose. Also, through read-out with optical CT, three-dimensional dose distributions measured by the gels can be obtained to compare with dose distributions produced by the Plaque Simulator[™] and RADCALC[®] programs. The effect of the plaque backing on the dose distribution can then be fully quantified, and eventually, this effect incorporated into the Plaque Simulator[™] planning system. Corrections for inhomogeneities associated with the plaque backing and seed holders are plaque specific, and must be fully quantified for more accurate dosimetry of treatments using ROPES eye plaques.

5. References

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