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STUDY OF ISODOSE CURVES OF AN EYE BRACHYTHERAPY PLAQUE

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ABSTRACT

The use eye plaque brachytherapy for intraocular tumors treatment is a process designed to protect healthy eye structures, as well as visual functions. It replaces enucleation when possible. The knowledge of the dose spatial distribution inside the eyeball and adjacent structures is very important to obtain the therapeutic dose, minimize the side effects and ensure efficiency in the process. Small variations in positioning the plaque on the ocular surface may generate a less effective treatment. Thus, in this work an eyeball phantom and a seed accommodation system similar to a commercially eye plaque model ROPES with diameter of 15 mm, were developed both in solid water Gammex 457 to conduct the study of the possible variation in the dose deposition inside the eye phantom. Radiochromic films were used to record isodose curves of two orthogonal plans within the simulator. The results showed that there is a difference in the dose deposition for the two orthogonal plans studied. This difference is 8.33% higher for the maximum dose value. Thus, a difference in dose that occurs due to the asymmetrical distribution of seeds on the eye plaque may interfere with the treatment, making it less effective.

Keywords: ocular brachytherapy, eye plaque, radiochromic film

1. INTRODUCTION

Eye cancers can generate losses in the visual functions of individuals affected with these diseases when are not fatal. The choroidal melanoma is the most common type of intraocular tumor among adults while retinoblastoma is the most common among children under five. The enucleation, which is the complete removal of the eyeball, is the type of treatment best suited for large tumors. For medium and small tumors preservation of eye structures can be done by using other treatments than enucleation. Radiotherapy may be used, as long as the stage and type of tumor permit its local control [1].

Due to high doses in healthy structures near the irradiated region, external beam radiotherapy (teletherapy) has been replaced by brachytherapy processes that generate a higher concentration of the dose in the tumor region, providing more satisfactory clinical responses.

Radioactive seeds of radon have been used for the treatment of choroidal melanoma in the early 1930s [2]. Since then several radionuclides have been used for the treatment of choroidal melanomas among them: iodine-125, palladium-103, cesium-137, cobalt-60, iridium-192, gold-198, strontium-90 and ruthenium / rhodium-106 [3]. Recently, iodine-125 and palladium-103 stand out as X and gamma photons emitters. The reason for this prominence is that the energy of the photon released by the radioactive seeds with these elements is low; approximately 29 keV for iodine-125 and 23 keV for palladium-103 and this feature makes the majority of the released energy be deposited close to the seeds containing such radionuclides. As brachytherapy seeds can radiate over a long enough time, a high dose is deposited in the region to be treated while the surrounding healthy tissues are preserved [1, 4, 5].

Eye brachytherapy is made with the aid of eye plaques, for example, the ones produced by ROPES group [5, 6] in which radioactive seeds are accommodated. These eye plaques can be loaded with iodine-125 or palladium-103 seeds [4, 6, 7].

The knowledge of the dose distribution within the eyeball in the planning and treatment of tumors using such plaques is of utmost importance for effective treatment. This dose distribution depends among other things on the radioisotope, on the plaque diameter, on the configuration of the seeds in its interior and also on the maximum number of seeds that can be accommodated in the plaque. In this work, an eye bulb and a seed accommodation system similar to the 15 mm diameter ROPES eye plaque, both of solid water (457 Gammex), were planned and developed to study possible differences of dose deposition of two perpendicular positions of the seed accommodation system next to the eye bulb.

2. Materials e Methods

For this work were developed one eyeball simulator device and a radioactive seeds accommodation system corresponding to the ROPES commercial plaque of 15 mm in diameter. To obtain the isodose curves within the eyeball simulator a radiochromic film gafchromic XRQA2 was used.

2.1. Eyeball simulator

A spherical eyeball phantom with 25 mm diameter, the standard size of a human adult eye, has been machined in solid water Gamex 457 with density of 1.04 g.cm^{-3}. This material simulates water allowing calculations of attenuation, absorption and scattering of radiation for a wide range of energies. The simulator consists of two hemispheres, as shown in Fig. 1.

Figure 1: Image of solid water hemispheres.

2.2. Development of systems to accommodate the eye phantom and the iodine-125 seeds

A system to accommodate the brachytherapy seeds which allow allocating the seeds in positions corresponding to the ROPES plaque of 15 mm was also machined in solid water. Commercial plaques, as they have to be placed in contact with the eye, have the spherical cap format. In this work, the system will have a different format, as in this work there is no need of shielding or to be inserted into the eye socket. Therefore, only the inner spherical shape and the distribution of the seeds in plaques are faithful to the commercial model. An image of the system is shown in Fig. 2a and the commercial model is shown in Fig. 2b.

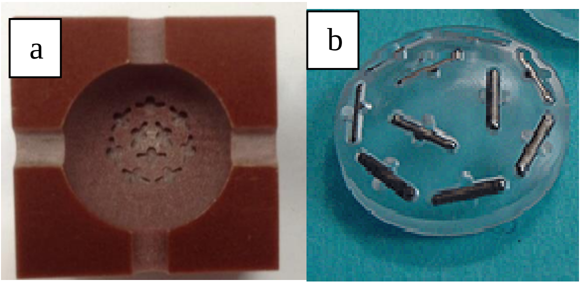

Figure 2a: System in solid water for Iodine-125 seeds accommodation. In 2b, ROPES commercial plaque.

To arrange the eyeball simulator in the seed accommodation system, cylindrical grooves were machined in orthogonal positions and in each of the hemispheres cylindrical rods were made, as can be seen in Figs. 1 and 2a, to allow the engagement between the phantom bulb and the seeds accommodation system.

2.3. Radiochromic films

The type of radiochromic film used in this study was GAFCHROMIC XRQA2 manufactured by International Specialty Products.

The X-rays quality used for calibration of radiochromic films was the RQR 3 of 61267 standards IEC (International Electrotechnical Commission). This radiation was selected because the average energy of the X-ray beam is 27.2 keV, very close to 29.0 keV, which is the energy emitted by iodine-125 seeds. For calibration, the films were cut into strips with dimensions of 3 cm x 10 cm, positioned at one meter from the X-ray PANTAK SEIFERT Model ISOVOLT 320HS with the aid of a 40 x 40 x 4 cm^3 Styrofoam plaque. The films were irradiated with doses between 0.25 cGy to 18.0 cGy.

After deposition of the desired dose on each strip, they were scanned in reflection mode, using a scanner HP Scanjet G4050. It was obeyed a minimum of 24 hours between irradiation and scanning. An image of the color of the strips after scanning is shown in Fig. 3. After the scanning the image colors were separated into RGB with the software ImageJ from the National Institute of health. Only the red component intensity, which has higher sensitivity calibration, was used and related to the deposited dose [8].

Figure 3: Darkening degree sequence of the strips after irradiation with the following doses: 0 (non-irradiated); 0.25; 0.50; 1.00; 2.00; 5.00; 10.0; 12.0; 15.0 and 18.0 cGy.

The calibration curve was constructed using Origin 7.5 software and is shown in Fig. 4.

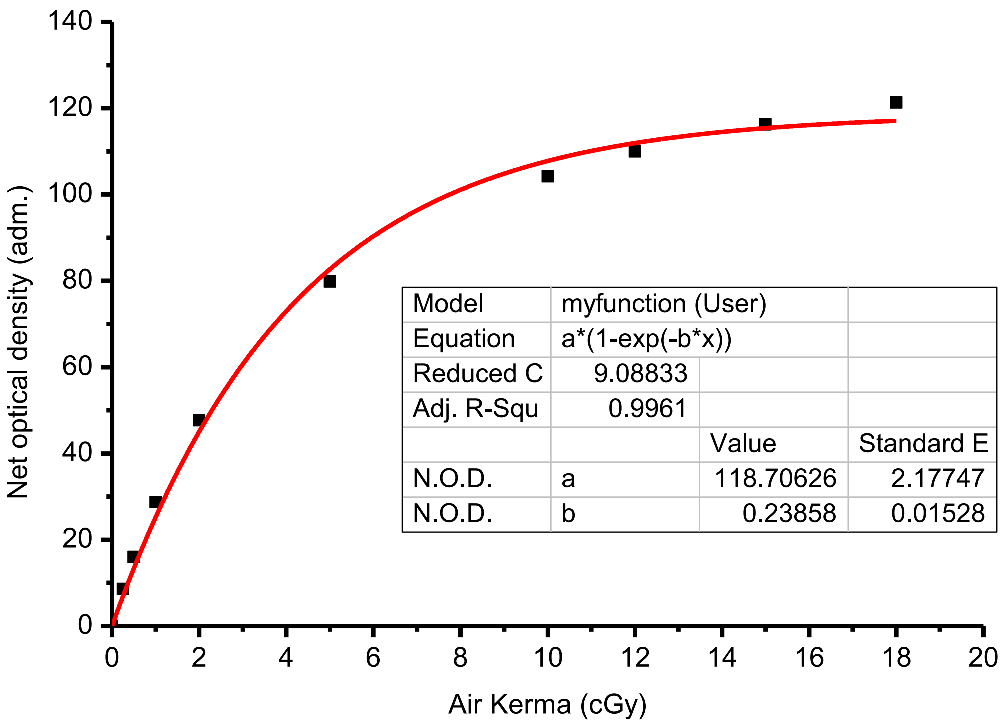

Figure 4: Radiochromic film calibration curve.

2.4 Experimental Procedures

The ten 125-Iodine seeds model 6711 from Amersham used in this work were donated by IPEN/CNEN.

To the survey of the doses inside the eye phantom a piece of the film in circular shape was positioned between the two hemispheres and these were embedded in the seeds system. Fig. 5 shows an image of the films used for dose measurements inside the bulb and for the background.

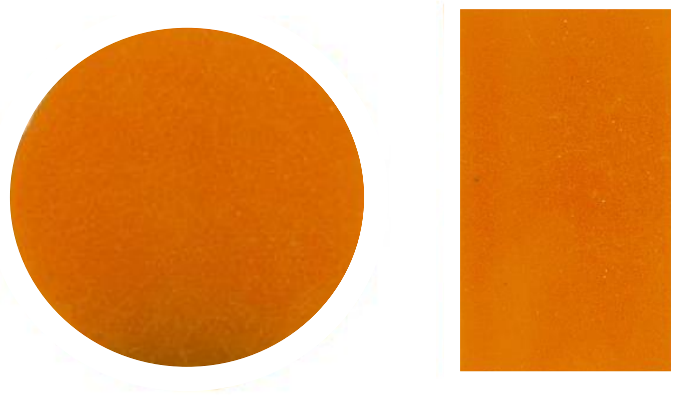

Figure 5: Image of the irradiated film (circle) and of the one to measure the background (rectangular).

As the measures with the films were made in solid water, and their calibration was held in air, to convert air kerma to absorbed dose in water a constant k was used, obtained by equation 1.

$$k = \frac{\left(\frac{\mu}{\rho}\right)_{water}}{\left(\frac{\mu}{\rho}\right)_{air}} \qquad (1)$$

where μ is the linear attenuation coefficient and ρ is the density of the material. The value of (μ/ρ) for water is 0.1186 $cm^2.g^{-1}$ and for air is 0.1060 $cm^2.g^{-1}$ for an energy of 30 keV. So the value for constant k was 1.112. [9]

3. RESULTS

A dosimetric survey of the seed accommodation system similar to the ROPES plaque of 15 mm diameter was conducted. Measurements were made for two mutually perpendicular planes: XZ and YZ. The doses in cGy for the experiments using the radiochromic film are shown in Figs.6 and 7.

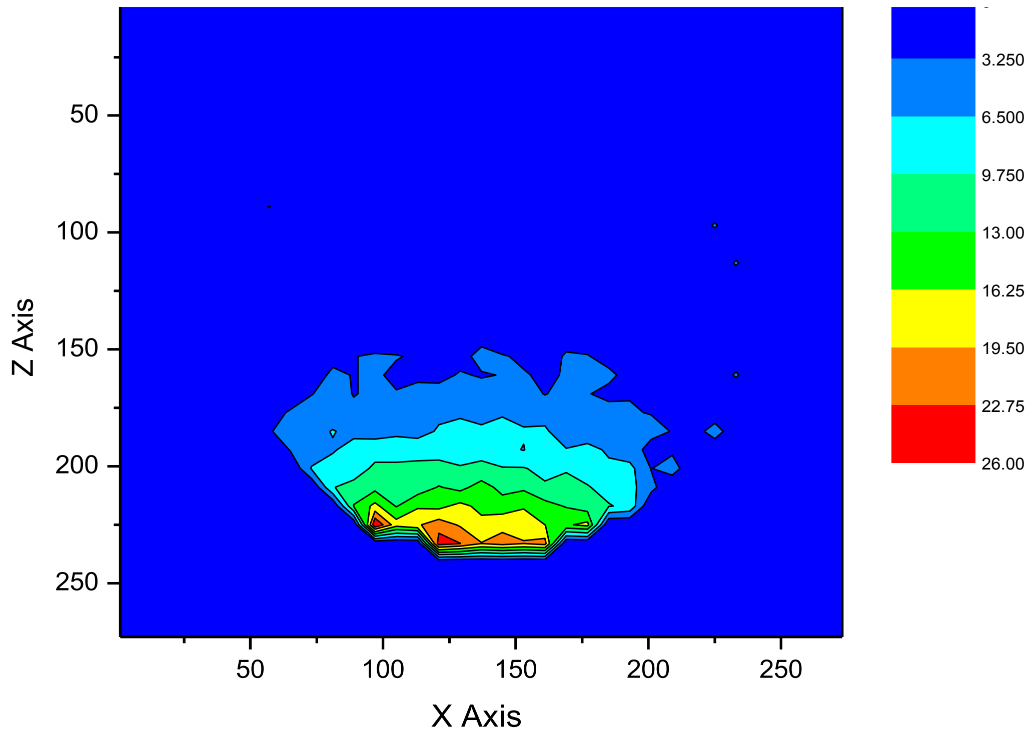

Figure 6: Obtained doses to the XZ plane (in cGy).

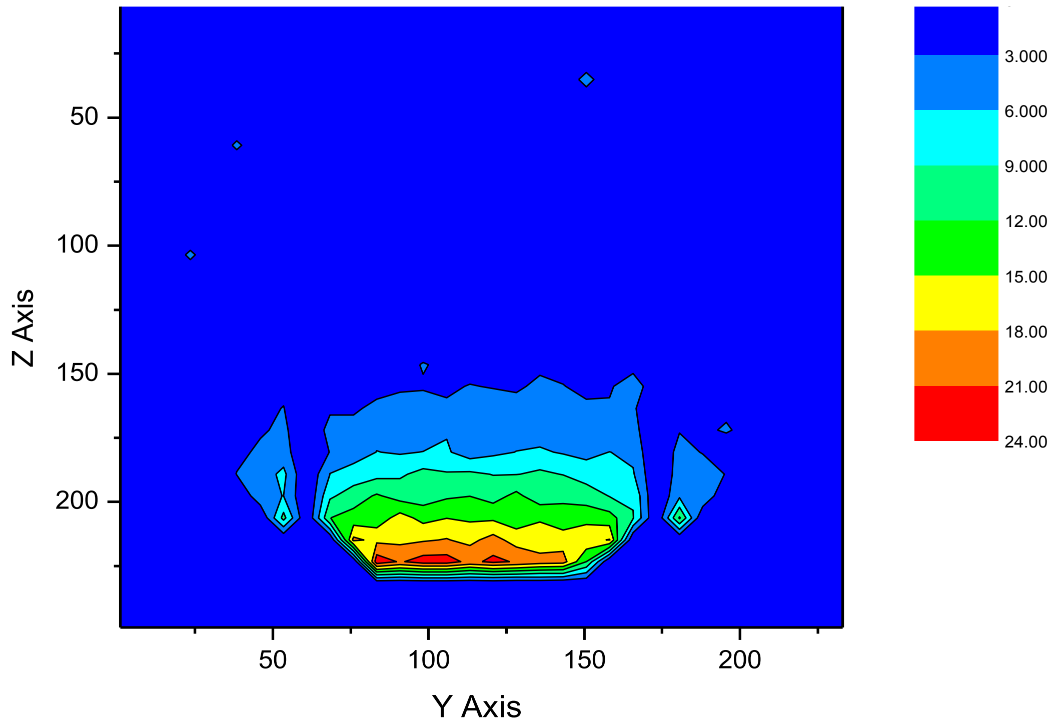

Figure 7: Obtained doses to the YZ plane (in cGy).

Comparing the doses in Fig. 6 and 7, it can be seen that they differ for all regions. In the regions of maximum dose (areas in red), the first experiment showed doses 8.33% greater than the second experiment.

4. CONCLUSIONS

It was found that the asymmetry in the seed accommodation system causes a difference in dose distribution in the tissue being treated. Therefore, small change in positioning the plaque in the ocular surface can promote differences in dose deposition. These differences become important when it is necessary to obtain the therapeutic dose for the tumor volume.

The eye brachytherapy is indicated for tumors within 10 mm in height and base diameter smaller or equal to 16 mm. The ICRU recommends that the dose in patient do not differentiate more than 5% of the prescribed dose [10]. As the eye has structures sensitive to radiation near the area to be treated, it is of fundamental importance that the planned dose is sufficient to eliminate cancer cells minimizing possible damage in healthy structures. Therefore, any differences between the planned dose and the dose administered to the patient may mean healing or not with damage to healthy tissue. Thus, a difference in the dose that occurs due to the asymmetric distribution of the seeds may interfere with treatment, making it less effective.

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