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A comprehensive dosimetric comparison between ^{131}Cs and ^{125}I brachytherapy sources for COMS eye plaque implant

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ABSTRACT

PURPOSE: To verify the dosimetric characteristics of ^{131}Cs source in the Collaborative Ocular Melanoma Study (COMS) eye plaque brachytherapy, to compare ^{131}Cs with ^{125}I in a sample implant, and to examine the accuracy of treatment planning system in dose calculation.

METHODS AND MATERIALS: Monte Carlo (MC) technique was used to generate three-dimensional dose distributions of a 16-mm COMS eye plaque loaded with ^{131}Cs and ^{125}I brachytherapy sources separately. A spherical eyeball, 24.6 mm in diameter, and an ellipsoidal tumor, 6 mm in height and 12 mm in diameter, were used to evaluate the doses delivered. The simulations were carried out both with and without the gold and gold alloy plaque. A water-equivalent seed carrier was used instead of the silastic insert designed for the traditional COMS eye plaque. The 13 sources involved were also individually simulated to evaluate the intersource effect. In addition, a treatment planning system was used to calculate the doses at the central axis for comparison with MC data.

RESULTS: The gold plaque had significantly reduced the dose in the tumor volume; at the prescription point of this study, that is, 6 mm from the edge of inner sclera, the gold plaque reduced the dose by about 7% for both types of ^{131}Cs and ^{125}I sources, but the gold alloy plaque reduced the dose only by 4% for both types of sources. The intersource effect reduced the dose by 2% for both types of sources. At the same prescription dose, the treatment with the gold plaque applicator tended to create more hot regions for either type of sources than were seen with the homogeneous water phantom. The doses of TPS agree with the MC.

CONCLUSION: The ^{131}Cs source is comparable to the ^{125}I source in the eye plaque brachytherapy. The TPS can provide accurate dose calculations for eye plaque implants with either type of sources.

Keywords: Brachytherapy; ^{131}Cs; ^{125}I; COMS eye plaque; MCNPX

Introduction

Eye plaque brachytherapy is a well-proven and recognized treatment technique in the management of intraocular malignant tumors (1–5). Eye plaque brachytherapy has been reported as successful in controlling ocular tumors (4) and to have an outcome similar to that of surgical enucleation for the medium-size and early-stage tumors (3, 4). Therefore, this therapy is always considered as an important option for treatment of ocular melanoma. Twenty years ago, the National Eye Institute launched the Collaborative Ocular Melanoma Study (COMS), and a set of COMS eye plaques were developed along with a set of treatment recommendations. Although in principle, any type of eye plaque could be used if the treatment goals could be achieved, the COMS eye

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plaques have become most popular for both their standardization and convenience. Currently, although other types of eye plaques are available (6, 7), the COMS eye plaque design is the most popular type used in eye brachytherapy (8). It is currently available in seven standard sizes, with diameters ranging from 10 to 22 mm in 2-mm increments. The COMS plaque is a portion of a spherical shell 0.5-mm thick with cylindrical collimating rim (8). The gold alloy used in the COMS plaque is 77% gold, 14% silver, 8% copper, and 1% palladium by weight (8, 9). The seeds are loaded in molded troughs of a silastic seed carrier insert that fits snugly in the concave aspect of the plaque. A 16-mm COMS plaque is shown in Fig. 1. For this case, 13 brachytherapy seeds of equal source strength would be placed to treat ocular tumors ranging from 10 to 12 mm in diameter, in compliance with the COMS' recommendation that a tumor-free margin of 2–3 mm should be maintained. A detailed description of the COMS eye plaques has been published elsewhere (8).

Since the advent of COMS eye plaques, many studies have been conducted to evaluate the dosimetry of different sources and the impact of eye plaques on the prescription dose (9–12). In the conventional COMS eye plaque brachytherapy, inhomogeneity was introduced by both the gold plaque itself and the silastic seed carrier. Chiu-Tsao *et al.* (10). first studied the impact of the silastic carrier and the gold plaque using Monte Carlo (MC) technique and thermoluminescent dosimeters (TLD). Later, de la Zerda *et al.* (11) also measured the dose distribution with TLDs. All studies showed that the silastic carrier and the gold plaque could reduce the dose by up to 10% at a depth of 1.0 cm on the plaque axis compared with a homogeneous water medium. Recently, Astrahan *et al.* (9) reported that, for ^{125}I sources, use of the silastic carrier results in a dose reduction of at least 10% in the vicinity of the tumor apex where the dose is usually prescribed, compared with the dose measured in water, and greater than 10% at the base of the tumor and adjacent retina where the dose is closely watched. In another study, Astrahan *et al.* (13) suggested that the silastic seed carrier insert is not a good choice, because it not only reduces doses at the points of interest but also creates a set of additional difficulties, such as handling the silastic insert with forceps behind an L-block, disassembling and sterilization of the eye plaque set, and others. According to Astrahan *et al.*, a water-equivalent seed carrier is dosimetrically desirable, but a thin, gold alloy, seed guide insert would make the job of handling and sterilizing eye plaque set easier.

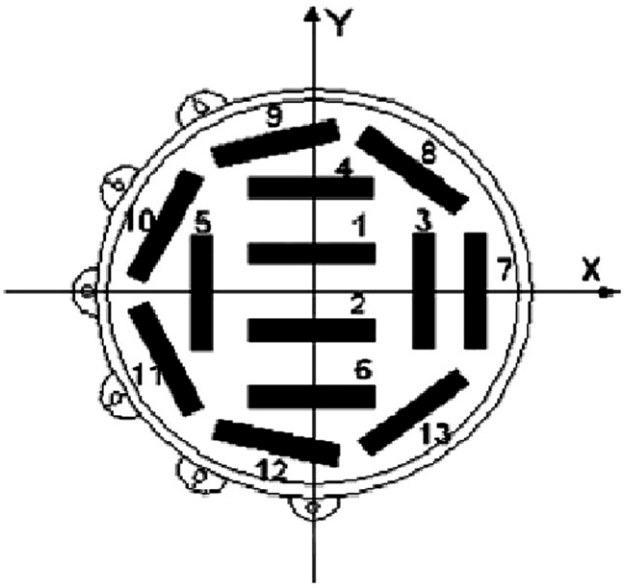

Fig. 1. Schematic diagram of a 16-mm eye plaque applicator with 13 seeds used in calculations (8).

Based on these studies, ^{125}I and ^{103}Pd sources have been reported to be suitable for the eye plaque brachytherapy, although other sources, such as ^{106}Ru, ^{60}Co, and ^{90}Sr, were also not ruled out (14, 15). The model CS-1 ^{131}Cs source (IsoRay Inc., Richland, Washington, DC) is a relatively new type of brachytherapy source that recently received Food and Drug Agency approval (16). In brachytherapy, interest in the ^{131}Cs source and its potential biologic effects has increased, because its average energy (30.4 keV) is only slightly higher than that of ^{125}I (28 keV), but it has a substantially shorter half-life (9.7 days) than ^{125}I (60 days). Although the CS-1 source has been used in prostate implants, its applicability in the eye plaque brachytherapy has not been fully explored. Recently, Melhus and Rivard (17) simulated the COMS eye plaque dosimetry of the model 200 ^{103}Pd, model 6711 ^{125}I, and model CS-1 ^{131}Cs sources using the Monte Carlo N-particle transport code version 5 (MCNP5) MC code and compared the doses along the central axis of eye plaque applicators using these sources. They reported a notable dose reduction by the gold eye plaque at the prescription point for all of these sources compared with the dose calculations in homogeneous water phantom (17). However, for eye plaque brachytherapy, although the doses at the eye plaque axis are important, other issues, such as the dose–volume histograms (DVHs) for the clinical target and eyeball volumes, and the accuracy of the treatment planning system (TPS) using the task group first update (TG43U1) approximations of single-source data, are equally important and have not been studied. Therefore, the main objectives of this project were as follows: to use Monte Carlo N-particle transport code extension (MCNPX) MC simulation to determine the dosimetric characteristics of the ^{131}Cs sources in the COMS eye plaque; to verify the gold plaque dose modification effect on the prescription dose; and to determine the effect of the ^{131}Cs sources on the DVHs as compared with that of the ^{125}I sources. The potential clinical consequences introduced by dosimetric difference motivated this study as well. The DVHs of the tumor and eyeball obtained from the MC simulations with and without the gold plaque applicator will provide a clinically relevant comparison of treatments using these two types of sources. The accuracy of the