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# The effects of variations in the density and composition of eye materials on ophthalmic brachytherapy dosimetry

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ABSTRACT

In ophthalmic brachytherapy dosimetry, it is common to consider the water phantom as human eye anatomy. However, for better clinical analysis, there is a need for the dose determination in different parts of the eye. In this work, a full human eye is simulated with MCNP-4C code by considering all parts of the eye, *i.e.*, the lens, cornea, retina, choroid, sclera, anterior chamber, optic nerve, and bulk of the eye comprising vitreous body and tumor. The average dose in different parts of this full model of the human eye is determined and the results are compared with the dose calculated in water phantom. The central axes depth dose and the dose in whole of the tumor for these 2 simulated eye models are calculated as well, and the results are compared.



## Introduction

As an intraocular cancer, the choroidal melanoma can be considered the most common cancer for adults. About 5% of all melanomas arise from the ocular and adnexal structures, and the majority (85%) of ocular melanoma is uveal in origin.[1] Until the 1980s, the removal of the eye by enucleation was the standard treatment of choroidal melanoma. Although enucleation has been the traditional method of treatment, there is a trend toward radiotherapy at present.[2] Among the various forms of radiotherapy, such as helium ion radiotherapy,[3] proton beam radiotherapy, and stereotactic radiotherapy,[4] brachytherapy using radioactive plaques is most widely used.[5]

Brachytherapy using ophthalmic plaque is a term used to describe the short-distance treatment of cancer with radiation from small, encapsulated radionuclide sources. Plaque-based brachytherapy permits higher tumor doses with greater sparing of noninvolved tissues compared with x-ray teletherapy. Also the plaque therapy is more accessible and less expensive, time-consuming, and labor-intensive than heavy-charged particle therapy. This method has shown to be a good alternative to enucleation for the treatment of eye tumor.[6,7]

In the mid-1980s, the Collaborative Ocular Melanoma Study (COMS) commenced a randomized survey on patients for comparing the efficacy of plaque brachytherapy for moderately large tumors (3–8-mm height) *vs.* enucleation.[8] In 2001, and subsequently in 2006, after enough long-term tracking of patients, it was reported by the COMS group that the survival rates for the 2 treatments were the same.[9,10]

Currently, making use of artificial radioactive element like $^{137}$Cs, $^{197}$Ir, $^{198}$Au, and $^{125}$I is rapidly increasing. These radioactive materials with different shapes and structures have been the objective of clinical studies to provide minimum irradiation to healthy tissues while delivering maximum doses to the tumor.[11]

In general, the ophthalmic plaques fall into 2 categories: (1) the ophthalmic applicators with relatively long-lived isotopes like $^{60}$Co and $^{106}$Ru, and (2) the sealed radioisotope sources that are temporarily inserted (*e.g.*, $^{192}$Ir and $^{125}$I).

Among many different plaque models, the plaques adhering to standards design must be used corresponding to the COMS protocol. These standardized plaques consist of a dome-shaped gold alloy backing and the brachytherapy seeds in the positions of silicon polymer carrier.[12]

In the past decades, several investigations have been done in the human eye dosimetry. In some of these works, Monte Carlo methods have been used to study dosimetry for different eye plaques brachytherapy. The codes like MCNP-4C, EGSnrc, Geant4, *etc.*, have been used in some studies.[13–16] In the majority of these simulations, the eye plaque is modeled at the center of a cubic water phantom, with 30 $\times$ 30 $\times$ 30-cm$^3$ dimensions and 0.998 g/cm$^3$ mass density. This modeled eye plaque indicates that in these simulations the water phantom is defined as human eye globe and the eye components and densities are replaced by the water.

However, the elemental compositions and densities of eye materials vary in the different parts of the human eye.[16] A full investigation of the effects of variations in the density and composition of eye materials needs a full model of the human eye. In this work, the human

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