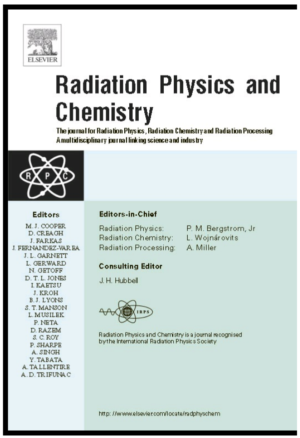

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Effect of elemental compositions on Monte Carlo dose calculations in proton therapy of eye tumors

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Recent studies in eye plaque brachytherapy have found considerable differences between the dosimetric results by using a water phantom, and a complete human eye model. Since the eye continues to be simulated as water-equivalent tissue in the proton therapy literature, a similar study for investigating such a difference in treating eye tumors by protons is indispensable. The present study inquires into this effect in proton therapy utilizing Monte Carlo simulations.

A three-dimensional eye model with elemental compositions is simulated and used to examine the dose deposition to the phantom. The beam is planned to pass through a designed beam line to moderate the protons to the desired energies for ocular treatments. The results are compared with similar irradiation to a water phantom, as well as to a material with uniform density throughout the whole volume. Spread-out Bragg peaks (SOBP) are created by adding pristine peaks to cover a typical tumor volume. Moreover, the corresponding beam parameters recommended by the ICRU are calculated, and the isodose curves are computed. The results show that the maximum dose deposited in ocular media is approximately 5-7% more than in the water phantom, and about 1-1.5% less than in the homogenized material of density 1.05 gr.cm^{-3}. Furthermore, there is about a 0.2 mm shift in the Bragg peak due to the tissue composition difference between the models. It is found that using the weighted dose profiles optimized in a water phantom for the realistic eye model leads to a small disturbance of the SOBP plateau dose.

In spite of the plaque brachytherapy results for treatment of eye tumors, it is found that the differences between the simplified models presented in this work, especially the phantom containing the homogenized material, are not clinically significant in proton therapy. Taking into account the intrinsic uncertainty of the patient dose calculation for protons, and practical problems corresponding to applying patient-specific eye modeling, we found that the results of using a generic phantom containing homogenized material for proton therapy of eye tumors can be satisfactory for designing the beam.

Keywords: Proton therapy, Bragg curve, SOBP, Simulation, Eye phantom, Uveal melanoma

I. INTRODUCTION

Uveal melanoma is the most common primary intraocular malignant tumor, causing visual impairment, loss of eye, and eventually metastatic disease [1]. Nowadays, enucleation has been supplanted by radiotherapy as the standard method of care for patients with uveal melanoma. External beam radiotherapy with heavy charged particles [2–4] and eye plaque brachytherapy [5–7] are two modalities of radiation therapy employed frequently for treating such tumors.

The main goal in choosing the most appropriate method for therapy is achievement of high radiation dose deposition in the tumor while sparing the surrounding healthy tissue as much as possible. Among the several available radiotherapy methods for treating tumors, proton therapy provides the ideal physical properties to deliver a precise and homogeneous dose distribution within the target volume, with preservation of sensitive normal tissues due to the distal fall-off of the dose beyond the spread-out Bragg peak, SOBP, and to the sharp lateral fall-off of the dose. Excellent discussions of proton therapy and heavy charged particles have been reviewed at length in the literature [8–10].

There are a large number of proton therapy facilities in operation worldwide, and more are currently under construction or planning [11]. This method is widely used for treatment of uveal melanoma. Proton beams for ocular tumor treatments require energy of about 70 MeV. In a proton-beam irradiation arrangement for the treatment of these tumors, patients are commonly treated in the seated position, and a facemask is used for immobilization. The eye is fixated on an external light source that can be adjusted to control the direction of the gaze during the treatment [12]. Typical treatment techniques and set-ups for treatment of ocular melanoma have been presented by Paganetti [13] and Munzenrider [14], and the results of proton therapy of these tumors in different centers can be found elsewhere [15–18].

After three decades of experience, the techniques used for treating uveal melanoma with proton therapy are well understood [19, 20], and recent research has focused on improving the dosimetric accuracy of these treatments. It is clear that accurate description of tumors and surrounding organs at risk is vital for proton therapy. In the special case of ocular tumors, treatment planning is commonly performed with the EYEPLAN program, de-

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