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Determination of the depth dose distribution of proton beam using PRESAGE™ dosimeter

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Abstract

PRESAGE™ dosimeter dosimeter has been proved useful for 3D dosimetry in conventional photon therapy and IMRT [1–5]. Our objective is to examine the use of PRESAGE™ dosimeter for verification of depth dose distribution in proton beam therapy. Three PRESAGE™ samples were irradiated with a 79 MeV un-modulated proton beam. Percent depth dose profile measured from the PRESAGE™ dosimeter is compared with data obtained in a water phantom using a parallel plate Advanced Markus chamber. The Bragg-peak position determined from the PRESAGE™ is within 2 mm compared to measurements in water. PRESAGE™ shows a highly linear response to proton dose. However, PRESAGE™ also reveals an underdosage around the Bragg peak position due to LET effects. Depth scaling factor and quenching correction factor need further investigation. Our initial result shows that PRESAGE™ has promising dosimetric characteristics that could be suitable for proton beam dosimetry.

1. Introduction

Proton beam therapy is changing the landscape of cancer patient care with promising results in many sites due to its unique physical characteristics. Proton beam commissioning is labor intensive and requires validation from several dosimetric systems. Depth dose measurements are performed for beam commissioning and patient specific field measurements in proton therapy. There is a need for a simple and convenient method for verifying depth dose profiles in proton beam therapy, especially for treating small tumor volumes at shallow depths. Ion chambers are most reliable [6], but film [7], MOSFET [8] and optically stimulated luminescent detector (OSLD) [9] have been advocated. A recent study shows that BANG3 polymer gel is capable of reproducing ion chamber dose data for modulated and un-modulated Bragg peak beams with different clinical beam energies [10]. Using PRESAGE™ and optical CT scanner for proton beam dosimetry was initially studied by Doran et al [11]. In this work, we have now extended these studies to include a comparison between PRESAGE™ dosimeter and ion chamber.

2. Methods and Materials

Three 8 cm diameter cylindrical shaped PRESAGE™ samples with a length of 6 cm were irradiated at 300 MU, 500 MU and 1000 MU respectively using un-modulated proton beams from the passive scattering beam delivery system at the Midwest Proton Radiotherapy Institute in Bloomington, Indiana. The beam energy was chosen in a way so that the proton beam stopped in the samples. The long axis of the dosimeter was placed along the beam central axis. A circular 10 cm in diameter aperture was used. To avoid light sensitivity, dosimeters were wrapped and kept in light tight plastic during exposure and shipment for optical readout measurement. For comparison, an advanced Markus parallel-plate ionization chamber (PTW-Freiburg GmbH, Freiburg, Germany) was placed in a Wellhofer scanning WP700 water tank for depth dose measurements (data at depth less than 2 cm was discarded due to front wall thickness offset). The PRESAGE™ dosimeter was scanned with 1 mm increment over the entire length by an optical-CT scanning system [1] to determine the percent depth dose distribution.

3. Results and Discussions

Figure 1 shows a comparison of measured data from PRESAGE™ samples showing signal attenuation coefficients along the central axis indicating radiation dose response. Figure 2 shows a highly linear dose response of PRESAGE™. The comparison of percent depth dose curves after normalizing data to the depth 2 cm is shown in Figure 3. PRESAGE™ showed an under-response in the Bragg peak compared to ion chamber. The peak-to-plateau dose ratio (the ratio of the dose at the peak of the Bragg peak to that at near-zero depth) obtained from PRESAGE™ samples was 2.34 which was about 13% less than the peak-to-plateau dose ratio registered from ionization chamber measurement in water (2.69). This linear energy transfer (LET) quenching effect is similar to what have been reported from Gafchromic EBT film dosimetry in proton beam [7] and BANG gel dosimetry in proton beam [12].

4. Conclusions

PRESAGE™ dosimeter has unique characteristics that could be utilized for proton beam therapy. Our measurements in proton therapy are promising and show potential for clinical use especially for small fields. However, to achieve a clinically-acceptable level of accuracy, depth scaling factor as a function of proton energy and quenching correction factor will be subjected to further investigation.

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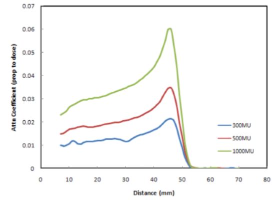

Figure 1.
Comparison of measured attenuation coefficients along the central axis of PRESAGE™ samples indicating radiation dose response.

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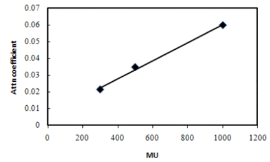

Figure 2.
The relationship between optical response from PRESAGE™ samples and dose monitor units.

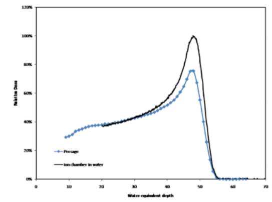

Figure 3.
Percent depth dose curves obtained from PRESAGE™ and ionization chamber measurements in water.