Investigation of photon and proton overlapping fields in PRESAGE® dosimeters

THE UNIVERSITY OF TEXAS MD Anderson Cancer Center

Mitchell Carroll, G. Ibbott, R. Grant, M. Gillin, J. Adamovics

Department of Radiation Physics

The University of Texas, M.D. Anderson Cancer Center, Houston, TX 77030

Purpose: As radiotherapy techniques become more advanced, researchers have been extensively studying three-dimensional dosimeters as an alternative to current methods in order to more accurately characterize the dose profiles. A new, solid radiochromic dosimeter called PRESAGE® by Heuris Pharma, LLC was developed as an alternative to polymer gels. It is an optically clear polyurethane matrix containing the leuco dye leucomalachite green whose reaction to free radicals can be measured by optical CT scanning [1]. Like polymer gels, it is nearly radiologically water equivalent in photon beams [2] while requiring some correction factor when irradiated by protons.

In previous studies, PRESAGE® dosimeters have been evaluated in open beams [3, 4]. With the introduction of stereotactic radiosurgery (SRS), intensity modulated radiotherapy (IMRT), and other advanced treatments, these dosimeters have been tested for three-dimensional verification [5]. Additional studies have been conducted to determine temperature, dose rate, and dose sensitivity [6, 7]. In order to fully assess their quality for clinical verification purposes of radiotherapy treatments with several beam segments, this study was implemented to evaluate the dose integration of overlapping dose volumes. Two formulations of PRESAGE® were used: one intended for, and irradiated with, proton beams and the other photon beams.

Materials/Methods: Cylindrical PRESAGE® dosimeters approximately 9 cm in height and 6 cm in diameter were used in this study and are shown in **Figure 1**. Photon irradiations were performed on Varian 2100 series linacs at the University of Texas M. D. Anderson Cancer Center in Houston, Texas using 6 MV open beams. Field sizes ranged from 3x3 cm^2 to 5x5cm^2 depending on field setup relative to dosimeter size. The dosimeter was irradiated using table-top conditions to a dose at d_{max} consistent across all dosimeters. The proton dosimeter irradiations were performed at the M. D. Anderson Proton Therapy Center (PTC). These were irradiated using a fixed gantry with a 4x4 cm^2 field size and 200 MeV beam in a water tank at approximately 15.8 cm surface-to-dosimeter distance. A spread-out Bragg peak (SOBP) of 3 cm was delivered approximately 6 cm into the dosimeter in order to fully capture all relevant dose regions. All irradiations were delivered through normal incidence to the flat top surface rather than the curved sides to reduce dose profile inhomogeneities.

For each treatment modality (photon, proton), two overlapping field setups were performed. These included a stationary dosimeter irradiated over six fractions and a dosimeter shifted laterally to the field to deliver a dose plateau in two fractions. All subsequent fractions were given within ten minutes and never less than one minute apart to simulated a lengthy clinical treatment delivery. Two dosimeters were irradiated for each setup. The dosimeters were paired, with one dosimeter given total dose by a single fraction while the other followed one of the overlapping field setups. The dosimeters were analyzed using the Duke Medium field-of-view Optical CT Scanner (DMOS) 24 hours after irradiation and exported to the Computational Environment for Radiotherapy Research (CERR) software platform where the doses were compared between paired dosimeters. Dose profiles were taken parallel to the beam path for all setups. Additionally, cross dose profiles of the of the dose plateau studies were taken.

Figure 1. A PRESAGE® dosimeter formulated for high-LET dosimetry.

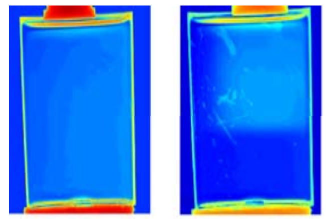

Figure 2. Image of a single PRESAGE® dosimeter prior to irradiation (left) and 24 hours after irradiation by a proton beam (right). Images taken from the DMOS reconstruction software.

Results: Paired dosimeter agreement was determined by the dose variations along the central axis to the overlapped irradiated fields of the fractionated and dose plateau field setups. Because of inconsistencies in dosimeter sizes between pairs and data lost at the edges of the dosimeters, spatial agreement between dose profiles was corrected for by matching distal ends of those irradiated with protons and the linear fit of the falloff after d_{max} of those irradiated with photons.

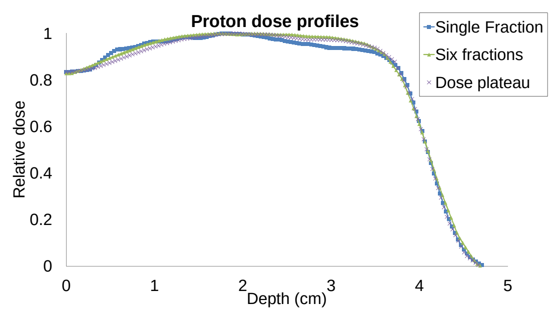

Figure 3. Relative dose profiles of the proton formulation of PRESAGE® showing agreement between single and multiple fraction irradiations from the proximal through the distal regions.

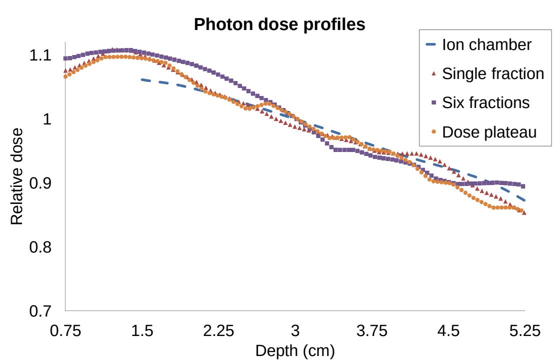

Figure 4. Relative dose profiles of photon formulation of PRESAGE® showing the agreement between single fractions, multiple fractions, and ion chamber data in the dose peak region.

Results continued:

Dose profile comparisons showed relative dose agreement between paired dosimeters within 5% along the SOBP region of the proton formulation as shown in **Figure 3**. Both of the sequential dose irradiations showed an under-response in the proximal region and an over-response in the distal side of the SOBP relative to the single fraction irradiation. Dose agreement between the photon dosimeters treated with sequential doses also over-responded by as much as 8% relative to the single fraction irradiation with the largest discrepancies near d_{max}. Additionally, cross-beam dose plateau profiles further characterized the change in recorded dose between the overlapping volume and the integration of the sequential fields as illustrated in **Figure 5** and **Table 1**.

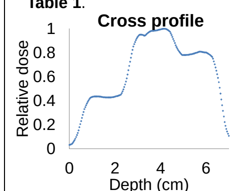

Figure 5. Cross profile of overlapping fields (100 and 200 cGy) treated with photons.

	Dose (cGy)	Average relative dose	Stdv
Photon	100.00	0.43	0.01
	200.00	0.79	0.01
	Plateau (300)	0.98	0.02
Proton	100.00	0.40	0.00
	200.00	0.72	0.00
	Plateau (300)	0.96	0.02

Table 1. Averaged relative doses taken over each dose plateau along the cross profile of overlapping fields.

Discussion: The proton formulation of PRESAGE® showed good dose agreement between single and overlapping field irradiations. Dose volumes treated with sequential beams, primarily in the distal end of the SOBP, actually resulted in dose profiles more consistent with expected results. The photon formulation had slightly less agreement, while the sequential field irradiations again showed a closer agreement with ion chamber data. Repetition of the dose plateau irradiations to remove irregularities seen in the dose profile as well as comparison with treatment planning system data will allow further verification. These results will aid future measurements of overlapping field treatment plans delivered to PRESAGE® for treatment verification of proton and photon 3D dosimetry.

References:

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