Characterization of the new Xoft Axxent Electronic Brachytherapy Source using PRESAGE ® Dosimeters

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Purpose

To characterize the Xoft Axxent electronic brachytherapy source using PRESAGE® dosimeters to obtain independent confirmation of TG-43U1 dosimetry values from previous studies and ascertain its reproducibility in HDR brachytherapy.

Motivation for this study

- PRESAGE®, developed by Heuris Pharma, LLC, is an optically transparent radiochromic dosimeter that is capable of creating a 3D assessment of dose distributions, potentially allowing for accurate comparisons with treatment planning calculations.[1]
- PRESAGE® dosimeters have been used to measure dose from various therapy modalities (i.e., linear accelerator, LDR brachytherapy sources, HDR brachytherapy sources) but little research has been preformed on the new electronic brachytherapy source known as the Xoft Axxent.
- In previous studies, Xoft Axxent has been used for skin treatments, vaginal cancers, and partial breast irradiation (PBI) in breast cancer.[2]

Method

PRESAGE® dosimeters are solid, polyurethane-based dosimeters doped with radiochromic leucodyes that produce a linear optical-density response when exposed to radiation. Eight 1-kg dosimeters were manufactured with channels to accommodate the Xoft Axxent catheter. To remove imaging artifacts due to oversaturated responses in the immediate vicinity of the source, half of the eight dosimeters were cast with a larger channel diameter of 15mm. Catheters fit the 5.4mm diameter channels whereas polyurethane plugs were inserted into the larger channels to create a uniform medium around the catheter. The dosimeters were scanned prior to irradiation with an optical-CT scanner to eliminate background signal and any optical imperfections from each dosimeter. During irradiation, the catheters were placed in the center of each channel. were irradiated to either 1517.3 cGy or 2017.5 cGy at 1 cm from the source. Post-irradiation scans were performed within 48 hours of irradiation. A 3D dose distribution was reconstructed by subtracting these two images and the radial dose function, $g_p(r)$, was calculated using in-house software:

$$g_p(r) = \frac{\dot{D}(r, 90°) \times r^2}{\dot{D}(r = 1, 90°)}$$

where, is dose rate at reference point, r.[4-6]

Figure 1: Since PRESAGE® is temperature and light sensitive, dosimeters were stored in a black, light-tight bag in a refrigerator at 4° C until irradiated. During irradiation, the PRESAGE® stayed in the black bag and was surrounded by rice, which was used as tissue equivalent material.[4]

Figure 2: The Modulator Test Fixture (MTF) at the University of Wisconsin ADCL, was used to mimic the Xoft Axxent Controller.

Figure 3: The Xoft Axxent catheter was plugged into the MTF. The catheter was then inserted into the cylindrical PRESAGE® dosimeters to irradiate them to 15 and 20 Gy.

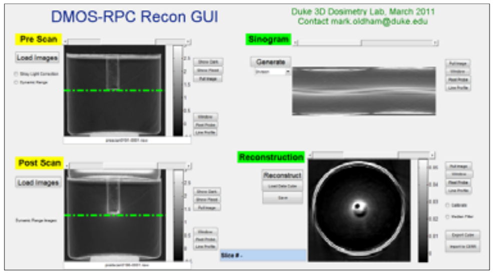

Figure 4: Pre- and post-irradiation scans were preform on the DMOS at IROC-Houston. Through a customized Matlab program, provided by Mark Oldham's 3D Dosimetry Lab at Duke, a sinogram and reconstruction were produced.

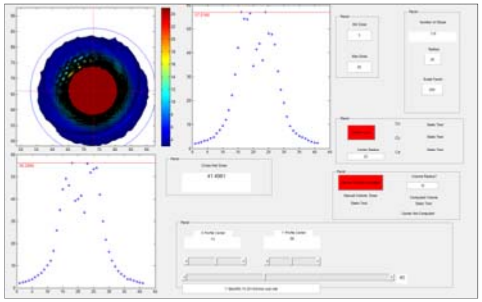

Figure 5: Through an in-house Matlab program, provided by Slade Klawikowski, the centers of the PRESAGE® were determined as well as the location of the Xoft cathode during irradiation. Specifically for this dosimeter, the exact location was shown to be (X=73,Y=66,Z=43). The dose in this plane was then further analyzed to measure the radial dose function.

r(cm)	Rivard's g(r)	Average g(r) d=5.4 mm	Differences in g(r) d=5.4mm	% Error g(r) d=5.4 mm	Average g(r) d=15 mm	Differences in g(r) d=15mm	% Error g(r) d=15 mm
1	1	1.000	0.000	0.000	1.000	0.000	0.000
1.2	0.92	1.045	0.125	13.553	1.083	0.163	17.681
1.4	0.848	1.047	0.199	23.467	0.990	0.142	16.746
1.6	0.786	0.935	0.149	18.902	0.826	0.040	5.141
1.8	0.732	0.813	0.081	11.104	0.730	0.002	0.239
2	0.683	0.732	0.049	7.136	0.769	0.086	12.628

Table 1: Small Channel (5.4mm) and Large Channel (15mm) irradiated to 15Gy and compared with Rivard et al. 2006.[3]

r(cm)	Rivard's g(r)	Average g(r) d=5.4 mm	Differences in g(r) d=5.4mm	% Error g(r) d=5.4 mm	Average g(r) d=15 mm	Differences in g(r) d=15mm	% Error g(r) d=15 mm
1	1	1.000	0.000	0.000	1.000	0.000	0.000
1.2	0.92	1.246	0.326	35.462	0.974	0.054	5.842
1.4	0.848	1.124	0.276	32.498	0.871	0.023	2.680
1.6	0.786	0.979	0.193	24.497	0.777	0.009	1.100
1.8	0.732	0.746	0.014	1.922	0.801	0.069	9.383
2	0.683	0.607	0.076	11.174	0.686	0.003	0.380

Table 2: Small Channel (5.4mm) and Large Channel (15mm) irradiated to 20Gy and compared with Rivard et al. 2006.[3]

Results

- Comparing measured radial dose rates with previous results revealed smaller percent errors when PRESAGE® irradiations were at lower maximum dose.
- The radial dose function of a point source, $g_p(r)$, includes dose fall-off on the axial plane that is due to photon attenuation and photon scatter. [3-4]
- The dosimeters showed small deviations in $g_p(r)$, from previous studies. Among the dosimeters irradiated to 1517.3 cGy, the $g_p(r)$ compared to previous studies fluctuated from 0.0043 to 0.3922.[3] This suggests small fluctuations can drastically change radial dose calculations.

Conclusion

- Pre- and post-irradiation scans of the PRESAGE® dosimeters used to determine the 3D dose distribution. Any slight geometric deviations between the pre and post scans are critical to overall estimation of the dose. It is thought that the larger percent error (17.6%) at d=15mm was a consequence of pre and post scan subtraction misalignment.
- The subtraction of pre-irradiation and post-irradiation scans of PRESAGE® dosimeters using an optical-CT scanner shows promising results in determining 3D dosimetry for Xoft Axxent devices; however, further research is needed.

References

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