DOSE RESPONSE OF GAFCHROMIC XR-T FILM TO A NEW ELECTRONIC BRACHYTHERAPY SOURCE

Sou-Tung Chiu-Tsao[1], Thomas W. Rusch[2], Steve Axelrod[2], Hung-Sheng Tsao[3], Louis Harrison[1]

[1]Beth Israel Medical Center, New York, NY; [2]*Xoft* microTube, Inc., Fremont, CA; [3]Sun Microsystems, Parsippany, NJ

ABSTRACT

Purpose: To study the dose response characteristics of GAFCHROMIC XR-T film to a new electronic brachytherapy source based on a miniature x-ray tube.

Method and Materials: A series of GAFCHROMIC® XR-T films were irradiated at a distance of 9 mm from a new Xoft microTube Flexible X-ray Probe with 40 kVp and 100uA setting in an RMI 457 solid water phantom. The irradiation times range from 0.2 to 12 minutes. Dose values were based on the dose rate generated from Monte Carlo calculations verified by miniature ion chamber measurements. The dose values ranged from 1 to 60 Gy. The films were scanned using red (665nm) and green (520nm) lights in PeC CCD100 microdensitometer. Spatial resolution of the scanned data was 0.2mm. The average optical density (OD) over 1mmx1mm area at the film center was obtained for each irradiated film. For the background film kept in this set, an average OD over 5x5mm area was determined as the background OD. The net OD (NOD) values were obtained by subtracting the background OD. Dose response curves (NOD vs. dose) were plotted for both red and green lights.

Results: The values of NOD/D(Gy) are 0.15 and 0.04 for low doses with red and green lights, respectively. The OD saturates at 10 and 40 Gy for red and green lights, respectively. While red light allows higher OD values at low doses, the green light has an advantage of a wider dynamic range for dose measurement.

Conclusion: GAFCHROMIC XR-T film is a promising tool for new electronic brachytherapy dosimetry.

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INTRODUCTION

- Xoft has developed an electronic high dose rate brachytherapy device. The Xoft microTube Flexible X-ray Probe delivers tight, conformal doses of x-radiation to the inner surface of a body cavity such as an excised tumor bed. See Device Description and Figures 3-4 (below).
- This poster describes the calibration of GAFCHROMIC® XR-T film to the Xoft microTube x-ray probe.
- The initial application of the Xoft microTube Flexible X-ray Probe has been to the conservative treatment of breast cancer utilizing a balloon-based Partial Breast Irradiation System. See Poster #140 in this session titled, "Electronic (Non Isotopic) High Dose Rate Brachytherapy (EHDRB): Design, Characterization and Pilot Animal Trial of a Novel Method of Accelerated Partial Breast Irradiation"
- The Xoft Treatment System is designed to shorten radiation treatment time while significantly reducing complications to the skin and surrounding healthy tissue. The Xoft Treatment System does not require a heavily shielded environment, making treatment potentially available for women without access to a facility with an HDR after loader. This technology eliminates handling and disposal of radionuclide sources.

METHODS

- **Objective**: To study the dose response characteristics of GAFCHROMIC XR-T film to a new electronic brachytherapy source based on a miniature x-ray source.
- **Instrument:** Xoft microTube Flexible X-ray Probe operated at 40 kVp and 100 μA
- **Films:** GAFCHROMIC® Model XR-T films (Lot #30189-2 from International Specialty Products Corporation). Film thickness: 0.21 mm
- **Design:** A series of calibration films (#0 – 10, about 2 cm x 2.5 cm) were irradiated at a distance of 9.055 mm from the x-ray tube axis in an RMI 457 certified grade solid water phantom (10 x 10 x 15 cm). Irradiation times ranged from 0.2 to 12 minutes.
- **Dose Values:** The dose values were based on the dose rate generated from MCNP-4C Monte Carlo calculations and verified by miniature ion chamber measurements (PTW 34013). Dose values ranged from 1 to 60 Gy.
- **Data Collection:** The films were scanned using a CCD100 microdensitometer from Photoelectron Corp. (PeC):
  - PeC-Red: Red LED light box (665 nm)
  - PeC-Green: Green LED light box (520 nm)
  - Spatial resolution: 0.2 mm per pixel

Phantom setup for calibration film

Figure 1. Side view

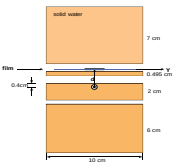
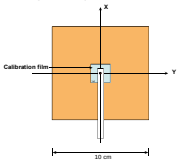


Figure 2. Top view



DEVICE DESCRIPTION

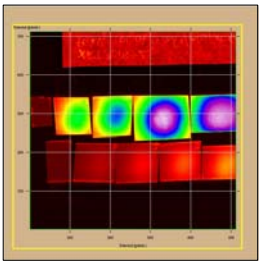
- The Xoft microTube Flexible X-ray Probe consists of a disposable, micro-miniature X-ray source integrated into a cooled, flexible, disposable probe.
- X-rays of 40-50 keV maximum energy are produced at the tip of the directable probe, which otherwise closely resembles current remote afterloading units.
- The X-ray source can be intensity modulated to mimic penetration and/or dose rate characteristics of many different isotopes, including HDR ^{192}Ir, ^{125}I and ^{103}Pd.
- Control variables are source operating voltage (penetration depth), beam current (dose rate), dwell time and dwell position.
- The Xoft microTube Flexible X-ray Probe can be inserted directly into tissue or into one or more lumens of an intracavitary or interstitial brachytherapy applicator, which is inserted during surgery (lumpectomy) or as an outpatient procedure up to five weeks later.
- This X-ray source is potentially appropriate for any accessible body cavity or excised tumor bed such as with breast cancer or gynecologic cancers.

Figure 3. Xoft Treatment System with Flexible X-ray Probe (above)

Figure 4. X-Ray Source – Scaled to Size

RESULTS

- The average optical density (OD) over a 1 mm x 1 mm area at the film center was obtained for each irradiated film.
- The background OD was determined to be the average OD over a 5 x 5 mm area for the background film kept in this set.
- The net OD (NOD) values were obtained by subtracting the background OD from the average OD.
- Dose response curves (NOD vs. dose) were plotted for both red and green lights.
- Data were compared with the same measurements obtained using an ^{125}I seed



Higher doses

Lower doses

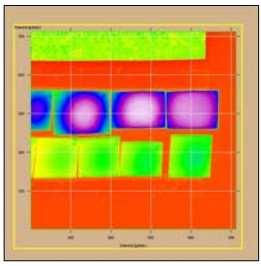


Figure 5. Image A of calibration films

Figure 6. Image B of calibration films

- Figures 5 and 6 present the raw microdensitometer images as measured with the red LED. The image in Figure 6 is shifted to include the two films at the right edge.
- The calibration films are arranged with dose increasing from left to right, with higher doses in the upper row.
- Numerical values of net optical density are listed in Figure 7 and plotted in Figure 8
- The values of NOD/D (Gy) are 0.15 and 0.04 for low doses with red and green lights, respectively, as compared to 0.30 and 0.06 when irradiated using ^{125}I.[1] The difference in dose response may result from the broader x-ray energy distribution from the Xoft microTube x-ray probe.
- The OD saturates at 10 and 40 Gy for red and green lights, respectively.

			Net Optical Density*1000	
Film#	time(min)	D(Gy)	PeC-Red	PeC-Green
0	0.0	0	0	0
1	0.2	1	145	40
2	0.4	2	257	86
3	0.6	3	359	114
4	0.8	4	446	130
5	1.0	5	529	154
6	2.0	10	843	283
7	3.0	15	1059	390
8	6.0	30	1280	692
9	9.0	45	1306	855
10	12.0	60	1259	852

Figure 7. Calibration film data for 40 kVp

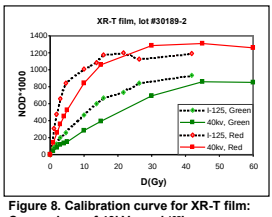


Figure 8. Calibration curve for XR-T film: Comparison of 40kVp and ^{125}I

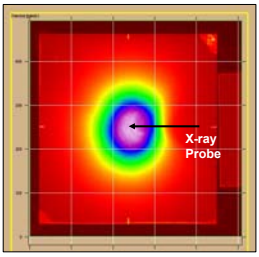


Figure 9. Film exposed for 8 minutes at a distance of 9 mm from the x-ray probe axis using 40 kVp and 100 μA

Dose rate (Gy/min)	Dose (Gy)
2.5	20
2.0	16
1.5	12
1.0	8
0.5	4
0.2	1.6
0.1	0.8

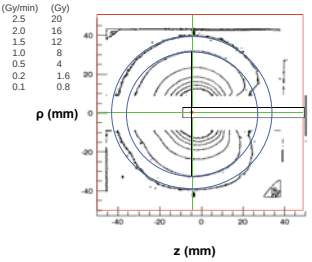


Figure 10. Isodose-rate curves projected into the plane through the x-ray probe axis

- Film in Figure 9 was exposed for 8 minutes to approach optical density saturation near the source thereby maximizing the range for dose determination.
- Measured isodose curves in the offset plane (Figure 9) were projected into the plane including the probe axis using a simple geometric transform. The transformed isodose curves are shown in Figure 10.
- Concentric circles in Figure 10 coincide with the 0.8 and 1.6 Gy isodose contours at points along the transverse bisector (green line) through the x-ray anode.
- The 0.8 and 1.6 Gy isodose lines deviate from spherical symmetry by less than 2.5 (7%) and 3.5 mm (11%), respectively, over the angular range from 0 to ±150 degrees from the distal direction (to the left in Figures 9 and 10).

REFERENCES

[1] S-T Chiu-Tsao, T. Duckworth, C. Zhang, N.S. Pate, C-Y Hsiung, L. Wang, J.A. Shih, and L.B. Harrison. "Dose response characteristics of new models of GafChromic films: Dependence on densitometer light source and radiation energy," submitted to Medical Physics, December, 2003.

SUMMARY

- GAFCHROMIC® XR-T film was irradiated in an RMI 457 solid water phantom using a Xoft microTube Flexible X-ray Probe.
- Calibration films were irradiated for 0.2 to 12 minutes with the x-ray probe operating at 40 kVp. Optical density was measured using a Photoelectron Corporation CCD100 microdensitometer with red (665 nm) and green (520 nm) LEDs.
- Net optical density was related to dose using miniature ionization chamber measurements and MCNP-4C Monte Carlo simulations.
- The x-ray probe dose distribution was then evaluated using the calibration curve.

CONCLUSIONS

- GAFCHROMIC XR-T film is a promising tool with acceptable optical density range for new electronic brachytherapy dosimetry.
- Initial measurements from one Xoft microTube x-ray probe indicate a spherically symmetrical dose distribution to within 11% over the angular range from 0 to ±150 degrees.