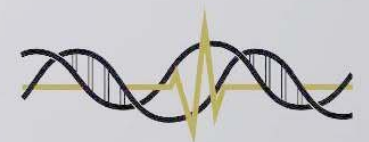


Dosimetric characterization of surface applicators for use with the Xoft eBx[®] system

R.M. Kennedy

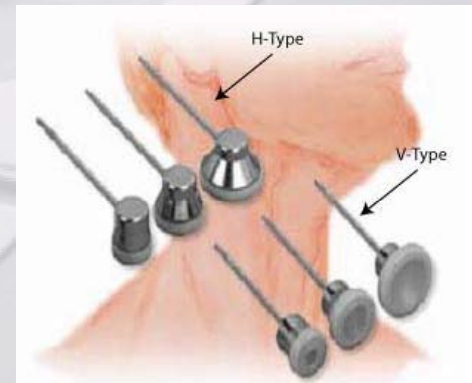
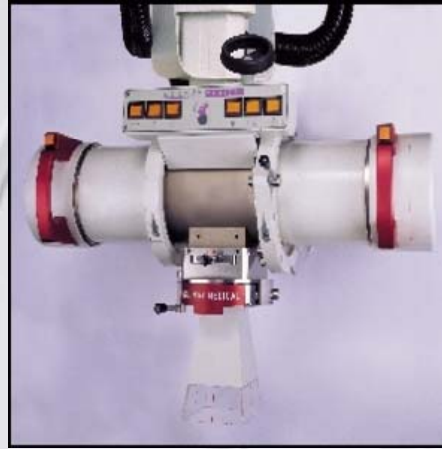
University of Wisconsin Medical Research Center
Madison, WI

April 23, 2010



Introduction

- Squamous and basal cell carcinomas are common but highly curable forms of skin cancer if detected early¹
- Successful treatment can be accomplished with
 - Orthovoltage X-rays
 - Linac based electron beam treatments
 - Brachytherapy sources in combination with specialized applicators
- Two main types of skin/surface applicators:
 - Electronic Brachytherapy (Xoft Inc.)
 - HDR (¹⁹²Ir) Brachytherapy



[1] American Cancer, "Cancer Facts & Figures 2009", Atlanta: American Cancer Society, 2009.

Images courtesy of (clockwise) <http://www.x-icon.com>, <http://www.bdssite.com/scc/photos.html>, Nucletron Corporation, and Xoft Inc.



Introduction continued

- Advantages of treatments with brachytherapy:
 - Shorter treatment times
 - » 40 Gy in 8 fractions twice weekly ²
 - Ability to overcome patient set up difficulties
 - Preference over surgical intervention because of reduce cosmetic complications
- However, how do we calibrate or commission these?
 - AAPM standard brachytherapy protocol: TG-43 ³
 - AAPM low energy x-ray beams protocol: TG-61 ⁴
- It is not clear what is appropriate for these devices:
 - Applicators effectively create a tightly collimated external beam

[2] Xofig, Inc. "Electronic Brachytherapy for skin cancer," white paper, Xofig Inc., 2009.

[3] M.J. Rivard, B.M. Coursey, L.A. DeWerd, W.F. Hanson, M.S. Huq, G.S. Ibbott, M.G. Mitch, R. Nath and J.F. Williamson, "Update of AAPM Task Group No.43 report: A revised AAPM protocol for brachytherapy dose calculations," Med. Phys. 31, 633-674 (2004).

[4] C.-M. Ma, C. W. Coffey, L. A. DeWerd, C. Liu, R. Nath, S. M. Seltzer, and J. P. Seuntjens, "AAPM protocol for 40–300 kV x-ray beam dosimetry in radiotherapy and radiobiology," Med. Phys. 28, 868–893 (2001).



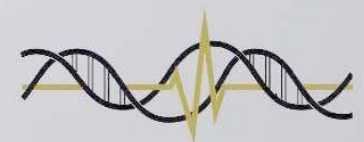
Motivation

- Axxent Applicators
 - Clinical recommendations made by Xoft Inc. based solely on measurements of TG-61 parameters
 - Certain characteristics of the Axxent applicators require modifications of TG-61 methods

In example:

- B_w is based on interpolations
- P_{stem} is set to 1.00

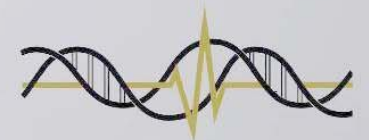
- Main goal → establish a cross over calibration methodology and/or dosimetry protocol between TG-61 and TG-43



Axxent[®] surface applicators

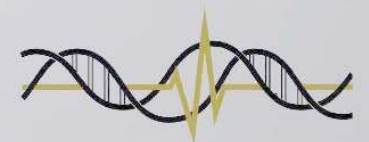
- Stainless steel conical applicator
- Available in four sizes:
 - 10, 20, 35, and 50 mm diameter
- Unique Al filter and SSD for each applicator
- Polystyrene cap on end of cone

Cone size	SSD
10 mm	21.6 mm
20 mm	21.7 mm
35 mm	21.7 mm
50 mm	31.4 mm



Methodology

- Ion chamber measurements of air-kerma
 - Attix Free Air Chamber (FAC)
 - Miniature ion chambers
- Radiochromic film measurements
- Monte Carlo simulations for comparison to measured values
- Comparison to published values in the Axxent Operators Manual

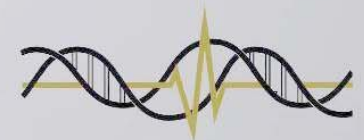


Ionization Chamber Measurements

- Chambers investigated:
 - PTW 34013
 - collecting vol: 0.005 cm^3
 - window without Kapton buildup: 2.35 mg/cm^2
 - window with Kapton buildup: 5.90 mg/cm^2
 - Prototype Standard Imaging A20
 - collecting vol: 0.003 cm^3
 - buildup thickness: 7.72 mg/cm^2
- Measured air kerma with miniature chambers at the window surface and with the FAC at 60, 80, 100 cm from the source
- Determined HVL1, HVL2, and HC for each applicator using the FAC



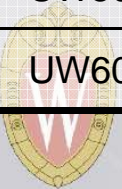
Image courtesy of PTW corporation



Free Air Chamber determination of HVL

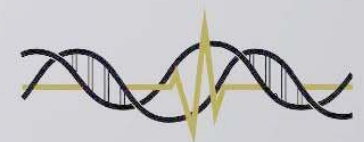
- Stability of sources checked with well chamber
- Source to chamber distance was 80 cm, filters were placed 30 cm from the source
- HVL data presented below are in mm Al
- “Xoft” HVL values are from Operators Manual

Applicator	HVL1 (UW)	HVL1 (Xoft)	% diff	HVL2 (UW)	HVL2 (Xoft)	% diff	HC (UW)	HC (Xoft)
10 mm	1.46	1.39	4.8	2.19	2.20	-0.5	0.67	0.63
20 mm	1.63	1.53	6.1	2.45	2.45	0.0	0.67	0.62
35 mm	1.60	1.57	1.9	2.46	2.60	-5.7	0.65	0.61
50 mm	1.64	1.56	4.9	2.43	2.57	-5.8	0.68	0.61
UW50-M	1.02	-		1.54	-		0.66	-
UW60-M	1.68	-		2.55	-		0.66	-

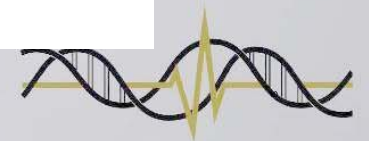
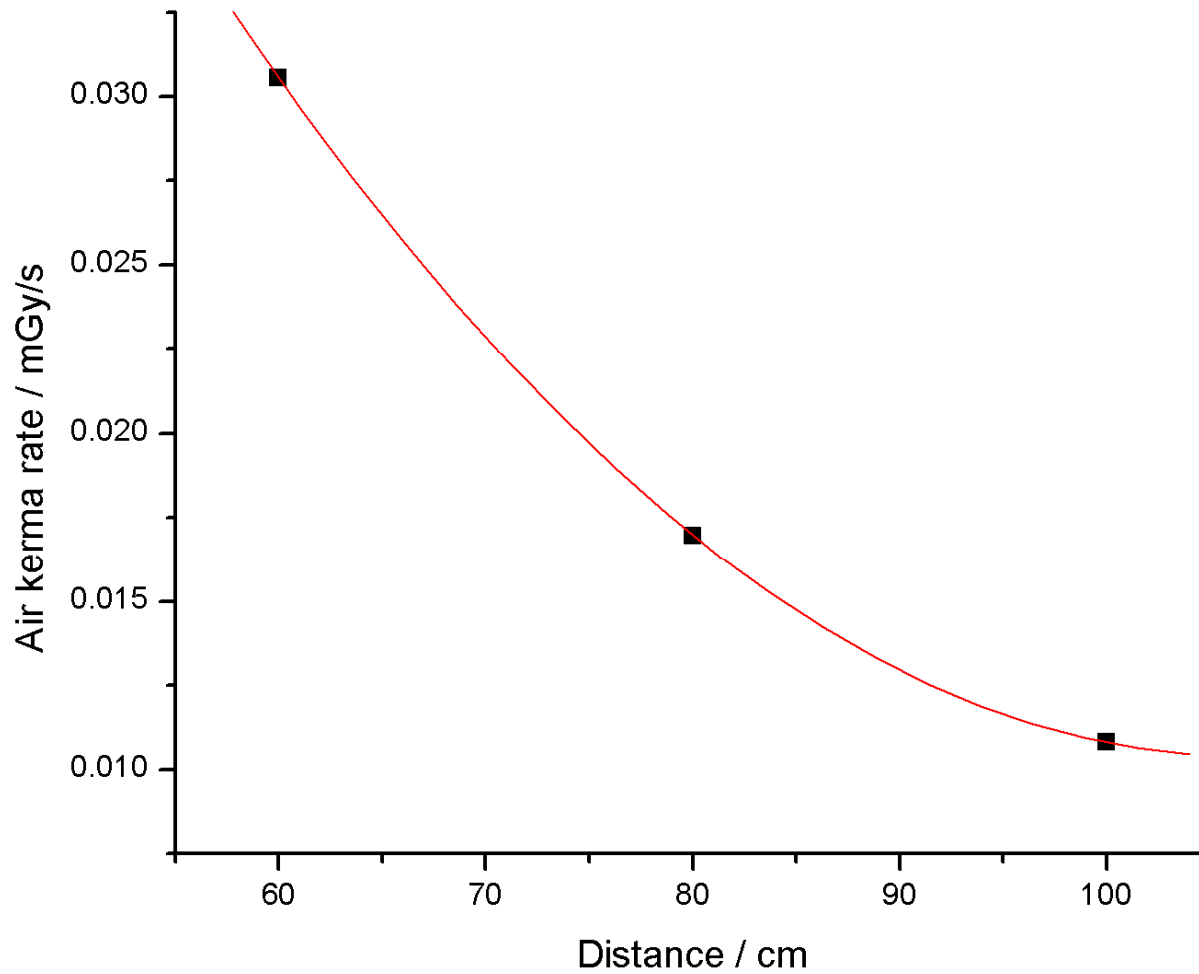


Air-kerma rate measurement methods and data analysis

- Miniature ion chambers were positioned flush to applicator window
- FAC measurements of air-kerma rate at 60, 80, 100 cm
- Output in mGy/s at window surface was determined by two methods:
 - Power fit of FAC data
 - Interpolation of N_k for Xoft using known HVL and N_k of standard beams for miniature ion chamber measurements



FAC measured data and power fit of air-kerma rate of 10 mm applicator

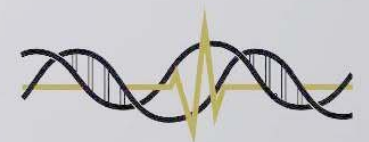
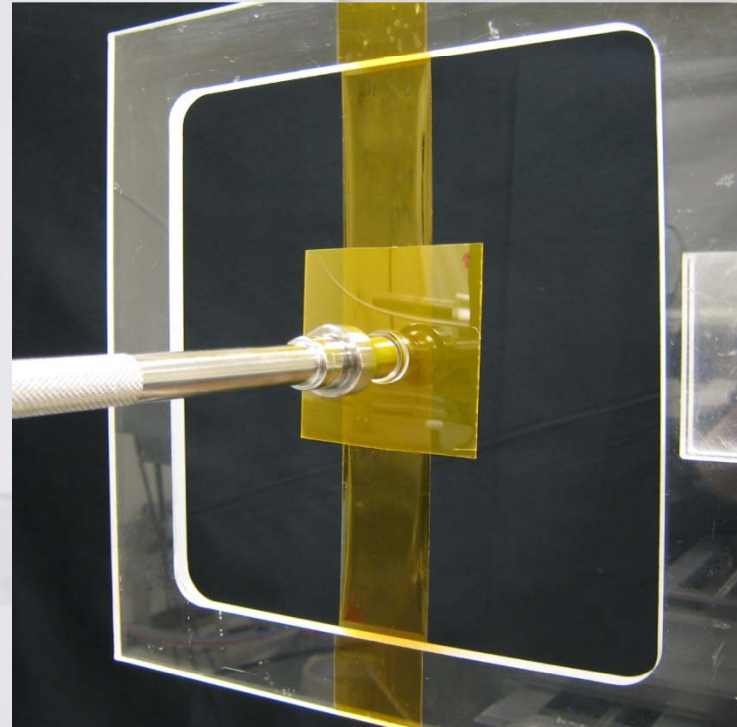


<i>10 mm applicator</i>			
Method	Chamber	Output (mGy/s)	% difference from power fit
Power	FAC	25.24	-
HVL interpolation of Xofter N_k	SI A20	24.80	1.74
HVL interpolation of Xofter N_k	PTW 340013	25.22	0.09
<i>50 mm applicator</i>			
Method	Chamber	Output (mGy/s)	% difference from power fit
Power	FAC	24.4	-
HVL interpolation of Xofter N_k	SI A20	10.50	56.99
HVL interpolation of Xofter N_k	PTW 340013	10.28	57.86

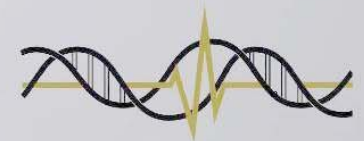
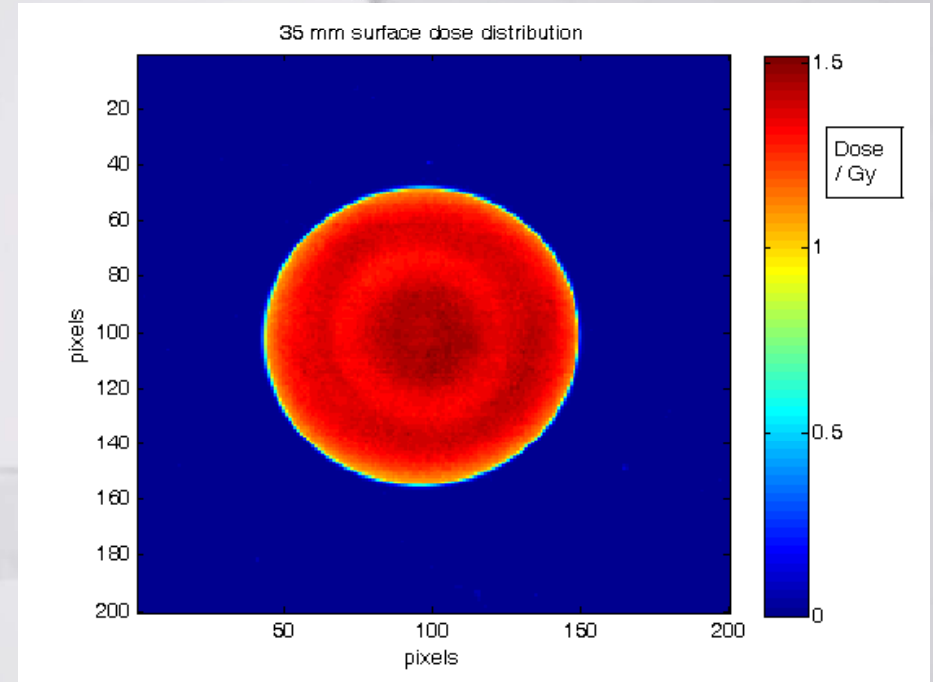
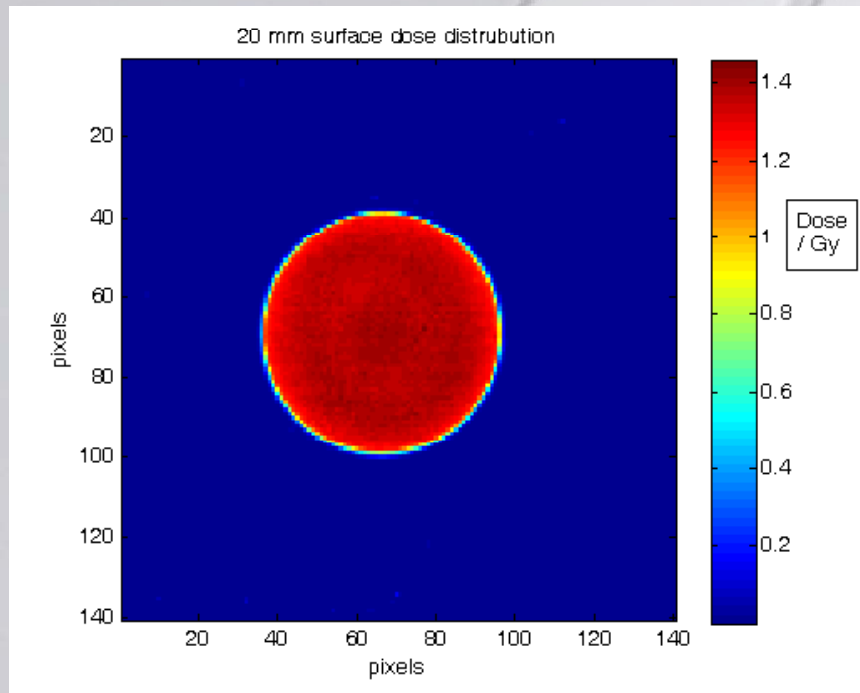


Radiochromic film

- EBT2 film from International Specialty Products Inc.
- Calibration curve created using UW60-M
- Measurements at applicator exit window
- Films were scanned with an Epson Expression 1000XL
- Analysis with ImageJ and Matlab

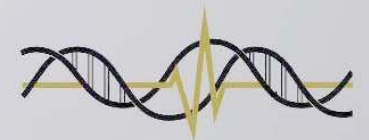


Radiochromic film

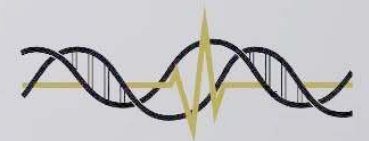
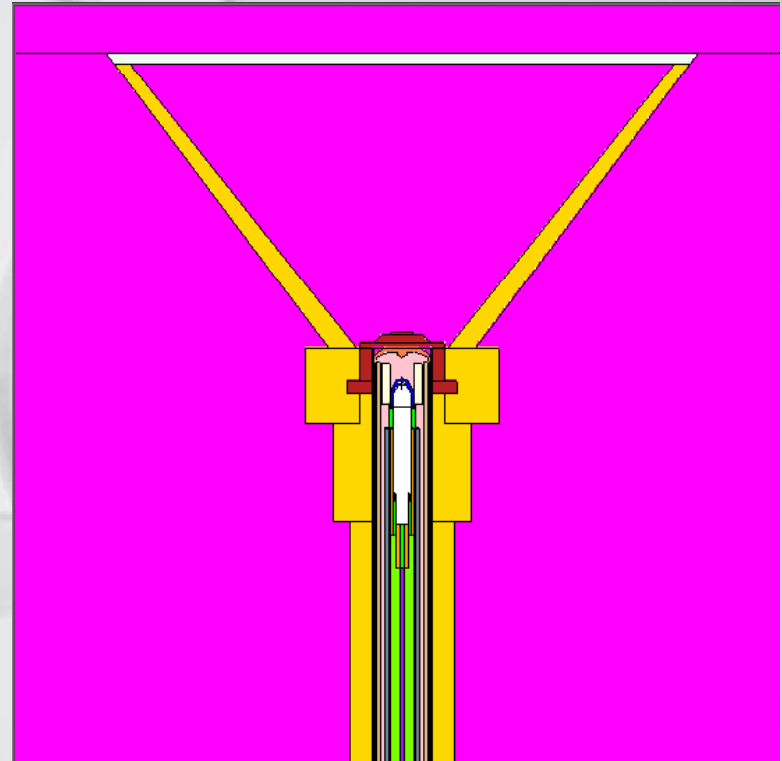
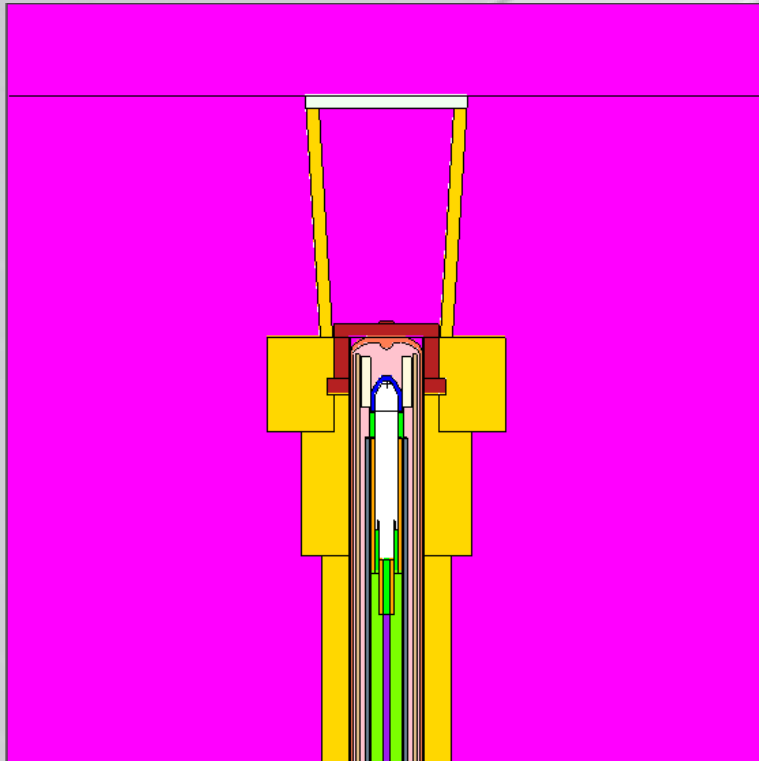


Monte Carlo simulations

- Preliminary study of air kerma and dose to water using MCNP5
- Tallied dose at depth in water using a mesh tally for comparison to published values in Operators Manual
- Tallied air kerma at 60, 80 and 100 cm from applicator with a tally cell of radius = 0.5 cm to simulate geometry of FAC measurements
- Tallied air-kerma at exit window for each applicator with a tally cell the size of the PTW chamber

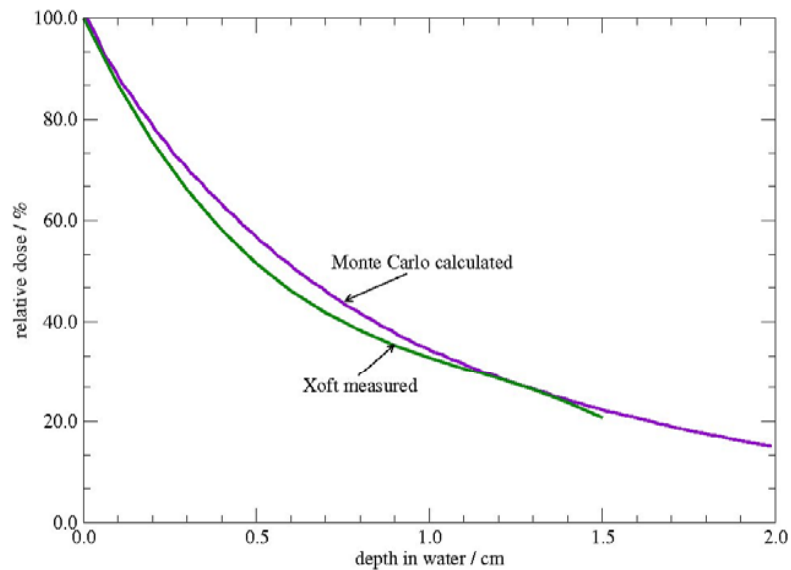


Monte Carlo simulations

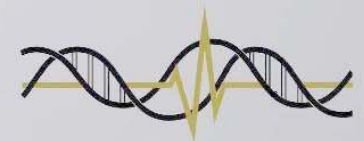
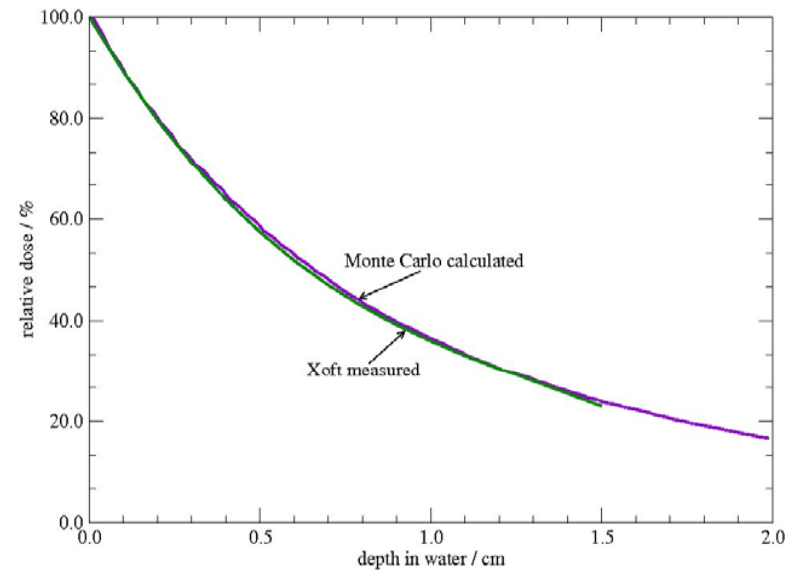


Depth dose curve comparison

20 mm diameter Xofter applicator depth dose in water



35 mm diameter Xofter applicator depth dose in water



Air kerma results

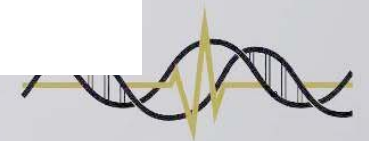
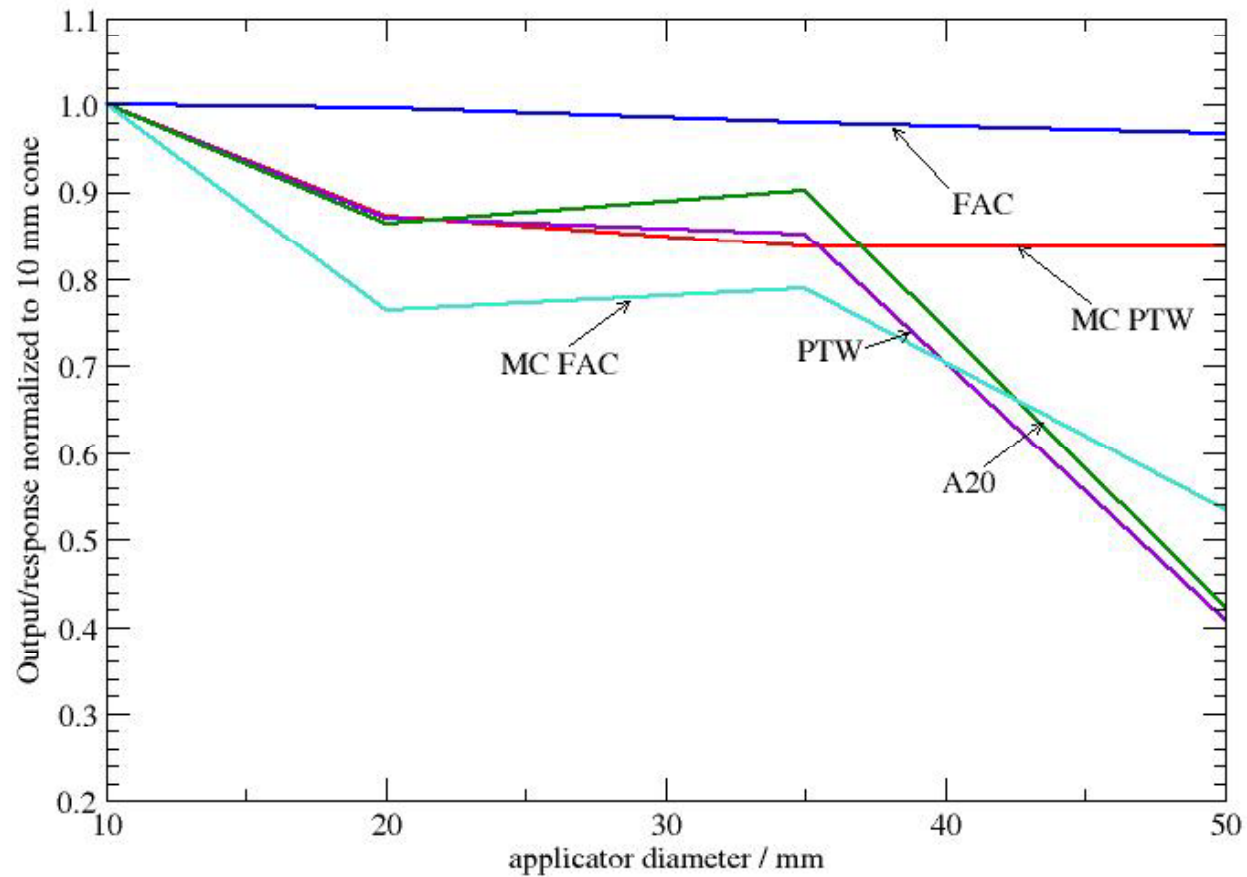
Normalized to 10 mm cone

Cone size (mm)	MCNP5 FAC(power)	MCNP5 r = 0.85 mm	PTW Chamber	SI A20 Chamber	FAC (power)
10	1.00	1.00	1.00	1.00	1.00
20	0.76	0.87	0.87	0.86	1.00
35	0.79	0.84	0.85	0.90	0.98
50	0.53	0.84	0.41	0.42	0.97



Air-kerma results

MC and measured trends of Xofter applicator output



Summary and Future work

- There is a clear need for a cohesive dosimetry protocol that accounts for the constraints of surface applicators
- Manufacturers have made recommendations on the calibration of these kinds of devices, however neither TG-43 or TG-61 can be applied as intended
- Further analysis into the discrepancy between the extrapolated FAC data and the miniature ion chamber data
- Monte Carlo simulation of the correction factors described in TG-61
- Additional Monte Carlo simulations as well as in phantom measurements of the effect of heterogeneities within the treatment field
- Ultimately the combination of measured data and Monte Carlo simulations will be the basis of a dosimetry protocol designed specifically for surface applicators



Acknowledgements

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- Travis McCaw
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