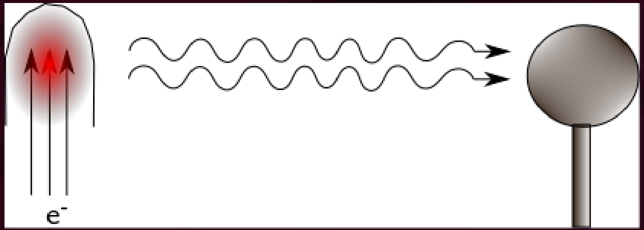


TG 292 on Electronic Brachytherapy Dosimetry: Current Status

Wesley Culberson, PhD, DABR
Department of Medical Physics, University of Wisconsin – Madison

July 30, 2018

AAPM 2018 JUL 29–AUG 2
BEYOND THE FUTURE!
60TH ANNUAL MEETING & EXHIBITION | NASHVILLE, TN

Disclosures

- None

Background / Rationale

- The last decade has seen a surge of eBT manufacturers and available applicators
- Each applicator can affect the resulting dose distribution in dramatic ways
- Each system with its own unique set of calibration tools, procedures and QA systems
- There exists minimal traceability to primary standards

Applicators

- Bare or in applicator
- Xoft balloon, vaginal, and cervical
- Zeiss INTRABEAM spherical

Background / Rationale

- No formal recommendations of the AAPM for dosimetry standards, formalisms, or adaptions of existing protocols for eBT
- Very few details on how to perform dosimetry measurements
- No electronic brachytherapy sources on the Brachytherapy Source Registry
- No other Task Groups for eBT dosimetry (except for TG 253 – Fulkerson presentation)

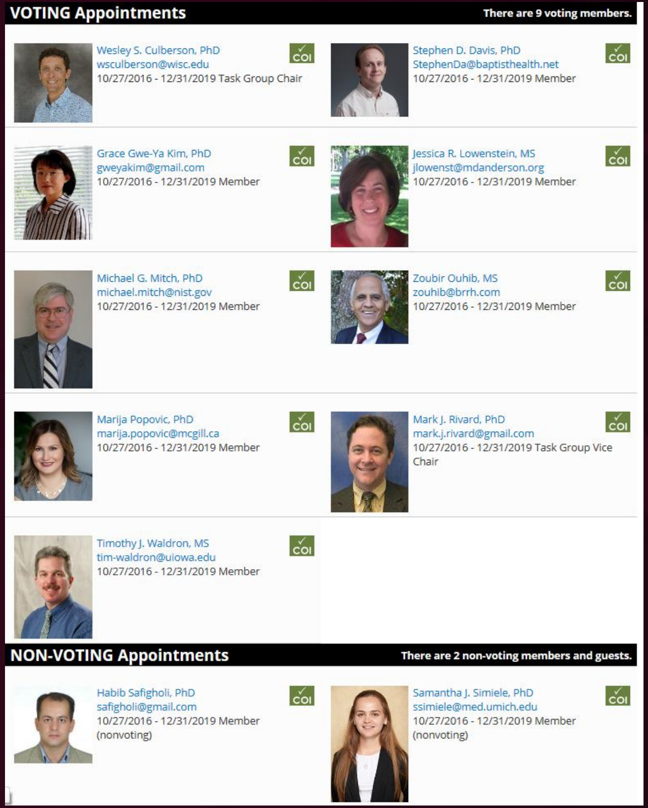
Task Group Formation

- Initial proposal submitted to the Working Group on Brachytherapy Dosimetry (WGBD) in February, 2015
  - TG292 -> WGBD -> BTSC -> TPC -> Science Council
- Approved by TPC in November, 2016
- Sunset date: December, 2019

Task Group Members

All 10 members have experiences with electronic brachytherapy dosimetry

- Wesley Culberson (chair)
- Mark Rivard (vice chair)
- Stephen Davis
- Grace Gwe-Ya Kim
- Jessica Lowenstein
- Michael Mitch
- Zoubir Ouhib
- Marija Popovic
- Timothy Waldron
- Habib Safigholi
- Samantha Simiele



Official Charges

For the interstitial, intracavitary, and intraluminary applications of electronic brachytherapy this Task Group will:

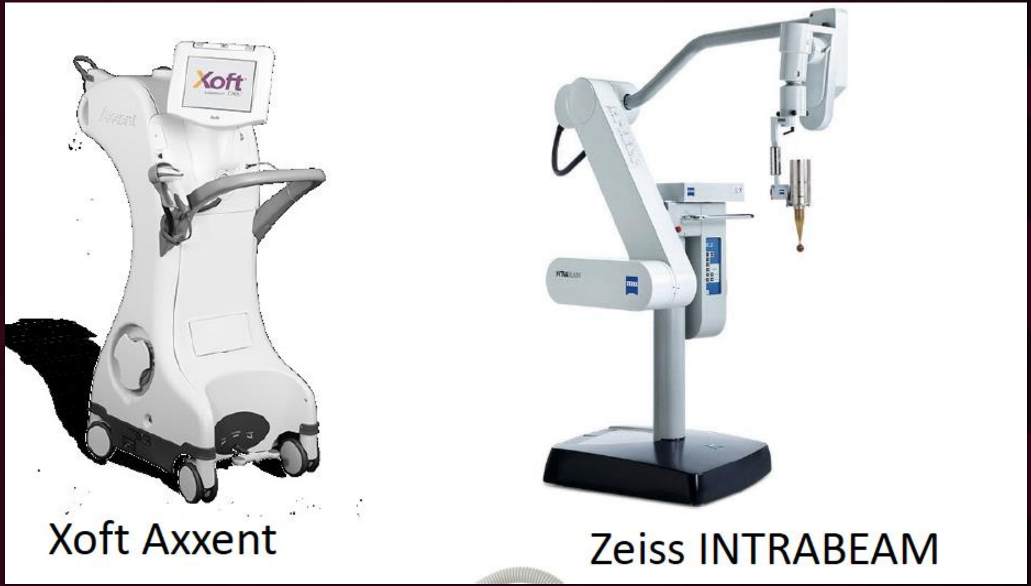
1. Review the approaches to electronic brachytherapy including:
   a. The various sources and applicators currently approved and marketed including the physical characteristics and differences from radionuclide-based brachytherapy modalities.
   b. The currently used methods of source output verification and dose calculations.
2. Develop recommendations for electronic brachytherapy dosimetry including:
   a. A modified TG formalism.
   b. A NIST-traceability for electronic brachytherapy source strength determination.
   c. Appropriate methods to measure and calculate dose distributions surrounding the sources.
   d. A description of the dosimetric effect when combining applicators with electronic brachytherapy sources.
   e. The inclusion on the AAPM-IROC Houston Brachytherapy Source Registry

Task Group Considerations

- TG 292 should work with the two other eBT Task Groups (TG 182 and TG 253), already in motion
- Should consider all manufacturers equally when making recommendations
- Risk-based analyses must be addressed

Systems Under Consideration

- Two systems being considered
- (Note that other eBT systems, such as Nucletron Esteya, are for surface applications only)



Systems Under Consideration

- Similarities
  - X-ray tube potentials very similar (50 kVp)
  - Both used for IORT in a variety of applicators
- Differences
  - Cooling systems (Xoft uses circulating coolant)
  - Steering (INTRABEAM system requires checks of e-beam steering)
  - Output monitoring
    - Xoft uses a well-type ionization chamber
    - INTRABEAM uses a parallel-plate based *Probe Adjuster and Ion Chamber holder* (PAICH)
  - Completely different sets of routine QA tests

Current Approaches

- Dosimetry based on manufacturer recommendations
  - Xoft Axxent based on TG-43 formalism

$$\dot{D}(r,\theta) = S_K \cdot \Lambda \cdot \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \cdot g_L(r) \cdot F(r,\theta)$$

Formalism initially recommended by Xoft

$$= \dot{K}_{50cm} \cdot \chi \cdot \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \cdot g_L(r,\theta) \cdot F(r,\theta)$$

Formalism currently recommended by Xoft

  - Zeiss Intrabeam based on TG-61 formalism

$$\dot{D}_W(r)\left[\frac{Gy}{min}\right] = N_k\left[\frac{Gy}{C}\right] \cdot Q(r)[C] \cdot \frac{T[K]}{T_0[K]} \cdot \frac{P_0[hPa]}{P[hPa]} \cdot k_Q \cdot k_{Ka \rightarrow Dw} \cdot 1\left[\frac{1}{min}\right]$$

Current Approaches

- Although both systems use air-kerma as the metric for source output, they have very different methods of determining the absorbed dose rate to water

The Xoft Approach

- In general terms
  - The Xoft approach is to determine the air kerma directly from the source and then utilize a single conversion coefficient from air kerma to absorbed dose to water at 1 cm from the source

$$\dot{D}(r,\theta) = S_K \cdot \Lambda \cdot \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \cdot g_L(r) \cdot F(r,\theta)$$

$$= \dot{K}_{50cm} \cdot \chi \cdot \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \cdot g_L(r,\theta) \cdot F(r,\theta)$$

  - From this location, the dose to other locations is scaled very similarly as in the TG-43 approach

The Intrabeam Approach

- In general terms
  - Standard PSDL-traceable air-kerma calibrations are provided for a small ion chamber (PTW 34013 – 0.005cc)
  - Calibration coefficients are then corrected for the presumed source x-ray spectrum
  - Air kerma to absorbed dose to water conversions are provided

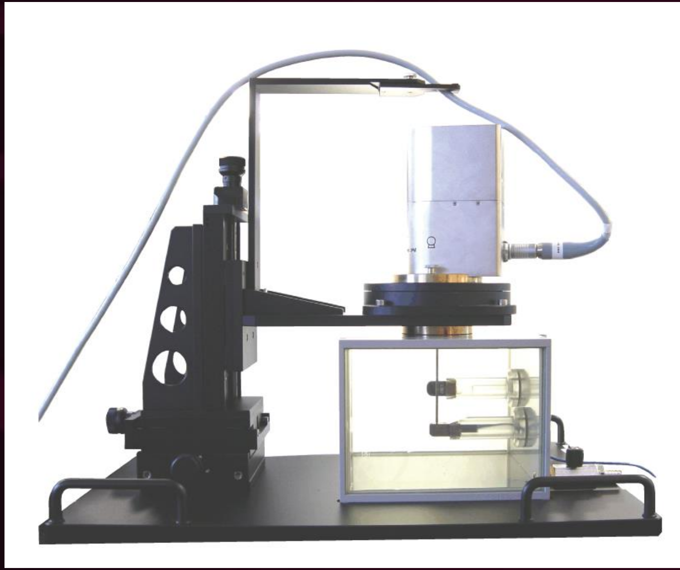
$$\dot{D}_W(r)\left[\frac{Gy}{min}\right] = N_k\left[\frac{Gy}{C}\right] \cdot Q(r)[C] \cdot \frac{T[K]}{T_0[K]} \cdot \frac{P_0[hPa]}{P[hPa]} \cdot k_Q \cdot k_{Ka \to Dw} \cdot 1\left[\frac{1}{min}\right]$$

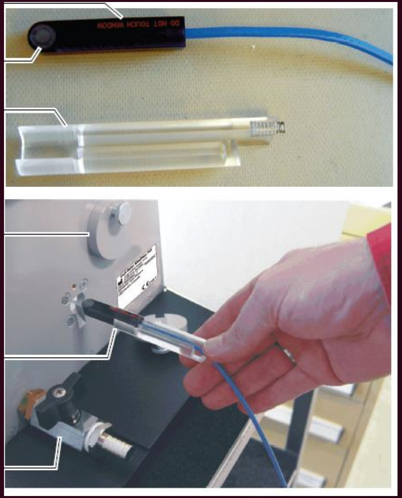
User Measurements

- For the Xoft system, the user measures the source output in a calibrated well-type ionization chamber with customized insert

User Measurements

- For the INTRABEAM system, the user measures the absorbed dose rate in water using a specialized water tank





images from INTRABEM Water Phantom Manual, V5.0

Traceable Quantities

Air kerma rate is traceable quantity for both systems

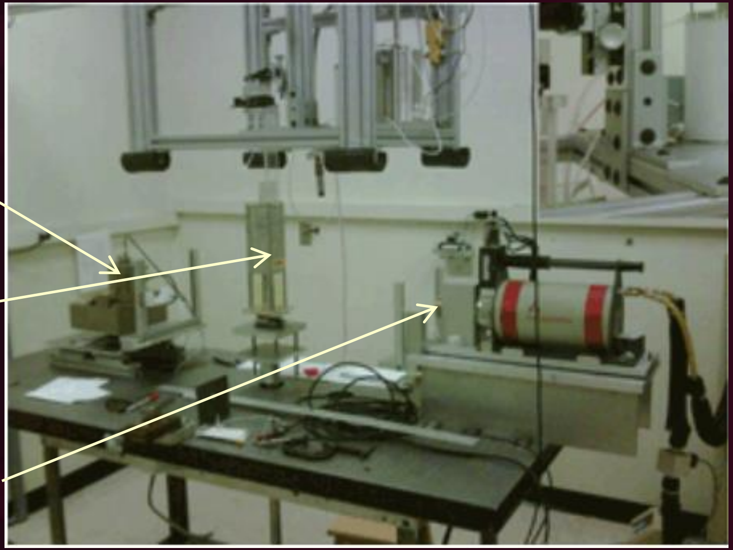
$$\dot{D}(r,\theta) = S_K \cdot \Lambda \cdot \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \cdot g_L(r) \cdot F(r,\theta)$$

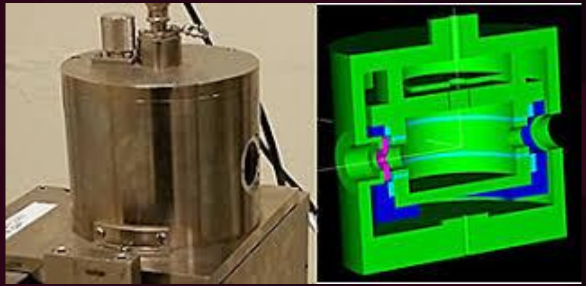
$$= \dot{K}_{50cm} \cdot \chi \cdot \frac{G_L(r,\theta)}{G_L(r_o,\theta_o)} \cdot g_L(r,\theta) \cdot F(r,\theta)$$

$$\dot{D}_W(r)\left[\frac{Gy}{min}\right] = N_k\left[\frac{Gy}{C}\right] \; Q(r)[C] \cdot \frac{T[K]}{T_0[K]} \cdot \frac{P_0[hPa]}{P[hPa]} \cdot k_Q \cdot k_{Ka \to Dw} \cdot 1\left[\frac{1}{min}\right]$$

Traceable Quantities

- Xoft Axxent air-kerma rate is traceable to NIST





Lamperti free-air chamber
(images from www.nist.gov)

Traceable Quantities

- Zeiss INTRABEAM air-kerma rates are indirectly traceable to standard x-ray beam series

	Beam quality	HVL mmAl
PTW	TW 50	1.13
PTW	TW 30	0.44
UW ADCL	UW50-L	0.79
UW ADCL	UW40-L	0.53
INTRABEAM	50 KvP	0.64

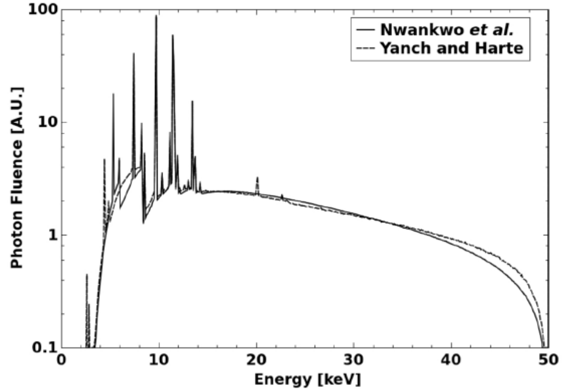


Figure 4. Simulated INTRABEAM 50 kV$_p$ photon spectra in air for source model parameters taken from Yanch and Harte (see table 1) and Nwankwo *et al.* Spectra are normalised to the area under the curve.

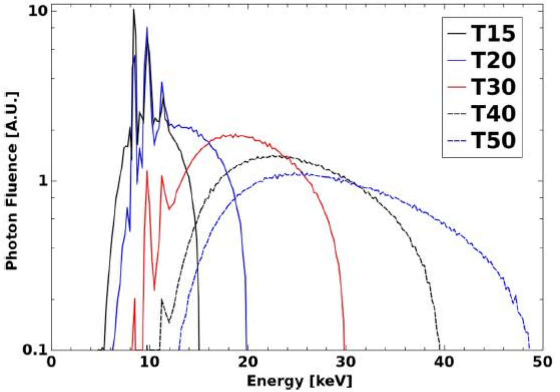


Figure 3. T-series kV reference photon beam spectra provided at PTB. These spectra were measured in air at 30 cm source-to-detector distance. Courtesy of Ludwig Büermann.

Figures from Watson et al 2017

Additional QA Tests

- In addition to the output measurements, a host of other QA tasks are recommended for each system
- For INTRABEAM system, the source alignment needs to be verified before use
  - multi-location diode system used
- “Internal radiation monitor” used to monitor output during treatment for the INTRABEAM system

Task Group Challenges

- Developing a complete understanding of the current formalisms and associated uncertainties
- New source models
  - Xoft Axxent S700 -> S7601
- New relevant publications
  - Several publications on Zeiss Intrabeam dosimetry since inception of TG 292, including one this month!

Task Group 292 Status

- Writing assignments delineated
- Gathering information on current approaches to eBT dosimetry
- Working with manufacturers (Xoft and Zeiss) to ensure complete understanding of the current methods

Recommendations

- No recommendations have been finalized by the group
- The goal is to be sensitive to current paradigms, but also provide clear recommendations for clinical users and researchers moving forward
- The Brachytherapy Source Registry will be considered

Sunset date Dec 31, 2019

Acknowledgements

- TG 292 Members
- Tom Rusch and Linda Kelly from Xoft
- Frank Weigand from Zeiss

Questions?