Radiological Physics and Surface Lesion Treatments with Electronic Brachytherapy

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Potential Conflict of Interest

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Outline

- Electronic brachytherapy (eBT) motivations
- Special physics considerations
- QA of eBT surface applications

Why eBT?

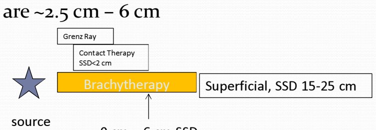
- Miniature x-ray sources delivering therapeutic doses of radiation
  - Bremsstrahlung x-rays created by targeting electrons onto a high-Z target (usually gold or tungsten)
- No radionuclides used, thus different regulatory requirements (no radioactive materials license needed)
- Commercial units have energies ranging from 30 – 90kVp
- Adjustable dose rates / tube currents
- Less shielding required due to low energies (compared to ^{192}Ir at least)
- Developed in the late 1980s, ~10 companies have pursued since then

Applications

- Approved* for use in intercavitary (APBI), interstitial, interluminary, and superficial treatments

eBT versus brachytherapy

- Definition of Brachytherapy by distance?
  - Literal Latin translation of brachytherapy is “near” or “short-distance” therapy
  - Historically, brachytherapy sources have either been implanted interstitially or directly on the surface
  - eBt units can be implemented interstitially or for surface treatments, but typically are not directly on the surface
  - eBt nominal SSDs are ~2.5 cm – 6 cm



Protocols

- No eBT-specific protocol
  - TG-43 and updates – Brachytherapy dosimetry formalism
  - TG-61 – Low and medium x-ray beams (40 – 300 kVp)
  - TG-56 – Code of practice for brachytherapy
  - TG-59 – HDR treatment delivery
  - TRS-398 – Absorbed dose to water
- eBT TG proposed

TG-43 limitations

- Photon emitting brachytherapy sources
- Assumption of a longitudinally symmetric source in water
- Source strength in terms of air-kerma, S_k
- These conditions not observed with eBT applicators
  - Axxent source has a standard based on air-kerma rate

$$\dot{D}(r,\theta) = S_{\mathrm{K}} \cdot \Lambda \cdot \frac{G_X(r,\theta)}{G_X(r_0,\theta_0)} \cdot g_X(r) \cdot F(r,\theta)$$

Rivard et al, *Med Phys* 31, 633-674 (2004)

TG-61 limitations

- Dosimetry protocol for low- and medium energy x-ray systems
- Descriptors of beam quality through half-value layer (HVL)
  - HVL measurements recommend 100 cm source to detector with attenuators placed 50 cm from the source

$$D_{\mathrm{w,z=0}} = M \cdot N_{\mathrm{K}} \cdot B_{\mathrm{w}} \cdot P_{\mathrm{stem,air}} \cdot \left[\left(\frac{\bar{\mu}_{\mathrm{en}}}{\rho}\right)^{\mathrm{w}}_{\mathrm{air}}\right]_{\mathrm{air}}$$

Ma et al, *Med Phys* 28(6), 868-893 (2001)

What's a good physicist to do?

- Be mindful of materials (low-energy)
- Ensure appropriate measurement geometry
- Consider detector size and perturbation
- Parallel plate chambers
- Thermoluminescent Dosimeters (energy response)
- Optically-Stimulated Luminescence Dosimeters (energy response)
- Film (calibration, scanner response)

What's a good physicist to do?

- Refer to peer-reviewed methodologies
  - TG-61/TRS-398
  - Fulkerson *et al* (Xoft)
  - Candela-Juan *et al* (Esteya)
  - Rivard *et al* (Hybrid TG-43)
  - ABS physics report on surface applicators
  - Forthcoming TG reports

What's a good physicist to do?

- Refer to peer-reviewed methodologies
  - TG-61/TRS-398

AAPM protocol for 40–300 kV x-ray beam dosimetry in radiotherapy and radiobiology

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IAEA TRS-398

Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water

What's a good physicist to do?

- Refer to peer-reviewed methodologies
  - Fulkerson *et al* (Xoft)

$$K_{\mathrm{air}} = M \cdot P_{\mathrm{elec}} \cdot P_{\mathrm{TP}} \cdot N_{\mathrm{K}} \cdot \boxed{P_{\mathrm{cham}}} \cdot \boxed{P_{\mathrm{POM}}}$$

Chamber correction factor

$$D_{\mathrm{water,d}} = K_{\mathrm{air}} \cdot \boxed{P_{\mathrm{D_w}}} = \frac{D_{\mathrm{a}}}{D_{\mathrm{cham}}}$$

factor

$$\left(\frac{\mathrm{SSD+d}}{\mathrm{SD}}\right)^2$$

$$P_{\mathrm{D_w}} = \frac{D_{\mathrm{phantom,d}}}{D_{\mathrm{a}}}$$

Fulkerson et al, *Med Phys* 41(2), 022103 (2014)

What's a good physicist to do?

- Refer to peer-reviewed methodologies
  - Candela-Juan (Esteya)
    - Flatness and Symmetry
    - HVL
    - Dosimetry (TRS-398/TG-61)

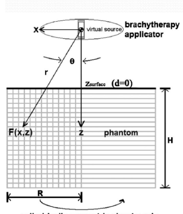
$$\dot{D}_w = \frac{M_Q N_{K,Q_0} k_{Q,Q_0} p_{stem,air}}{t} \left[\left(\frac{\mu_{en}}{\rho}\right)^w_{air}\right]_{air} \left(\frac{SSD + d_c}{SSD}\right)^2$$

Candela-Juan et al, J Contemp Brachy 7(2) 189-195 (2015)

What's a good physicist to do?

- Refer to peer-reviewed methodologies
  - Rivard *et al* (Hybrid TG-43)

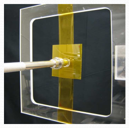
(i) Identify the dose distribution cylindrical axis of symmetry;
(ii) select an active length L;
(iii) derive a radial dose function $g(r)$ along the virtual source long axis, and determine the origin where the virtual source center will be located;
(iv) derive the 2D anisotropy function $F(r,\theta)$; and
(v) choose a virtual dose rate constant Λ at the reference point to reproduce Monte Carlo-calculated dose values using the above parameters.

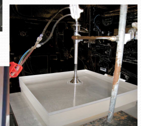


Rivard et al, *Med Phys* 36, 1968 (2009)

Other considerations

- HVL
- Percent depth dose
- Flatness and symmetry
- Dose linearity with mA
- Safety
  - Shielding (minimal) and survey
  - Electrical hazards
- Patient-specific cutouts





Images courtesy R Fulkerson and C Candela-Juan