Extrapolation chamber measurements of beta-emitting ophthalmic sources

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Eye cancer considered rare
- 2,810 new cases for 2016 in U.S.¹
- Can metastasize to liver

Formerly treated with enucleation
- Still accepted for large melanomas

Radiation treatment
- Ophthalmic applicators
- Episcleral plaques
- Proton beam therapy
- Gamma Knife®
Positioned in contact with eye
  - Not surgically placed

Planar $^{90}$Sr/$^{90}$Y source
  - $\beta$ emitter with $E_{\text{max}} = 2.280$ MeV
  - Secular equilibrium with 28.79 yr half-life

Treatment of pterygium (Surfer’s Eye)
  - Improvement in recurrence rate following surgical removal of benign growth$^1$
  - No longer manufactured

Surface dose rate measured with extrapolation chamber

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Episcleral plaques

- Concave shape
  - Sutured to eye for 3–7 days

- Brachytherapy seeds
  - $^{125}$I, $^{103}$Pd, $^{131}$Cs
  - COMS plaque with $^{125}$I seeds popular in U.S.

- $^{106}$Ru/$^{106}$Rh distributed source
106Ru episcleral plaques

- Manufactured by Eckert & Ziegler BEBIG (Berlin, Germany)
  - Popular in Europe with 16 sizes available

- 106Ru/106Rh distributed source
  - β emitter with E_{max} = 3.541 MeV
  - Secular equilibrium with half-life of 373.59 d
Dosimetry for seeded plaques
  - Based on air-kerma strength standard
  - Dose calculations from AAPM TG-43U1 and TG-129 reports\textsuperscript{1,2}

Eye plaques with distributed source
  - No primary measurement device exists to determine surface dose

Develop a convex windowless extrapolation chamber to measure surface dose rate from $^{106}$Ru episcleral plaques

- **Windowless** design
  - Difficult to maintain curved shape with very thin entrance window
  - Metal brachytherapy source held at voltage bias

- Assess accuracy of **current dosimetry techniques** for $^{106}$Ru plaques
  - Scintillator measurements by manufacturer$^1$
  - Radiochromic film measurements$^2$

- Improve accuracy of **dose prescriptions** in eye plaque therapy
  - Dose to sclera and tumor apex

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1. BEBIG ruthenium eye applicator customer information, 2002.
Parallel plate ionization chamber in which air gap distance between electrodes is varied
  - Change in ionization current with air gap used to calculate surface dose

NIST calibration service for $^{90}$Sr planar applicators from 1977-2015

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1. NIST, IRD-P-09, 2010.
Perform measurements with:

Planar windowless extrapolation chamber
&
NIST-calibrated $^{90}$Sr ophthalmic applicator

Planar windowless extrapolation chamber
&
Flat $^{106}$Ru episcleral plaque

Convex windowless extrapolation chamber
&
Curved $^{106}$Ru episcleral plaque
Methods:

- EGSnrc correction factors
  - Backscatter
  - Change in out scatter as a function of air gap
  - Attenuation in entrance window of NIST extrapolation chamber

- Capacitance measurements
  - Determine area of collecting electrode
  - Initialize chamber air gap
Agreed within NIST uncertainty in source calibration of ±3.5% \((k=1)\)
- Verified accuracy of windowless chamber design

Lower dose rate attributed to source positioning
- For NIST calibration, source located at position of maximum signal
- For UWMRRC measurements, source centered in front of electrode
Flat $^{106}\text{Ru}$ plaque source

- Flat $^{106}\text{Ru}$ plaque acquired from BEBIG before being stamped into its customary curved shape
- Performed measurements with planar windowless extrapolation chamber and radiochromic film
Comparison made with radiochromic film measurements
- Agreement within 5%

Results will also be compared with scintillator measurements made by manufacturer BEBIG

<table>
<thead>
<tr>
<th>Trial</th>
<th>Decay-corrected surface dose rate (mGy/s)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2.49</td>
</tr>
<tr>
<td>2</td>
<td>2.54</td>
</tr>
<tr>
<td>3</td>
<td>2.55</td>
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<tr>
<td>Avg.</td>
<td>2.53 ± 0.03</td>
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Planar windowless extrapolation chamber with flat $^{106}$Ru source
Convex collecting electrode by Standard Imaging (Middleton, WI)

Motion stages used to align concave source and electrode

Extrapolation chamber results will be compared with film measurements in plastic eye phantom and manufacturer calibration data
Clinical impact

- Commission treatment planning system with measured dose profiles
  - Compare distribution in eye with predicted profiles from manufacturer data
  - Evaluate impact on clinical dose prescriptions to sclera and tumor apex

- Plan to develop technique to transfer extrapolation chamber standard for surface dose
  - Ionization chamber measurement at clinic
  - Standardize dose reporting in clinical trials

1. Eye Physics, LLC (Los Alamitos, CA)
Conclusions

- Need exists for a primary dosimeter to measure surface dose rate from $^{106}$Ru episcleral plaques
  - Develop convex windowless extrapolation chamber

- Verified accuracy of dose rate measurements using extrapolation chamber without an entrance window
  - Agreement with NIST calibration for $^{90}$Sr ophthalmic applicator

- Observed agreement between extrapolation chamber measurements and film measurements with custom flat $^{106}$Ru plaque
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Questions?