State of Plaque Brachytherapy for Treatment of Ocular Lesions

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Purpose

• What is plaque therapy?
• Discuss locations and types of lesions.
• Review history of plaque brachytherapy.
• Describe a typical workflow.
• Discuss variations between institutions.
• Review recent developments.
Plaque Therapy

• Used in the treatment of ocular lesions.

• Plaques loaded with radioactive seeds are surgically placed in close proximity to the tumor.

• The sources rapid dose fall-off is used to deliver a high tumor dose while sparing the retina.
Plaque Types
Plaque Sutured Over Tumor
Common Lesions: Choroidal Melanoma

– Annually ~2500 cases of the following in the US.
– Subfoveal, Juxtapapillary/Circumpapillary
Common Lesions:
Iris & Ciliary Body Melanomas
Less - Common Lesions

• Other lesions treated with plaques:
  – Hemangiomas
  – Retinoblastoma
  – Exudative Macular Degeneration
  – Pterygium

Pterygium Lesion
Risk Factors

• Ocular melanomas are more prevalent in people with light eyes (green & blue).

• There is a higher overall risk for Australians due to hole in the o-zone.

• Wear sunglasses.
History

1930: Choroidal Melanoma treated with radon.

• Interest grew with preservation of vision.

• A variety of procedures, Isotopes, and plaque designs were developed.
  – I-125, Pd-103, Ru-106
  – Cs-131, Ir-192, Au-198, Co-60, Sr-90
1985: Collaborative Ocular Melanoma Study (COMS)

- Objective: standardization for comparison
- COMS created as a multi-institutional trial tasked with comparing plaque therapy to enucleation.
- Defined which tumors could be treated and over what period of time.
  - 2.5 to 10 mm in height and no greater than 16 mm diameter.
  - Tumor height verified accurately with ultrasound.
  - Standardized dosimetric considerations, such as prescription point.
  - Candidate requirements:
    - 21 or older
    - primary melanoma in only one eye with no history of metastatic disease.
Plaque Program at OHSU

- Program has been active for over 30 years.
- Number of cases per year has been rising.
- Currently using I-125.

![Graph showing procedures per year from 2009 to 2014.](image)
General Workflow

1. Consult & Simulation
2. Planning
3. Localization
1. Consult & Simulation

- Ophthalmology: Measure tumor dimensions

Wide-angle color fundus image collage.

A-mode & B-mode Ultrasound
1. Consult & Simulation

• There is no shortage of imaging modalities!

Optical Coherence Tomography  Contrast Angio
1. Consult & Simulation

• Radiation Oncology:
  – The physician will discuss radiation safety, treatment side effects, and expected outcome with the patient.
  – Discuss margins with physicist.
    • Typical margins are 2 – 3 mm.
    • Prescribe 85 Gy to a point.
2. Planning - Inputs

- Knowledge of seed coordinates allows the TG-43 formalism to be applied.

### Basic Plan Inputs

- Tumor Dimensions
- Prescription Pt. Coordinate
- Source Locations
- Prescription Dose
- Treatment Date & Times
- Tumor Location on Orbit?
- Special Factors?
2. Planning - TG-43 Formalism

\[
\dot{D}(r, \theta) = S_K \cdot \Lambda \cdot \frac{G_L(r, \theta)}{G_L(r_0, \theta_0)} \cdot g_L(r) \cdot F(r, \theta)
\]

• Source Strength
  – Air Kerma Strength \((S_K)\)
  – For I-125: 1 mCi = 1.27 U

• Source Type
  – Dose Rate Constant \((\Lambda)\)
  – Seed Specific: 0.981 cGy/h/U

• Location factors
2. Planning – Location Factors

- Geometry Function
- Radial Dose Function
  - Fall-off from scatter and attenuation.
- Anisotropy Function
  - Source self-attenuation

\[ G_P(r, \theta) = r^{-2} \]
\[ G_L(r, \theta) = \frac{\beta}{L r \sin \theta} \text{ if } \theta \neq 0^\circ \]
\[ G_L(r, \theta) = \left( r^2 - \frac{L^2}{4} \right)^{-1} \text{ if } \theta = 0^\circ \]
2. Planning - Verification

• An independent check and calc is needed to verify the plan and primary calculation.
  – Should be perform by independent physicist.
  – Verifying a plan requires two of the following:
    • Excel/Matlab Handcalc
    • RadCalc
    • Brachyvision
    • Pinnacle
    • Plaque Simulator
    • Nomogram
3. Localization

Method used at Cleveland Clinic
3. Localization - Verification

- OHSU does not locate suture positions prior to plaque placement.
  - Illumination / Visualization still used.
  - Plaque placement is verified by an ophthalmic echographer who uses a 10 MHz probe in B-mode.
Concerns

• What are reasonable prescription points for a given tumor?

• For a given tumor different seed activities would be ordered simply because of the calculation system being used.
Prescription Depth

• Some centers prescribe to tumor apex.
• Some use tumor apex + margin.
• Some use COMS prescription point.
• OHSU uses a tiered system:

<table>
<thead>
<tr>
<th>Tumor Depth (mm)</th>
<th>Prescription Point (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2.5</td>
<td>3.0 inside sclera</td>
</tr>
<tr>
<td>2.5 – 2.9</td>
<td>3.5 inside sclera</td>
</tr>
<tr>
<td>3.0 – 3.4</td>
<td>4.0 inside sclera</td>
</tr>
<tr>
<td>3.5 – 3.9</td>
<td>4.5 inside sclera</td>
</tr>
<tr>
<td>4.0 – 5.0</td>
<td>5.0 inside sclera</td>
</tr>
<tr>
<td>&gt; 5.0</td>
<td>Apex of Tumor</td>
</tr>
</tbody>
</table>
**Depth is Important!**

### Plaque Simulator Treatment Plan

<table>
<thead>
<tr>
<th>Tumor 1 TAX (mm)</th>
<th>Avg. dose rate (cGy/hr)</th>
<th>Total Dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>267.1</td>
<td>269.4</td>
</tr>
<tr>
<td>1.00</td>
<td>200.6</td>
<td>202.4</td>
</tr>
<tr>
<td>2.00</td>
<td>157.3</td>
<td>158.7</td>
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<tr>
<td>3.00</td>
<td>125.9</td>
<td>127.0</td>
</tr>
<tr>
<td>4.00</td>
<td>102.0</td>
<td>102.9</td>
</tr>
<tr>
<td>5.00</td>
<td>83.39</td>
<td>84.11</td>
</tr>
<tr>
<td>6.00</td>
<td>68.71</td>
<td>69.31</td>
</tr>
<tr>
<td>7.00</td>
<td>57.08</td>
<td>57.57</td>
</tr>
<tr>
<td>8.00</td>
<td>47.78</td>
<td>48.20</td>
</tr>
<tr>
<td>9.00</td>
<td>40.30</td>
<td>40.64</td>
</tr>
<tr>
<td>10.00</td>
<td>34.24</td>
<td>34.53</td>
</tr>
</tbody>
</table>

**Critical Site**

<table>
<thead>
<tr>
<th>Avg. dose rate (cGy/hr)</th>
<th>Total Dose (Gy)</th>
</tr>
</thead>
</table>
Planning Factors

There are many variables a system chooses to include or disregard in the calculation.

– Silastic Attenuation (12-15%)
– Point vs. Line Source Model
– Orbit Size
– Scleral Thickness
– Anterior Chamber Thickness
– Tissue Density
– Backscatter & Collimation
What variation exists in the US?

• A survey was designed to evaluate inter-institution consistency.
• Additional information was obtained by telephone and site visits.
• Many respondents had previously taken part in the COMS study.
Survey Question

• What seed activity would be ordered to deliver 85 Gy to your usual prescription point for the following parameters?
  – What would the tumor apex dose be under these conditions?
  – 100 hour implant time for a fully loaded plaque with an insertion time of 9:00 AM on March 10 and removal at 1:00 PM on March 14.
Survey Results

Shallow Tumors are more affected by prescription point depth.
Considerations

• Survey investigated the simplest cases.
• Actual implant durations vary from 72–168 hrs
• ABS – Ophthalmic Oncology Task Force (2014)
  – Offers guidance on Dose Prescription.
  – Following their advice to prescribe to apex and cover tumor would be a step in the right direction for standardization.
• Survey only focused on I-125
  – Pd-103 has arguable advantages.
Recent & Upcoming Literature


- ABS-OOTF: “The American Brachytherapy Society consensus guidelines for plaque brachytherapy of uveal melanoma and retinoblastoma” (Ophthalmic Oncology Task Force)
  - 47 Centers worldwide took part in their study & recommendations.

- TG-221: “AAPM Recommendations for Ocular Brachytherapy”
  - Expected publication in December of 2014.
Future Directions

• Outcome Databases
  – Wills Eye and Cleveland Clinic projects underway.

• Intraocular Silicone Oil
  – Can reduce retina dose by ~55% in some cases.

• Consideration of Pd-103
  – Majority of centers still use I-125.
  – Pd-103 has faster dose fall-off (higher gradients).

• Collaboration and standardization.
Summary

• Plaque therapy has been used to effectively treat ocular melanomas for many years.

• Opportunities exist to maintain tumor control while reducing dose to critical structures and improve preservation of vision.

• Development of standardization methods is needed.
Special Thanks

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