DOSIMETRIC VALIDATION OF THE AGX-100 I-125 SEEDS FOR ROPES EYE PLAQUE BRACHYTHERAPY

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Introduction

Purpose

Methods

Results
  i. TPS (Plaque Simulator) to RadCalc comparison
  ii. TPS to Film Dosimetry comparison

Conclusions
I-125 eye plaque brachytherapy is most commonly used to treat uveal melanoma (iris, ciliary muscle and choroid).

The ROPES (Radiation Oncology Physics and Engineering Services Australia) plaque is available in multiple sizes and attachment methods (lugs, flange, notched).

ROPES plaques used at POWH include; 11 mm, 15 mm flange, 15 mm lugs, 15 mm notched and 18 mm lugs.

Figure 1 – (a) ROPES eye plaque insertion. (b) The 15 mm ROPES eye plaque including, dummy plaque, seed carrier Perspex insert, backing and ejector plug.
INTRODUCTION

- Theragenics Corporation purchased the Oncura™ brachytherapy line from GE Healthcare, October 2016.
- Distribution of I-125 Oncoseed model 6711 was ceased in Australia.
- Limited dosimetry parameters for AgX™100 I-125 seeds based on TG-43 dose calculation, early 2017.

Figure 2 – The AgX100 low dose rate brachytherapy radioactive seed.
PHYSICAL DIMENSIONS

Oncura Oncoseed (model 6711)

- 1-125 adsorbed on silver rod
- 0.05 mm titanium
- 0.8 mm
- 3.0 mm
- 0.5 mm
- 4.5 mm

Theragenics AgX-100 seed

- Radioactive Coating (AgI)
- [1.0 - 5.0 μm]
- 0.59 ± 0.03 mm
- 4.50 ± 0.1 mm
- 3.50 ± 0.05 mm
- 0.4-0.6 mm
- 0.80 ± 0.03 mm
- 0.70 ± 0.04 mm
To validate the AgX™ 100 I-125 seeds for ROPES eye plaque brachytherapy.

- Assess AgX™ 100 I-125 seeds before they were accepted for clinical use using independent calculation systems (Plaque Simulator, RADCALC) and film dosimetry.
METHODS

Verification of AgX100 seed for use in ROPES eye plaques:

1. Implementation in TPS (Plaque Simulator)

2. Independent check (RadCalc) and comparison to TPS

3. Film dosimetry measurements and comparison to TPS
METHODS: BEBIG PLAQUE SIMULATOR (PS) V6.4.6

Treatment Planning System:
- Plaque Simulator™ (BEBIG, Germany) is used to calculate the treatment times for eye plaque insertions.
- Dose calculations in PS based on TG43 data and formalism for radioactive sources.

Upgrade:
- Plaque Simulator software upgraded from v6.0.4 to v6.4.6:
  a) To implement AgX100 seed model.

Figure 3 – Screenshot of the graphical user interface (GUI) for the Plaque simulator TPS software.
METHODS: MODELLING AGX-100 SEED

Verify Upgrade:
- Dose calculations performed on existing plans to ensure the upgrade did not have any significant effects.

Modelling:
- **Dose Rate Constant** in PS used the average value of published data,
  \( \lambda = 0.953 \text{ cGy/(U} \cdot \text{h)} \)
- **Anisotropy data** used was published by Mourtada et. al. for \( 0.25 \text{ cm} \leq r \leq 5 \text{ cm} \)
  - Linearly interpolated from 0° to 90° in steps of 1°
- **Radial function data** used in PS was published by Mourtada et. al. for \( r \leq 4 \text{ cm} \)
  - Linearly interpolated in steps of 0.02 mm

- Chen Z et al. Brachytherapy 2012; 11: 476-482
**METHODS: INDEPENDENT VERIFICATION**

**Standard plans**

- Standard treatment plans were created in PS v6.4.6 and RadCalc:
  - 11 mm, 15 mm, 15 mm (notched) and 18 mm eye plaques
  - Treatment time: 1 hour
  - Treatment depth: 0 mm (sclera) to 10 mm
  - Seed activity: 100 U (78.74 mCi)
  - Seed type: AgX100 I-125

![Figure 4 – (a) Seed arrangement in PS. (b) Seed arrangement in RadCalc.](image)

Compared results of standard plans calculated using Plaque Simulator and RadCalc.
METHODS: FILM DOSIMETRY

- All film measurements were performed using EBT3 Gafchromic Film (Ashland Inc., Wayne, NJ, USA).

- Calibration films were irradiated using a Therapax DXT 300 orthovoltage unit up to 2 Gy:
  - 10 x 10 cm² cone, 50 cm SSD, 75 kVp, HVL 2.63 mm Al

- Two sets of EBT3 Film measurements were conducted to verify the accuracy of the TPS:
  i. Single AgX100 seed in Solid Water
  ii. 15 mm ROPES eye plaque loaded with ten AgX100 seeds

Figure 5 - EBT3 calibration films.
METHODS: FILM DOSIMETRY PHANTOMS

i) Measured the dose rate for a single AgX-100 seed using EBT3 film in a Solid Water block phantom with backscatter 5 cm.

ii) Custom made Solid Water eyeball phantom with diameter of 24 mm, cut into 2 mm slices.
METHODS: EXPERIMENTAL SETUP - ROPES

- Ten 11.29 mCi AgX100 seeds loaded into a 15 mm ROPES eye plaque.
- 5 x 5 cm² pieces of EBT3 film at depths 4 mm, 6 mm, 8 mm and 10 mm.
- Each measurement had 5 cm Solid Water backscatter and an enclosed water phantom was placed on top of the plaque for full water scatter conditions.
- PS v6.4.6 prescription dose =1 Gy.
  - Times ranged between 49-106 min

Figure 8 - Schematic diagram of ROPES plaque measurements
RESULTS: PS VS RADCALC
RESULTS: DOSE CALCULATIONS

Comparison of standard plans: PS vs RadCalc

<table>
<thead>
<tr>
<th>Tumour depth (mm)</th>
<th>11mm (cGy)</th>
<th>15 mm (cGy)</th>
<th>15 mm Notched (cGy)</th>
<th>18mm (cGy)</th>
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</thead>
<tbody>
<tr>
<td>0 (inner sclera)</td>
<td>-0.7%</td>
<td>-0.6%</td>
<td>0.4%</td>
<td>2.1%</td>
</tr>
<tr>
<td>1</td>
<td>-1.3%</td>
<td>0.5%</td>
<td>1.8%</td>
<td>1.9%</td>
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<tr>
<td>2</td>
<td>-1.3%</td>
<td>0.3%</td>
<td>1.3%</td>
<td>1.6%</td>
</tr>
<tr>
<td>3</td>
<td>-1.0%</td>
<td>0.3%</td>
<td>0.8%</td>
<td>1.3%</td>
</tr>
<tr>
<td>4</td>
<td>-0.8%</td>
<td>0.1%</td>
<td>0.2%</td>
<td>0.9%</td>
</tr>
<tr>
<td>5</td>
<td>-1.0%</td>
<td>-0.3%</td>
<td>-0.2%</td>
<td>0.4%</td>
</tr>
<tr>
<td>6</td>
<td>-1.0%</td>
<td>-0.5%</td>
<td>-0.4%</td>
<td>0.1%</td>
</tr>
<tr>
<td>7</td>
<td>-1.1%</td>
<td>-0.7%</td>
<td>-0.7%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>8</td>
<td>-1.1%</td>
<td>-0.7%</td>
<td>-0.8%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>9</td>
<td>-0.9%</td>
<td>-0.6%</td>
<td>-0.8%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>10</td>
<td>-0.8%</td>
<td>-0.6%</td>
<td>-0.9%</td>
<td>-0.4%</td>
</tr>
</tbody>
</table>
EBT3 film was post-scanned 24 hours after irradiation.

Film analysis was performed using net optical density method to calculate dose planes.

Mean dose measured in a small ROI surrounding CAX for each depth.

Solid Water correction factor 1.038 applied to all measurements.

Figure 9 – (a) Single seed EBT3 film (3.63 mm depth) (b) Loaded ROPES plaque EBT3 film (4 mm depth)
## RESULTS: SINGLE AGX-100 SEED

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>EBT3 film Dose (cGy)</th>
<th>PS Dose (cGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6 ± 0.2</td>
<td>25 ± 1</td>
<td>25</td>
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<tr>
<td>3.6 ± 0.2</td>
<td>79 ± 3</td>
<td>83</td>
</tr>
</tbody>
</table>

Figure 10 - Experimental set-up of single AgX100 seed measurements
# RESULTS: 15 MM ROPES PLAQUE

<table>
<thead>
<tr>
<th>Depth (mm)</th>
<th>PS Dose (cGy)</th>
<th>EBT3 Film Dose (cGy)</th>
<th>% diff to PS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 ± 0.2</td>
<td>146 ± 6</td>
<td>149.98</td>
<td>1.6</td>
</tr>
<tr>
<td>6.1 ± 0.2</td>
<td>94 ± 4</td>
<td>97.36</td>
<td>0.8</td>
</tr>
<tr>
<td>8.1 ± 0.2</td>
<td>96 ± 4</td>
<td>98.09</td>
<td>2.4</td>
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<tr>
<td>10.1 ± 0.2</td>
<td>98 ± 4</td>
<td>98.09</td>
<td>3.7</td>
</tr>
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</table>
CONCLUSIONS

- Plaque Simulator v6.4.6 was found to be acceptable for clinical use for the Theragenics AgX100 I-125 seed with the ROPES plaques.

- Independent dose checks were performed using RadCalc v6.2.3.6 for the ROPES plaques and the agreement between Plaque Simulator v6.4.6 and RadCalc is less than 2% for clinically relevant tumour depths.

- Film dose measurements with the 15 mm ROPES plaque confirmed the validity of Plaque Simulator v6.4.6