Towards a Spectroscopic Determination of Dose To Water For Low-Energy Brachytherapy Sources

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Fall 2013 NCCAAPM
Madison, WI
Current Brachytherapy Dosimetry

- TG-43
  - TLD and Monte Carlo determined dose distributions to water
  - Tabulated for clinical use
Model-Based Dose Calculation Algorithms (MBDCAs)

- Could replace TG-43
- Boltzmann solvers and Monte Carlo that compute patient specific dose distributions
- Use computational model of the source and patient CT dataset

- How can we verify through measurement the source models used in the algorithm?
Pre-Clinical Verification Techniques

Current Technique:
- Measure dose to water with TLDs
- Compute dose to water with the MBDCA
- Compare results

Proposed Technique:
- Energy fluence emitted from encapsulation
- Medium independent verification
Emitted Energy Fluence

- Emitted energy fluence is influenced by internal source geometry
Emitted Energy Fluence

- Emitted energy fluence varies with:
  - Position on encapsulation
Emitted Energy Fluence

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Emitted Energy Fluence

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Emitted Energy Fluence

- Emitted energy fluence varies with:
  - Position on encapsulation
Emitting Energy Fluence

- Emitted energy fluence varies with:
  - Position on encapsulation
  - Direction of emission from encapsulation
• Emitted energy fluence varies with:
  – Position on encapsulation
  – Direction of emission from encapsulation
• Emitted energy fluence varies with:
  – Position on encapsulation
  – Direction of emission from encapsulation
Emitted Energy Fluence

• Emitted energy fluence varies with:
  – Position on encapsulation
  – Direction of emission from encapsulation
Emitted Energy Fluence

- Emitted energy fluence varies with:
  - Position on encapsulation
  - Direction of emission from encapsulation

(i) Energy: Primary
(ii) Energy: fluorescent
Emitted Energy Fluence

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  – Direction of emission from encapsulation

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Emitted Energy Fluence

- Emitted energy fluence varies with:
  - Position on encapsulation
  - Direction of emission from encapsulation
Emitted Energy Fluence

- How much of the variation with space and direction needs to be measured?
- Initial answer: enough that measurements could be used to accurately compute the dose distribution in water
This Work:

• Used Monte Carlo simulations to:
  – Determine the variation in the emitted fluence with position and direction of emission
  – Determine which variations impact the dose distribution
  – Determine resolution needed for dose distribution
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• Used Monte Carlo simulations to:
  – Determine the variation in the emitted fluence with position and direction of emission
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  – Determine resolution needed for dose distribution
Source Models Studied

- Oncura 6711
- Bard 1251
- Best Medical 2301
- IsoAid Advantage
- Best Medical 2335
- Theragenics Model 200
Coordinate System: Z, θ, φ
Methods: Positional and Directional Variation

- Generated phase space files of photons leaving encapsulation of each source
- Phase space files were histogrammed with bin widths given below:

<table>
<thead>
<tr>
<th>Coordinate</th>
<th>Bin Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>1 µm</td>
</tr>
<tr>
<td>Polar angle</td>
<td>0.1°</td>
</tr>
<tr>
<td>Azimuthal angle</td>
<td>1°</td>
</tr>
</tbody>
</table>
Results: Z Variation
Results: Polar Angle

Varies with respect to: Z
Results:
Azimuthal Angle

Varies with respect to: Z, θ
Results: Azimuthal Angle
Methods: Impact of Variation on Dose

• Computed dose distribution in water with original phase space file

• Altered phase space file to sample either Z, θ, or φ with a uniform probability distribution

• Computed dose distribution with each modified phase space file
Results: Impact of Variation on Dose

![Graph showing the impact of variation on dose](image-url)
Methods: Resolution Needed For Dose Calculation

• Simulated spectral measurements at a given spatial and directional resolution
• Resolutions represented collimator sizes that would be used in measurement

• Compute dose to water with simulated measurements
• Compare to actual dose distribution
Results: Resolution Needed For Dose Calculation

• Computation times became prohibitively long
• Closest dose distribution within 1.5%

<table>
<thead>
<tr>
<th>Coordinate</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>10 µm</td>
</tr>
<tr>
<td>Polar angle</td>
<td>0.01 rad</td>
</tr>
<tr>
<td>Azimuthal angle</td>
<td>1°</td>
</tr>
</tbody>
</table>
Conclusions

• The emitted energy fluence of the sources studied:
  – Have non-trivial spatial and angular variations
  – Require measurement of spatial and directional variation at high resolutions for accurate dose calculations
Future Work

• How much of the variation with space and direction needs to be measured?

• Enough that measurements could be used to accurately compute the dose distribution in water

• A subset that is sensitive to potential errors in the computational models
Acknowledgements

• Larry DeWerd
• John Micka

• UW-MRRC students and staff
• UW-ADCL customers whose calibrations provide support for research

Any questions?
Dose from the Emitted Fluence

- Can use experimental data to populate a phase space file for Monte Carlo
  - Position \((x,y,z)\), direction \((\theta,\varphi)\), energy
- Compute dose in Monte Carlo using phase space file
• Real sources have complex internal structures
Emitted Energy Fluence

- Cause non-trivial distribution of the emitted energy fluence with position and direction of emission