Calibration, dosimetry, and radiation safety for a directional brachytherapy source
AAPM Spring Clinical Meeting
Kissimmee, FL
3/31/2019

Disclosures

• Rush University is participating in a pancreatic cancer study sponsored by CivaTech and funded by the NIH.

Who needs a directional IORT brachytherapy source?

• Treat positive margins without treating adjacent tissue
• Our experience
  — 9 patients planned in previous three years
  — 3 patients cancelled at time of surgery
• Clinical trial NCT02843945

First two patients treated with CivaSheet at RUMC, treating resection margins in left psoas and left abdominal wall (Zhen et al 2018)
Outline

• Description of the CivaDot
• Review of CivaDot and CivaSheet dosimetry
• CivaDot calibration procedure
• Radiation safety concerns

Description of CivaDot/CivaSheet

• CivaDot
  – 103Pd source
  – Gold shield
• CivaSheet
  – Bioabsorbable polymer sheet
  – Source spacing 8 mm
  – Can order
    • 5x10 cm (6x12 sources)
    • 5x15 cm (6x18 sources)

Review of CivaDot and CivaSheet Dosimetry

• Source modeling
• Verification of source model
• Source strength nomogram
• Pre-and-post implant dosimetry of a directional source
Source Modeling

• Source specified for dose calculation according to modified version of TG-43 protocol
• Source parameters provided by vendor
• Modeled, E.g., in Brachyvision

TG-43 Parameters

• TG-43 parameters described by Rivard, Brachytherapy 16(2):421-432 using MCNP6
• Anisotropy functions shown
• Shows, e.g., at 10 cm from source, dose on shielded side is 20% dose on hot side

Verification of Source Model

• We independently compared TG-43 model to both MC simulation and film
• A within 1.7%
• g(r) within 0.5% for MC, 2.7% for film
• f(r,θ) within 0.9% (0-85° 100-180°)
Pre-and-post implant dosimetry of a directional source

- Difficulty of performing treatment planning in commercially available TPS (e.g., Brachyvision)
  - Determining source orientation
  - Specifying source orientation within the TPS

- In Brachyvision, the source is modeled with finite size
- Relative location of two coordinates gives source position
- Manual method: orient viewing plane orthogonal to intended source direction, and click-and-drag source
CivaDot calibration procedure

- NIST → UW ADCL → RUMC
- An HDR 1000 plus Well-typed ion Chamber with a CivaDot-specific insert was sent to Wisconsin ADCL
- An AKS calibration factor was obtained (7.912x10^11 U/A)

Reference Air Kerma Strength

- Measurement performed at UWM using VAFAC (Aima 2015)
- Tested for repeatability, compared to NIST WAFAC, and further investigated (Aima 2018)
CivaDot calibration procedure

<table>
<thead>
<tr>
<th>Source Holder Orientation (Degrees)</th>
<th>Current Vs Seed Rotation (Hot Side Up)</th>
<th>Current Vs Seed Rotation (Hot Side Down)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Current</td>
<td>2.5</td>
</tr>
<tr>
<td>90</td>
<td>Current</td>
<td>0</td>
</tr>
<tr>
<td>180</td>
<td>Current</td>
<td>0</td>
</tr>
<tr>
<td>270</td>
<td>Current</td>
<td>0</td>
</tr>
</tbody>
</table>

Seed Hot Side Up - Hot Side Down % Difference
1 54.36 53.64 1.32%
2 54.48 53.62 1.58%
3 52.58 51.84 1.41%
4 52.70 51.86 1.59%
5 52.75 51.76 1.88%
6 54.15 53.52 1.16%
7 52.46 51.63 1.59%
8 51.51 50.81 1.35%
9 52.17 51.29 1.69%
10 51.82 51.22 1.16%

Average 52.90 52.12 1.47%

EXAMPLE CALIBRATION
Patient Name: MRN

Source Information:

Measurement Devices:
- well chamber
- Source Holder
electrometer
- U/pA
- pA/
- Rdg

Measurements:

\[ S_k = M_{raw} \cdot PEL \cdot CT,P \cdot NS_k \]

Temperature: 23.1 °C

Pressure: 997.4 mbar

CT,P = \( \frac{T}{(273.15+22)} \cdot \frac{1013}{P} \)

Important: Gold Mark er faced away from the hinge cover. Rotate the holder to measure at four cardinal angles.

Readings @+300V

<table>
<thead>
<tr>
<th>Dot 1</th>
<th>Dot 2</th>
<th>Dot 3</th>
<th>Dot 4</th>
<th>Dot 5</th>
<th>Dot 6</th>
<th>Dot 7</th>
<th>Dot 8</th>
<th>Dot 9</th>
<th>Dot 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rdg1 (0°)</td>
<td>2.714</td>
<td>2.726</td>
<td>2.633</td>
<td>2.636</td>
<td>2.632</td>
<td>2.710</td>
<td>2.619</td>
<td>2.574</td>
<td>2.613</td>
</tr>
<tr>
<td>Rdg2 (90°)</td>
<td>2.758</td>
<td>2.759</td>
<td>2.662</td>
<td>2.685</td>
<td>2.685</td>
<td>2.741</td>
<td>2.668</td>
<td>2.613</td>
<td>2.646</td>
</tr>
<tr>
<td>Rdg3 (180°)</td>
<td>2.720</td>
<td>2.733</td>
<td>2.634</td>
<td>2.632</td>
<td>2.636</td>
<td>2.715</td>
<td>2.628</td>
<td>2.584</td>
<td>2.609</td>
</tr>
<tr>
<td>Rdg4 (270°)</td>
<td>2.680</td>
<td>2.679</td>
<td>2.588</td>
<td>2.588</td>
<td>2.598</td>
<td>2.664</td>
<td>2.578</td>
<td>2.531</td>
<td>2.566</td>
</tr>
</tbody>
</table>

Average (pA)

<table>
<thead>
<tr>
<th>Dot 1</th>
<th>Dot 2</th>
<th>Dot 3</th>
<th>Dot 4</th>
<th>Dot 5</th>
<th>Dot 6</th>
<th>Dot 7</th>
<th>Dot 8</th>
<th>Dot 9</th>
<th>Dot 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rdg1 (0°)</td>
<td>2.718</td>
<td>2.724</td>
<td>2.629</td>
<td>2.635</td>
<td>2.637</td>
<td>2.707</td>
<td>2.623</td>
<td>2.575</td>
<td>2.608</td>
</tr>
<tr>
<td>Source Strength (U)</td>
<td>2.206</td>
<td>2.212</td>
<td>2.134</td>
<td>2.139</td>
<td>2.141</td>
<td>2.198</td>
<td>2.130</td>
<td>2.091</td>
<td>2.118</td>
</tr>
</tbody>
</table>

Mean Source Strength

Comparison:

Central U

0.95%

Difference between Vendor and User Value

0.04

Date of User Calibration: 2/11/2019

Time of User Calibration (24h): 13:45

Expected source strength: 2.13

Decay from Vendor Calibration: 1.038

2.15

Standard deviation of the Batch

Chamber Calibration Factor:

NSk 7.970E-01

Electrometer correction factor:

PEL 0.999

CivaTech CivaDot holder 201601-11 3/17/2016

Standard Imaging SuperMax P113204

Standard Imaging HDR 1000 plus A96081 4/25/2018

Vendor Calibration Ref Date: 2/12/2019

Vendor Calibration Ref Time (24h): 11:00

Vendor Stated Source Strength: 2.049

Manufacturer

Model

Serial Number

Calibration Date

Rush University Medical Center

CivaSheet Pd-103 Source Strength Calibration

Manufacturer Civa
Radiation Safety Concerns

- Establish a policy and procedure

- Policy and procedure should include training/instructions for all required parties
- Training includes safe practices
Radiation Safety Concerns

- PHYSICIST performs calibration on 10 seeds:
  - 3 mCi/dot maximum activity → 30 mCi
  - 420 mrem/hour at 10 cm, it would take 130 hours to reach hand dose maximum
  - Can easily spend less than one minute per seed → 720 calibrations

- Compare to surgeon dose:
  - Remember: Time / distance / shielding!
  - NB: Use the tweezers, not your fingers!

References

- M.J. Rivard, A directional 103Pd brachytherapy device: Dosimetric characterization and practical aspects for clinical use, Brachytherapy 16(2):421-432
THANK YOU FOR YOUR ATTENDANCE