Proton Therapy National Ion Chamber Intercomparison

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IROC’s Mission

Provide integrated radiation oncology and diagnostic imaging quality control programs in support of the NCI’s NCTN Network thereby assuring high quality data for clinical trials designed to improve the clinical outcomes for cancer patients worldwide.
IROC Proton Activities

• Proton facility questionnaire
• Annual remote output checks
• Proton phantom audits
• On-site dosimetry review
• Clinical trial knowledge assessments
• IGRT credentialing
Proton Calibration Protocol History

• 1998: ICRU 59 Protocol
  1) air kerma ($N_x$) calibration -or-
  2) absolute dose to water ($N_{D,w}$) calibration
     – Most early institutions used air kerma calibration

• 2000: IAEA TRS 398 Protocol
  – Absolute dose to water calibration

• 2007: ICRU 78
  – Endorsed use of TRS 398
Experimental Goals

NIST, IROC (then the RPC), and NCI organized ion chamber round robin with goals to:

• Compare individual users’ calibrations with a standard calculation
• Compare different proton calibration protocol results
• Derive consensus $k_Q$ values for new calibration ion chambers
Experimental Design

- 9 proton institutions participated, as well as NIST and IROC
- 22 ion chambers (11 thimble and 11 parallel plate) used
Experimental Design

- Each chamber freshly calibrated at MD Anderson Accredited Dosimetry Calibration Laboratory (ADCL)
- Received in-air \( (N_x) \) and in-water \( (N_{D,w}) \) calibration factors
Experimental Design

- 2 “clinical” scattered proton beam configurations used: brain and prostate
- Measurements performed in water
- Each user measured dose per monitor unit
## Experimental Design

<table>
<thead>
<tr>
<th>Simulated Treatment Site</th>
<th>Prostate</th>
<th>Brain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>250 MeV</td>
<td>120 MeV</td>
</tr>
<tr>
<td>Scatterer size</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Applicator size</td>
<td>small</td>
<td>medium</td>
</tr>
<tr>
<td>R$_{90}$</td>
<td>260 mm H$_2$O</td>
<td>60 mm H$_2$O</td>
</tr>
<tr>
<td>R$_{10}$</td>
<td>270 mm H$_2$O</td>
<td>63 mm H$_2$O</td>
</tr>
<tr>
<td>M$_{95-90}$</td>
<td>96 mm H$_2$O</td>
<td>34 mm H$_2$O</td>
</tr>
<tr>
<td>Aperture size</td>
<td>96 mm x 96 mm</td>
<td>46 mm x 46 mm</td>
</tr>
<tr>
<td>Aperture-to-surface distance</td>
<td>70 mm</td>
<td>85 mm</td>
</tr>
<tr>
<td>Chamber position</td>
<td>at isocenter</td>
<td>at isocenter</td>
</tr>
<tr>
<td>Chamber depth</td>
<td>212 mm H$_2$O</td>
<td>45 mm H$_2$O</td>
</tr>
<tr>
<td>Residual range</td>
<td>58 mm H$_2$O</td>
<td>18 mm H$_2$O</td>
</tr>
</tbody>
</table>
Experimental Design

• D/MU calculated by each user using the TRS 398 $N_{D,w}$ method with fresh chamber factors
• D/MU calculated by a single user using the TRS 398 $N_{D,w}$ method with fresh chamber factors
• D/MU calculated by a single user using the ICRU 59 $N_x$ method with fresh chamber factors
• D/MU calculated by a single user using the ICRU 59 $N_{D,w}$ method with fresh chamber factors
Preliminary Findings

• None of the clinical users were still using ICRU 59 – all had transitioned to TRS 398
• We’ll focus on variations in D/MU determined by multiple users as compared to single user
Results: Brain Field

**Multi-user**
- max-to-min = 2.75%
- 2 SD = ± 1.54%
- Difference between thimble chamber and parallel plate results

**Single user**
- max-to-min = 2.32%
- 2 SD = ± 1.22%
- Slightly smaller spread than for multi-user determinations
- Smaller difference between thimble and parallel plate than multi-user results
Results: Prostate Field

Multi-user
- max-to-min = 2.97%
- 2 SD = ± 1.62%
- Similar spreads to that demonstrated with ICRU 59 $N_x$ method in 1998 intercomparison (Vatnitsky)

Single user
- max-to-min = 1.75%
- 2 SD = ± 1.05%
- Significantly smaller spread than for multi-user determinations
Results: New $k_Q$ Values

Results suggest better consistency could be obtained using new $k_Q$ values for $R_{res}$ between 18 - 50 mm

- T1v2, T1v3: 1.014  
  - T1v1 value = 1.006
- Markus 23343: 1.010  
  - old value = 1.003
- Markus 34045: 0.997  
  - no previous value
- PPC05: 1.007  
  - no previous value
Takeaways

• The spread of D/MU values using the TRS 398 $N_{D,w}$ method and different detectors is similar to results of previous intercomparisons, slightly larger than using ICRU 59 $N_x$ method, and smaller than the spread of values using ICRU 59 $N_{D,w}$ method.

• Use of the TRS 398 $N_{D,w}$ method by multiple institutions can provide sufficiently consistent results for use in inter-institutional protocols.
Future Calibration Protocol Development

\[ k_s = \alpha_0 + \alpha_1 \left( \frac{M_1}{M_2} \right) + \alpha_2 \left( \frac{M_1}{M_2} \right)^2 \]

• High instantaneous dose rate requires adjustment of \( k_s \) measurements
  – Users switch to higher calibration bias (e.g. 400 V instead of 300 V), or use continuous equation instead of pulsed/pulsed-scanned
  – TRS 398 working on update, has solicited feedback
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Thank you.
Questions?