Mission

1. Assure NCI and cooperative groups that institutions participating in clinical trials deliver prescribed doses that are comparable and consistent. (Minimize dose uncertainty)

2. Help institutions to make any corrections that might be needed.

3. Report findings to the community.

IROC QA Program (2015)

55 countries
IROC-H Verification of Delivery of Tumor Dose

- Reference calibration (NIST traceable) evaluated by IROC Dosimeters
- Correction Factors: Field size & shape, Depth of target, Transmission factors, Treatment time evaluated by IROC visits and chart review
- Tumor Dose evaluated by IROC phantoms

On-Site Dosimetry Review Audit

TG-51 Addendum

Addendum to the AAPM’s TG-51 protocol for clinical reference dosimetry of high-energy photon beams

- Defines reference class chambers (V≥0.05cm³) performance (Table III)
- Includes new chamber models
- New radial beam profile correction (FFF beams)
- Provides clarity but also reaffirms the recommendations of TG-51
Ion Chambers - Photons

- ADCL calibrated 0.6 cm³
  - Smaller volume chambers (> 0.05 cm³) okay if traceable to another 0.6 cm³ and meets requirements of Table III in addendum
- NO parallel plate chambers
- Waterproof (Go ahead and get one)
  - Most common: Exradin A12, PTW 30013
- Non waterproof needs a 1mm PMMA sleeve that does not leak!

Ion Chambers - Electrons

- Parallel-plate or cylindrical chambers okay
  - Cylindrical for energies > 6 MeV per protocol (R₁₀ ≥ 2.6 cm)
  - Cylindrical – parallel plate if care in placement
- Always use a parallel plate chamber for 4 MeV beams
  Caution as to where the inside surface of the front window is located

<table>
<thead>
<tr>
<th>P11</th>
<th>FTW Ros</th>
<th>Verhagen Ros</th>
<th>Marcus</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.000 (+1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.002 ± 0.1% (+3)</td>
<td>1.002 (+1)</td>
<td>0.999 ± 0.3% (+2)</td>
</tr>
<tr>
<td>8</td>
<td>1.000 (+1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1.003 ± 0.1% (+3)</td>
<td>0.998 (+1)</td>
<td>0.998 (+1)</td>
</tr>
<tr>
<td>12</td>
<td>1.000 ± 0.1% (+3)</td>
<td>0.997 ± 0.2% (+2)</td>
<td>0.995 (+1)</td>
</tr>
<tr>
<td>16</td>
<td>1.003 ± 0.1% (+3)</td>
<td>0.998 ± 0.2% (+2)</td>
<td>1.001 ± 0.8% (+2)</td>
</tr>
<tr>
<td>20</td>
<td>1.000 ± 0.1% (+3)</td>
<td>1.002 (+1)</td>
<td>1.000 ± 0.1% (+1)</td>
</tr>
</tbody>
</table>

Ion Chambers - Electrons

- All chambers must have an ADCL calibration coefficient EXCEPT PARALLEL PLATE CHAMBERS
  - AAPM recommendation is to cross calibrate parallel plate chamber with cylindrical chamber in a high energy electron beam (worksheet C a la TG-39)
  - ADCL N_D,w = good  TG-51 k_ecal = bad
  - Use of (N_D,R,w*k_ecal) results in an error of 1-2%
    ONE EXCEPTION – Exradin P11 seems to be okay
  - FUTURE: TG-51 electron addendum new k_ecal values
Measurement Techniques

- Accurate placement of cylindrical ion chamber at depth (<0.1 mm)
  - Whether manual or electronic motor driven, there must be a **starting reference point**

Two techniques

1. Surface method

   ![Surface method diagram](image)

2. “Cowboy” method

   ![Cowboy method diagram](image)

- Accuracy depends on cutting ruler
- Used for reference starting point
- Periodic check of depth

Measurement Techniques

- Parallel plate ion chambers
  1. Flat surface makes it easy to measure depth
  2. Accurate ruler needed
  3. Must know where the inside surface of the front window is located
Effective Point of Measurement and Beam Quality

- **Photons**
  - Calibration depth: 10 cm
  - "Point of measurement" is the center electrode of a cylindrical chamber and the front window of a parallel plate chamber

- **Electrons**
  - Calibration depth: $d_{ref}$

Beam quality should always be measured using the "effective point of measurement".

- $0.6r_{cav}$ shift to effective point
- $0.5r_{cav}$ shift to effective point

Beam quality should always be measured using the "effective point of measurement".

- $R_{50}$ beam quality SSD: 100 cm
- Field size: $\geq 10 \times 10 \text{ cm}^2$

Beam Quality Conversion Factors

- **Photons**
  - $k_Q$
  - Tabular values much easier to read

- **Electrons**
  - $k_{R_{50}}$
  - Only small figures, no tables

Beam Quality Conversion Factors

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For spreadsheets plot the tabular data and derive empirical fit for specific chamber.

Be sure to have an independent check of the empirical fit function.

**Beam Quality Conversion Factors**

- **Photons**
  - $k_Q$
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- **Electrons**
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Good figures at:

**Charge Measurements**

\[ M = P_{\text{ion}} \times P_{\text{TP}} \times P_{\text{elec}} \times P_{\text{pol}} \times M_{\text{raw}} \]

- **\( P_{\text{TP}} \) correction factor**
  - Mercury thermometers and barometers most accurate (but they are no longer kosher)
  - Hg barometers T&G corrections needed
  - Quality aneroid or digital can be used
    - Check annually against a standard
    - Digital purchased with a calibration does not mean accurate but rather what it read at certain pressures or temperatures

- **\( P_{\text{elec}} \) correction factor**
  - ADCL calibration for each scale needed

- **\( P_{\text{pol}} \) correction factor**
  - Change polarity requires irradiation (600 to 800 cGy) to re-equilibrate chamber
  - Use of eq 9 in TG-51 requires that you preserve the sign of the reading or

\[
P_{\text{pol}} = \frac{M_{+}^{\text{raw}} + M_{-}^{\text{raw}}}{2|M_{\text{raw}}|}
\]

  - \( P_{\text{pol}} \) should be near unity for cylindrical chambers and slightly larger correction for parallel plate chambers

---

**Charge Measurements**

- **\( P_{\text{ion}} \) correction factor**
  - High dose rate capabilities result in higher \( P_{\text{ion}} \)
  - Change in bias requires irradiation (600 to 800 cGy) to re-equilibrate chamber.
  - \( P_{\text{ion}} \) depends on chamber, beam energy, linac and beam modality
    - Greater than 1.000
    - Tends to increase with energy

\[
\begin{align*}
0.975 & \quad 0.980 \\
0.985 & \quad 0.990 \\
0.995 & \quad 1.000 \\
1.005 & \quad 1.010 \\
1.015 & \quad 1.020
\end{align*}
\]

---

**Charge Measurements**

<table>
<thead>
<tr>
<th>Sequence #</th>
<th>Response norm to 1st rdg (-300V) for a beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor</td>
<td>à A-12' D NEL'' X PTW''</td>
</tr>
<tr>
<td>Monitor</td>
<td>@ d10 6 x @ d10 18 x</td>
</tr>
<tr>
<td>Monitor</td>
<td>@ d5 18 x</td>
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<tr>
<td>Monitor</td>
<td>@ dm 20 e @ dm 6 e</td>
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</tbody>
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<table>
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<tr>
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<tbody>
<tr>
<td>250 kV</td>
<td>Monitor</td>
<td>à A-12' D NEL'' X PTW''</td>
</tr>
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<td>250 kV</td>
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<td>Monitor</td>
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</tr>
</tbody>
</table>
Charge Measurements

- Electron beam gradient ($P_{gr}$) correction factor
  - No correction for photon beams since correction included in $k_Q$
  - Only for cylindrical ion chambers
  - Ratio of readings at two depths
    \[ P_{gr} = \frac{M(d_{ref} + 0.5r_{cav})}{M_{raw}(d_{ref})} \]
    - The reading at $d_{ref} + 0.5r_{cav}$ should have the same precision as the reading at $d_{ref}$ since:
      \[ \text{Dose} = M(d_{ref}) \times \text{(many factors)} \times \frac{M(d_{ref} + 0.5r_{cav})}{M(d_{ref})} \]

Charge Measurements

- Electron beam gradient ($P_{gr}$) correction factor
  - $E < 12$ MeV; typically $P_{gr} > 1.000$
  - $E \geq 12$ MeV; typically $P_{gr} \leq 1.000$
  - Why? Because for low electron energies $d_{ref} = d_{max}$ and this places the eff. pt. of measurement in the build up region thus a ratio of readings greater than 1.000.
  - At higher electron energies $d_{ref}$ is greater than $d_{max}$ and as such the eff. Pt. of measurement is on the descending portion of the depth dose curve thus a ratio of readings less than 1.000.
Clinical Depth Dose

- Always measure using the effective point of measurement
  - Re-measurement not suggested for existing Linacs, but TG-51 came out in 1999. New Linacs should incorporate shift
- Always use the clinical depth dose (value TPS calculates) to make the correction from the calibration depth (10 cm) to the reference depth ($d_{\text{max}}$)
  - Calibration now consistent with TPS dose calculation

Clinical Depth Dose

- For photons – do not use the beam quality value $\%dd(10)_x$ to take dose from 10 cm to $d_{\text{max}}$
- For electrons – depth dose correction for $\geq 15/16$ MeV is significant ($\sim 98.5\%$ - 16 MeV and $\sim 95.5\%$ - 20 MeV)
  - Caution!!! Super big problem if you use % depth ionization data (3-5% error for high energy electron beams)
## MLC QA a la TG-142

### Criteria
- **3%/2 mm**

### Measurement vs. Monte Carlo

- **Varian 6 MV IMRT H&N**
- **Criteria**
  - **3%/2 mm**

### Heterogeneity Corrections

<table>
<thead>
<tr>
<th>Percent of area with a certain value</th>
<th>Percent of area with a certain value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
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<td>40</td>
<td>60</td>
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</tr>
<tr>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

### It's all about leaf position accuracy!
Lung: TLD dose vs TPS calc

C/S and MC (Multiplan) show a difference

Acuros shows good results, but not identical

Monte Carlo results are not consistent
**TLD Dose Findings**

- Measured doses systematically lower than calculated doses for C/S AAA algorithms (p<0.0001)
- No significant difference between C/S AAA algorithms

---

**Small Field Dosimetry**

**What is the truth?**

Help is on the way!

Joint AAPM/IAEA Small Field Dosimetry CoP will be published soon.

---

**Small Field Dosimetry Volume Averaging Correction**

G. Azangwe, Med Phys. 41 (7) 2014
Situation is even worse if you consider using field sizes less than 0.5 x 0.5 cm²

Proton Therapy

Human tissue: equal in the eyes of both photons and protons

Tissue Substitutes: There’s discrimination, as they are not equal in the eyes of photons and protons
Not so good…..

Stopping Power vs. HU Curve

Summary
- TG-51 Implementation is straightforward
  - Must read the protocol and follow the prescriptive steps
  - Many suggestions to clarify confusion have been made
- MLC QA is critical
- Heterogeneity correction algorithms are not all the same
- Small field dosimetry requires extra attention
- Proton tissue substitutes are unique
- IROC Houston QA Center is always available for assistance. Give us a call if you have questions.