Dosimetry audits in radiotherapy: IAEA perspective

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IAEA methodology for dosimetry audits

Remote audits (TLD/RPLD, film)  On-site audits (IC, film)

Reference dosimetry, beam parameters and end-to-end audits
Participants in the IAEA/WHO postal audits:
>2200 radiotherapy centres in 132 Member States
IAEA/WHO TLD results for Co-60 and high energy X rays, 1969-2016

Currently >95% of the results are within 5% acceptance limit
## IAEA/WHO TLD results analysis (1)

### Centre size

<table>
<thead>
<tr>
<th></th>
<th>1 machine</th>
<th>2 machines and more</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>N, %</td>
<td>N</td>
</tr>
<tr>
<td>res. &lt;5%</td>
<td>1536</td>
<td>79</td>
</tr>
<tr>
<td>res. 5-10%</td>
<td>188</td>
<td>10</td>
</tr>
<tr>
<td>res. 10-20%</td>
<td>150</td>
<td>8</td>
</tr>
<tr>
<td>res. &gt;20%</td>
<td>65</td>
<td>3</td>
</tr>
</tbody>
</table>

### Medical accelerator vs. Co-60 units

- **Medical accelerator**: 96% of results are within the 5% acceptance limits. Of these, 1% are between 5-10%, 1% are between 10-20%, 2% are between 20% and more.

- **Co-60 units**: 87% of results are within the 5% acceptance limits. Of these, 7% are between 5-10%, 3% are between 10-20%, 3% are between 20% and more.

### Age of RT machine (years)

<table>
<thead>
<tr>
<th>Age of RT machine (years)</th>
<th>Percentage of results outside the 5% acceptance limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5</td>
<td>5%</td>
</tr>
<tr>
<td>6 to 10</td>
<td>10%</td>
</tr>
<tr>
<td>11 to 20</td>
<td>15%</td>
</tr>
<tr>
<td>21 to 30</td>
<td>20%</td>
</tr>
<tr>
<td>30 and more</td>
<td>30%</td>
</tr>
</tbody>
</table>

Larger radiotherapy centres having newer linacs perform better than single machine centres equipped with old Co-60 units.
### IAEA/WHO TLD results analysis (2)

<table>
<thead>
<tr>
<th>Protocol</th>
<th>N</th>
<th>N, %</th>
<th>Before follow up</th>
<th>After follow up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N (res. &lt;5%), %</td>
<td>N (res. &lt;5%), %</td>
</tr>
<tr>
<td>ND, w based</td>
<td>4545</td>
<td>59</td>
<td>96.7</td>
<td>99.0</td>
</tr>
<tr>
<td>Nk based</td>
<td>1354</td>
<td>18</td>
<td>93.9</td>
<td>98.6</td>
</tr>
<tr>
<td>Nx based</td>
<td>364</td>
<td>5</td>
<td>80.5</td>
<td>94.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>1422</td>
<td>19</td>
<td>82.4</td>
<td>92.8</td>
</tr>
</tbody>
</table>

- **First participation in the TLD audit**
  - 78% <5%
  - 11% 5-10%
  - 7% 10-20%
  - 4% 20% and more

- **Subsequent participation in the TLD audit**
  - 86% <5%
  - 8% 5-10%
  - 4% 10-20%
  - 2% 20% and more

Currently 98% of results are within 5% acceptance limit after follow-up.

Radiotherapy centres participating regularly in IAEA/WHO dose audits and using modern dosimetry protocols have better results than newcomers to the audit programme.
1. Dosimetry audit methodologies for national dosimetry audit networks (DAN) are developed through IAEA consultants meetings.

2. Feasibility studies are conducted by the IAEA staff in co-operation with the Medical University of Vienna.

3. Multicentre pilot studies are organized by the IAEA with project participants to test the methodologies internationally.

4. Pilot audit runs are organized by DANs with a few local RT centres to test the methodologies locally.

Dosimetry audit methodologies are available on request: dosimetry@iaea.org
Remote audit: small beams

- TLD output check and film profile for small photon MLC shaped fields.
- Photon beam small field output factors (OF) shaped with an MLC

Beam output and beam profiles for fields: 2 x 2 cm² (film) and 2 x 5 cm² (TLD and film)


Participants:
Algeria, Brazil, China, Cuba, Czech Rep., India, Poland, Thailand; Austria, Belgium, Finland, Sweden, UK, USA
Small beam pilot study: film results

6 MV, Varian Trilogy, Eclipse 8.6

- Good agreement for 50% isodose does not mean the rest of the profile is well modelled by TPS.
- The agreement of the cross-plane profiles is less satisfactory than for the in-plane profiles (leaf ends modelling, TPS commissioning, MLC positioning uncertainty).

6 MV, Varian Clinac 600 C, Eclipse 8.6
Small beam audit: OF results by DANs

OF generated/published for Elekta, Monaco

OF generated/published for Siemens, Prowess Panther

OF generated/published for Varian, Eclipse

<table>
<thead>
<tr>
<th></th>
<th>Field size (cm²)</th>
<th>2x2</th>
<th>3x3</th>
<th>4x4</th>
<th>6x6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1.012</td>
<td>1.005</td>
<td>0.997</td>
<td>0.996</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.012</td>
<td>0.010</td>
<td>0.009</td>
<td>0.007</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>6x6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>0.992</td>
<td>0.997</td>
<td>1.003</td>
<td>1.005</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.045</td>
<td>0.016</td>
<td>0.012</td>
<td>0.008</td>
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</table>

<table>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>94</td>
<td>96</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>1.030</td>
<td>1.017</td>
<td>1.011</td>
<td>1.003</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>0.031</td>
<td>0.013</td>
<td>0.012</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Participating RT centres:
Algeria, Brazil, China, Cuba, Czech Rep., India, Poland, Thailand
Acceptance limits:
- ±7% for TLD in PTV
- TLD dose at OAR <2.8 Gy
- EBT3 film: 90% pixels passing gamma criteria (3 mm, 3%, 20% threshold).

Average gamma results = 98.7%
min = 91.0%, max = 100%

<table>
<thead>
<tr>
<th>Position</th>
<th>Mean $D_{\text{meas}}/D_s$</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTV_S</td>
<td>0.995</td>
<td>0.030</td>
</tr>
<tr>
<td>PTV_I</td>
<td>0.992</td>
<td>0.026</td>
</tr>
<tr>
<td>OAR_S</td>
<td>1.018</td>
<td>0.065</td>
</tr>
<tr>
<td>OAR_I</td>
<td>1.005</td>
<td>0.053</td>
</tr>
</tbody>
</table>
IAEA on-site audit procedures

Dosimetry audits of beam parameters for teletherapy, TPS calculations and brachytherapy

Verification of TPS calculations for 3D conformal treatment techniques through end-to-end audit
IAEA supported TPS audit in Europe

Dosimetric verification of radiotherapy treatment planning systems in Serbia: national audit
Laza Ristic1,2, Zorica Petrovic1,2, Milutin Bauca1,2, Miljan Teodorovic1,2, Ognen Cudic1,2, Eduard Gershlevskii3 and Joanna Iwowska3

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Treatment planning systems dosimetry auditing project in Portugal
M.C. Lopes1,2,3, A. Cavaço4, K. Jacob5, L. Medeiros1, S. Germano6, S. Faustino1, J. Lencastre7, M. Trindade7, J. Vale7, V. Batal7, M. Sousa7, A. Bombardi8, S. Brígido8, S. Macedo8, P. Pepin9,10, E. Díaz11, A. Martins11, A. Pinheiro12, F. Marques12, C. Deliza12, L. Silva12, M. Rodrigues12, L. Carneiro12, E. Gershlevskii3,1 and Joanna Iwowska3,1

Acta Oncologica

Original article
Dosimetric inter-institutional comparison in European radiotherapy centres: Results of IAEA supported treatment planning system audit
Edunard Gershlevskii1, Osiola Poczyniak2, Zorica Petrovic2, Joseph Giacca3, Krzysztof Chelmiksi3, Maria do Carmo Lopes4, Joanna Iwowska5 and Jacob Van Dyk6,7
1North Estonian Medical Centre, Department of Radiotherapy, Tallinn, Estonia
2National Institute of Oncology, Budapest, Hungary
3Institute of Oncology Vojvodina, Sremci Kamenica, Serbia
4St. Elizabeth Institute of Oncology, Bratislava, Slovakia
5M. Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Warsaw, Poland
6Portuguese Institute of Oncology, Lisbon, Portugal
7North Estonian Medical Center, Department of Radiotherapy, Tallinn, Estonia

6 MV Varian HE, Eclipse AAA

% of measurement points exceeding agreement criteria

Centres

Frequency

Calibration
Output wedge factor
Beam fitting
Small field output
Wedge positioning
CT to ED conversion

description of problem
The IAEA develops methodology for on site IMRT/VMAT H&N end-to-end audits currently tested in a multicentre pilot study.

The audit uses anatomical structures of a specially designed CIRS SHANE phantom.

Implementation: training of auditors and circulation of the dedicated phantom among countries.
Lessons learnt

• Audits offer resolution of discrepancies in dosimetry
• Audits lessen the likelihood of major errors
• Audits reduce smaller errors leading to reduced uncertainties in the dose delivery
• Audits provide confidence when introducing new technologies
• Audits improve treatment quality for many patients

Audits improve radiotherapy practices
Acknowledgments: IAEA past staff, consultants and participants in the IAEA coordinated research projects on dosimetry audits in radiotherapy.

THANK YOU