Mailed dosimetry auditing in Proton Therapy
Eurados intercomparison of passive dosimeter response in proton spot scanning beam

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The European Radiation Dosimetry Group (EURADOS)
- Network of more than 67 European institutions (Voting Members) and 300 scientists (Associate Members)

WG9 – Radiation Dosimetry in Radiotherapy
- Out-of-field dose assessment in RT
- Neutron dosimetry in PT
- Mail dosimetry auditing in PT
Dosimetry auditing of proton therapy centres
- Not yet available in Europe
- Lack of international and national primary dose standards for proton beams
- Need for harmonization

Dosimetry auditing of photon therapy centres
- International program of IAEA
- National programs for mail auditing radiotherapy centres
- Mainly using Alanine or TLD

*TLD Postal Dose Audit Service*
Passive dosimeter systems

- **Alanine**
- Thermoluminescent Dosimeters (TLD)
  - MCP-n
  - MTS-n
- Optically stimulated luminescent detectors (OSL)
  - Luxel
- Radiophotoluminescent detectors (RPL)
  - GD-302M
    - No filter
  - GD-352M
    - Filter

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<tr>
<th>SCK-CEN Technique</th>
<th>Detector</th>
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<tbody>
<tr>
<td>TLD</td>
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<td>OSL</td>
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Proton spot scanning beam

- Cyclotron Center Bronowice (CCB) – IFJ, Krakow, Poland
- Proteus C-235 cyclotron (Ion Beam Applications S.A., Belgium)
- Protons of up to 230 MeV can hence be delivered to the clinical target volume using the Pencil Beam Scanning (PBS)
- PTW 41023 water phantom
- Proton therapy SOBP
  - 10 cm x 10 cm field
  - Different layers defining
    - ≠ Range
    - ≠ Modulation
- Theratron 780E (Co60)
  - TRS-398

Irradiation conditions

Position the dosimeter reference point in the middle of the SOBP

TLD, OSL, RPL

Dw = 2 Gy

Alanine

Dw = 10 Gy
- **SOBP configurations**
  - Change the **modulation** width
    - Range 20 Modulation 5 (R20M5)
    - Range 20 Modulation 10 (R20M10)
    - Range 20 Modulation 15 (R20M15)
    - Range 20 Modulation 20 (R20M20)
  - Change the **range**
    - Range 5 Modulation 5 (R5M5)
    - Range 10 Modulation 5 (R10M5)
    - Range 15 Modulation 5 (R15M5)
    - Range 20 Modulation 5 (R20M5)
    - Range 25 Modulation 5 (R25M5)

- **Data analysis**
  - **Relative efficiency** of the dosimeters to Co60 in the different PT configurations
  - Dosimeter and batch **reproducibility** (repetitive irradiations and/or readings in Co60 (>5 repetitions))
Monte Carlo simulations

- Monte Carlo simulations (using MCNPx 2.7.0)
  - Proton energy spectrum in the position of the dosimeter (middle of the SOBP)
  - Average proton energy/LET

![Graph showing proton energy spectra and average proton energy/LET in different depths.](image-url)
**Monte Carlo simulations**

- Increased energy in the middle of the SOBP for larger modulation width
- Comparable energy spectrum for different ranges same modulation in the middle of the SOBP

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<tr>
<th></th>
<th>R5M5</th>
<th>R10M5</th>
<th>R15M5</th>
<th>R20M5</th>
<th>R25M5</th>
<th>R20M5</th>
<th>R20M10</th>
<th>R20M15</th>
<th>R20M20</th>
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<tr>
<td><strong>Average energy (MeV)</strong></td>
<td>44.3</td>
<td>45.87</td>
<td>47.1</td>
<td>47.6</td>
<td>47.8</td>
<td>47.6</td>
<td>67</td>
<td>85</td>
<td>100.7</td>
</tr>
<tr>
<td><strong>Average LET (keV/um)</strong></td>
<td>1.38</td>
<td>1.35</td>
<td>1.32</td>
<td>1.31</td>
<td>1.31</td>
<td>1.31</td>
<td>1.00</td>
<td>0.83</td>
<td>0.73</td>
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Range ↑ Modulation ↑
Response Alanine

- Relative response was between 6% and 4% lower in proton fields compared to Co60
- With minimal rise for increased modulation (increased energy/decreased LET)
- No significant difference between alanine (ISS vs UH)

Minimal rise in the response for increased modulation

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<th>Alanine</th>
<th>Institute</th>
<th>ISS</th>
<th>UH</th>
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<tr>
<td>Dosimeter reproducibility</td>
<td>0.67%</td>
<td>0.62%</td>
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<tr>
<td>Batch reproducibility</td>
<td>0.81%</td>
<td>0.38%</td>
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</table>
- Relative response to Co60 between 0.67 and 0.78
- Increased response for increasing modulation (same range)
- No influence on response changing the range (same modulation)
- Response is inversely proportional to LET

### TLD (MCP-n)

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<th>1.94%</th>
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<td>Batch reproducibility</td>
<td>1.78%</td>
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Relative TLD efficiency of MTS-N and MCP-n on proton LET.

*M. Sadel et al., Radiation Measurements 82 (2015) 8-13*
• Relative response to Co60 between 0.86 and 0.96
• No difference observed for changing modulation/range
• Large error bars (1.8-6 %)
  • Sample holder positioning not dedicated for Luxel pellets
  • Repositioning in reading system

Sawakuchi, et al. AIP 2008
- Relative response to Co60 between 0.79 and 0.85
- GD-302M (without filter) has higher response compared to GD-352M (with filter) except for R20M20 and R25M25
LET dependence of RPL detectors

Response inversely proportional to LET
Similar for GD-352M and GD-302M

Response in function of range

Increased response for higher range
Conclusions and future steps

Response of different passive detector systems in clinically used proton spot scanning beam

- Alanine most promising
- TLD (MCP-N)
  - Response inversely proportional to LET - Corrections will be needed
- OSLd (Luxel) large uncertainties
- RPL – LET dependent

Auditing of PT centres with detectors from different institutes (2017)

- PTCOG/Eurados
- Perform auditing of 10 centres for eye proton therapy
- Alanine pellets from 3 different institutes (IFJ, ISS, Uhasselt) as well as RPLs (RBI)
THANKS!!!