Measuring very small field output factors with a Roos chamber

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Small field reproducibility

- The reproducibility with which a SRS system is able to deliver planned field sizes is critical.
- Charles et al. have shown a 1 mm change in field size may result in central axis dose errors from 1.7% to 20% (increasing with decreasing field size), for fields ≤12 mm.
- Kairn et al. have identified variations of up to 2.2 mm between measured dimensions of nominal 6×6 mm² fields, leading to central axis dose differences of 11%.
- Neal et al. reported differences of 1.3 mm between observed and logged MLC positions.
- Establishing small field reproducibility can be time consuming (water tanks or film).
Crowe, Kairn, Charles, Inness performed a national audit of field size variation using EBT3 film covering 36 combinations of beam production, collimator system and beam quality.

Standard deviations in MLC defined field edges of 0.5 mm frequently observed.
Dose area product

- Integral dose area product measurements are quick and easy
- Use with small radiotherapy fields is not a new idea
- In the literature:
  - Large area chambers used
    - PTW Bragg peak chamber, with entrance window diameter of 8.4 cm
  - Measurement of dose area product / dose length product also obtained by scanning the field
- Here we examine characterisation of collimator position reproducibility using ubiquitous Roos chamber
Experimental setup

- Roos chamber (PTW34001) used
  - largest parallel plate chamber, other than an interesting survey meter

- Roos output ratio, $ROR = \left( \frac{M_{\text{field}}}{M_{10\times10}} \right)_{\text{Roos}}$
  - Differs from conventional output factor due to effect of guard ring

- Measurements performed using jaws, Millennium 120 MLC, and BrainLab micro-MLC
- 100 MU delivered, 95 cm SSD, measurement at 5 cm depth, with 10 cm backscatter
- Centre of chamber aligned using crosshairs
Experimental setup

- EBT3 film placed immediately above chamber (i.e. at isocentre)
  - Used for field size measurement
- Roos chamber reproducibility tested before and after irradiations using a $10 \times 10 \text{ cm}^2$ field
  - Standard deviations approximately 0.2% of mean signal
- For MLC fields, jaws were 5 mm from leaf edges in direction of motion and 2 mm from leaf boundaries orthogonal to direction of motion
- Measurements made at some larger fields to evaluate behaviour in fields exceeding active area of the chamber

<table>
<thead>
<tr>
<th>Collimator</th>
<th>Constant dimension (cm)</th>
<th>Varied dimensions (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jaws</td>
<td>1.0</td>
<td>0.8, 0.9, 1.0, 1.1, 1.2</td>
</tr>
<tr>
<td>M120</td>
<td>1.0</td>
<td>0.8, 0.9, 1.0, 1.1, 1.2</td>
</tr>
<tr>
<td>m3 µMLC</td>
<td>1.2</td>
<td>1.0, 1.1, 1.2, 1.3, 1.4</td>
</tr>
<tr>
<td>m3 µMLC</td>
<td>0.6</td>
<td>0.4, 0.5, 0.6, 0.7, 0.8</td>
</tr>
</tbody>
</table>
Nominal and measured field sizes

![Nominal and measured field sizes graph](image)
Results

- Linear relationship observed between field width and measured ROR
  - For field sizes smaller than Charles et al.'s ‘very small field’ definition (15 mm)
  - Gradient of approximately 30 %/cm² (i.e. 0.3 %/mm²)
  - 1 mm change in 1×1 cm² field area results in a 3% change in ROR
  - Allowing for uncertainties arising from reproducibility (0.21%) and regression (0.95%), this system is capable of detecting a 0.33 mm leaf position change in a 1×1 cm² field area
- 1 mm shifts in Roos chamber position (corresponding to laser localisation tolerance in TG142) resulted in a mean dose difference of 1.2%
  - Low sensitivity to setup errors compared to diodes
Testing suitability of a linac for SRS

1. Position Roos chamber at isocentre in a water equivalent phantom
2. Take five to ten readings at reference field size, to establish measurement reproducibility
3. Take two or more readings at the smallest field size intended for use in SRS
4. Open and close the collimator and repeat step 3
5. Close and open the collimator and repeat step 3
6. Repeat steps 4 and 5 until sufficient data for assessing reproducibility is acquired
7. Estimate the delivered field size in square mm as each %ROR divided by 0.3%
8. For MLC systems, divide this field area by field size in direction orthogonal to leaf motion
9. If the collimation system is found to be unable to reproduce very small fields within 1 mm, the linac is unsuitable for SRS
Conclusion

- This system can be used to evaluate collimator reproducibility
- The system could be used for constancy checks
  - Given sensitivity of small field output to source occlusion, the method might be useful to verify output before and after adjustments to steering (for either MLC or cone based systems)
- The use of this method does not require direct field size measurement, unless the collimator system differs substantially from the 3 used in this study