Australian Clinical Dosimetry Service

Developing a dosimetry audit for MRI-Linacs

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Australian Clinical Dosimetry Service

Our Vision

To provide a comprehensive suite of audit modalities covering all common clinical practice

– to find gross dosimetry errors
– to improve national dosimetry
– ultimately to ensure patient safety
Radiotherapy in Australia

- 100 Facilities
- 227 Treatment Machines

**AND RISING**

- New Facilities
- New Technology
Radiotherapy in Australia

MRI-Linacs 2019-2020

- Townsville
- Sydney
- Melbourne
ACDS Audit Structure

Level I
OSLD

Level Ib
Ion chamber

Level II
2D Array vs. TPS

Level III
IC, microDiamond, film

Output check (mail out)
Output check (onsite)
Test of TPS (onsite)
End-to-end test (onsite)
ACDS Audit Structure

Level I
OSLD

Level Ib
Ion chamber

Level II
2D Array vs. TPS

Level III
IC, microDiamond, film

Modalities
Photons
FFF
Electrons

Modalities
Photons FFF
Electrons
Small field OF

Modalities
Conformal
IMRT VMAT
FFF

Modalities
Conformal
IMRT VMAT
FFF SABR
ACDS Audit Structure: new developments

Level I
OSLD

Level Ib
Ion chamber

Level II
2D Array vs. TPS

Level III
IC, microDiamond, film

SRS    MRI-Linacs    4D    Protons
MRI-Linac Audit Development Aims

• Establish robust dosimetry in magnetic fields
  – Detector response comparison
    • Reference dosimetry
    • Modulated fields
    • Magnetic field correction, $k_B$
• Modify existing phantoms
  – Plan and measure dose for existing audit cases
  – Image with MRI and CT
• Future development
  – MR compatible 2D detector array
  – MR-only planning
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The Australian MRI-Linac
The Australian MRI-Linac

- 6MV FFF Linatron MP industrial linac (Varian)
- Millennium 120-leaf MLC (Varian)
- 1 Tesla open bore magnet, 82 cm diameter bore, 50cm gap
- MR imaging based on Magnetom Avanto (Siemens)
- 6 SIDs from 1.8m to 2.8m
- Horizontal beam inline with magnetic field

*Image courtesy of Jarrad Begg, Ingham Institute, Liverpool, NSW*

### Detector Comparison

<table>
<thead>
<tr>
<th>Detector Type</th>
<th>Traceability</th>
<th>Magnetic Field Correction $k_B$</th>
<th>Measurement Uncertainty (1 $\sigma$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ion Chamber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTW 30013</td>
<td>ARPANSA</td>
<td>0.9937$^1$</td>
<td>0.7 %</td>
</tr>
<tr>
<td>IBA CC13</td>
<td>ARPANSA</td>
<td>0.9969$^1$</td>
<td>0.7 %</td>
</tr>
<tr>
<td>microDiamond</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTW 60019</td>
<td>ARPANSA</td>
<td>1.000</td>
<td>1.3 %</td>
</tr>
<tr>
<td>Passive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EBT3 Film</td>
<td>ARPANSA</td>
<td>1.000</td>
<td>3.2 %</td>
</tr>
<tr>
<td>Alanine</td>
<td>NPL</td>
<td>0.997$^2$</td>
<td>1.0 %</td>
</tr>
</tbody>
</table>

2. Billas I, National Physical Laboratory, UK (2019) Personal communication
Detector Comparison: Reference Field

- Field size at SID: 10 cm x 10 cm
- Depth: 10 cm
- Detector axis at SID
- All detectors “side-on” to beam
- Water phantom and CIRS Solid Water
- Dose calculated via TRS-398
  - $k_B$ magnetic field correction
  - $k_{SW}$ solid water correction
Reference: Detectors compared to PTW 30013 in Water

* Detector calibration is traceable to National Physical Laboratory, Teddington, UK
Reference: Detectors compared to PTW 30013 in Water

ACDS Optimal Range ± 1.4% (2σ)

* Detector calibration is traceable to National Physical Laboratory, Teddington, UK
Reference: Effect of $k_B$ correction on data spread

* Detector calibration is traceable to National Physical Laboratory, Teddington, UK
Detector Comparison: IMRT Field

- 5-segment IMRT, lateral field
- Measurement point off-axis
- All detectors “side-on” to beam
- CIRS Solid Water and Thorax Phantom
- Dose calculated via TRS-398
  - $k_B$ magnetic field correction
  - $k_{SW}$ solid water correction
Detector Comparison: IMRT Field

Region of Interest
6 mm x 6 mm
IMRT: microDiamond, EBT3 Film compared to CC13

![Graph showing dose variation from ACDS CC13 for different materials.](image)
IMRT: microDiamond, EBT3 Film compared to CC13

ACDS Optimal Range ± 3.3% (2σ)
IMRT: Alanine compared to CC13

Alanine calibration is traceable to National Physical Laboratory, Teddington, UK
IMRT: Alanine compared to CC13

ACDS Optimal Range \( \pm 3.3\% (2\sigma) \)

Alanine calibration is traceable to National Physical Laboratory, Teddington, UK
MRI-Linac Audit Development Aims

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Imaging: CIRS Thorax Phantom

CT

MRI
Imaging: Modified CIRS Thorax Phantom

T2 Spin Echo

- Water-filled Perspex tubes
- Perspex CC13 plugs
- SuperStuff Bolus (NL-Tec) – surface contour
Conclusions

• The multi-detector comparison in a 6X-FFF, 1T inline MRI-Linac showed agreement within the optimal ranges applied to ACDS dosimetry audits.
  – Reference ±1.4% (2σ)
  – IMRT ±3.3% (2σ)

• Water-filled inserts and commercial bolus products may provide a simple solution to adapting the ACDS audit phantom for MRI-Linac imaging.
THANK YOU

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