COMMISSIONING AND END-TO-END TESTING OF THE LEKSELL GAMMA KNIFE® ICON™

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Conflict of interest

- Elekta have funded my attendance to this conference.
Perfexion™ to Icon™

- 3 and a half weeks
  13th July – 7th August 2015.

- Installation, LGP system upgrade, Elekta testing, critical exam, Bristol commissioning and applications training.

- First patient treated using mask on 10th August 2015.
Commissioning & QA

- **Following installation:**
- Check of safety systems (Critical Examination – UK)
- CBCT dose measurements: dose in air, CTDI, effective dose.
- Image quality checks using CatPhan: spatial resolution, contrast to noise ratio & uniformity.
- HVL
- CBCT precision check
- Accuracy and function of HDMM
- End to end verification of plan dosimetry
CTDI & Effective Dose

- Good agreement.
- Low Effective Dose per scan.

<table>
<thead>
<tr>
<th>Preset</th>
<th>CTDI mGy Elekta Spec</th>
<th>CTDI_{air} mGy</th>
<th>CTDI_{w} mGy</th>
<th>E_{DLP}</th>
<th>Effective Dose mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low dose</td>
<td>2.5</td>
<td>3.6</td>
<td>2.36</td>
<td>0.0023</td>
<td>0.11</td>
</tr>
<tr>
<td>High dose</td>
<td>6.3</td>
<td>9.24</td>
<td>6.03</td>
<td>0.0023</td>
<td>0.28</td>
</tr>
</tbody>
</table>
HVL

Stated filtration: 11.1 mm Al equivalent

Measured 11.2 mm.
Image Quality

- The image quality has to be constant over time to assure an equal quality of the co-registration process.

CATPHAN® 503
Image Quality – 9 Month Study (n=12)

Image Uniformity

<table>
<thead>
<tr>
<th></th>
<th>Ref. value</th>
<th>Mean Uniformity (%)</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low dose (2.5mGy)</td>
<td>&lt; 21%</td>
<td>13.2</td>
<td>1.3</td>
</tr>
<tr>
<td>High dose (6.3mGy)</td>
<td>&lt; 21%</td>
<td>12.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Spatial Resolution

<table>
<thead>
<tr>
<th></th>
<th>Ref. value</th>
<th>Mean Spatial Resolution lp/cm</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low dose (2.5mGy)</td>
<td>≥ 6</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>High dose (6.3mGy)</td>
<td>≥ 6</td>
<td>8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Contrast to noise Ratio (CNR)

<table>
<thead>
<tr>
<th></th>
<th>Ref. value</th>
<th>Mean CNR Value</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low dose (2.5mGy)</td>
<td>&gt; 0.5</td>
<td>1.0</td>
<td>0.10</td>
</tr>
<tr>
<td>High dose (6.3mGy)</td>
<td>&gt; 0.8</td>
<td>1.7</td>
<td>0.16</td>
</tr>
</tbody>
</table>

• Better than specification
CBCT precision check

- Movement in x (L-R) following collision

![CBCT Precision Check Results: Maximum Deviation (mm)](chart)

- System tolerance <0.4mm
- Minor collision with CBCT arm
- Recalibration of CBCT arm
HDMM System

Sub mm increments of reflector achieved in x, y, z using Elekta ‘ball bearing tool’ with Vernier scale.

Absolute value of reflector displacement displayed on HDMM trace.

Results showed 0.04mm agreement with HDMM system.
HDMM triggered interruption

- HDMM pauses treatment if displacement exceeds limit for > 2 sec.
- Single 16mm shot test plan.
- Repeated 60-second readings acquired and mean output calculated.
- During the last reading a pause was created by moving the reflector, pausing irradiation. Then 60s reading was completed.
- Results: Output was within 0.3% of the uninterrupted reading.
Fractionated Gamma Knife: Pituitary Adenomas Abutting the Optic Nerve/Chiasm

• **CASE STUDY**
  • 74 Year Old (RW) – otherwise fit and well
  • Presented with visual loss in 2010
  • Transphenoidal resection- vision recovered
  • Small, growing residual
  • Abuts the optic nerves
  • Further surgery unable to fully resect
  • SRS would overdose the optic nerve with significant risk of optic neuropathy
  • IMRT/VMAT would over treat the normal brain with increased neurocognitive impact and increased risk of stroke and secondary tumour
Prescription isodose 85%
GTV 3.75cc
37 shots
12.3 minutes per #

VMAT 1 mm PTV

45Gy in 25#
Cover PTV by 95%

FGK 0.5mm PTV
End-to-end checks
Chamber measurements

- 3 patients treated and 3 on treatment.
- Copy plan to spherical solid water phantom.
- Move to cover active volume of chamber with low gradient region of plan.
- Irradiate Pin point TW31010 with 1# (1.8Gy).
## End-to-end checks

### Chamber measurements

<table>
<thead>
<tr>
<th>Patient</th>
<th>Mean dose to chamber volume per fraction (Gy)</th>
<th>Measured dose (Gy)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.89</td>
<td>1.94</td>
<td>-2.6</td>
</tr>
<tr>
<td>2</td>
<td>1.86</td>
<td>1.87</td>
<td>-0.3</td>
</tr>
<tr>
<td>3</td>
<td>1.89</td>
<td>1.91</td>
<td>-1.1</td>
</tr>
<tr>
<td>4</td>
<td>1.93</td>
<td>1.97</td>
<td>-2.1</td>
</tr>
<tr>
<td>5</td>
<td>1.77</td>
<td>1.77</td>
<td>0.1</td>
</tr>
<tr>
<td>6</td>
<td>2.16</td>
<td>2.17</td>
<td>-0.5</td>
</tr>
</tbody>
</table>

All chamber measurements within 3% - gives good confidence.
End-to-end checks
Film measurements

• Used EBT2 film.
• Film calibration required 0.5Gy – 8Gy.
• Copied plan to CBCT of phantom with film holder.
• Placed films on C.A. and 5mm and 10mm sup and inf (z) of CA.
• Irradiate with 2 #’s

+10 mm
+5 mm
C/A
-5 mm
-10 mm
End-to-end checks
Film measurements

- Films scanned using EPSON scanner 10000xl.
- Transmission mode.
- Used red channel information.
- Calibration applied using Omnipro ImRT software.
- Matlab utilised for direct comparison of film and LGP isodose plots.
- Dose correction applied and recorded.
Patient 1 – Central Axis (z=100mm)

3% dose correction on C.A.
Patient 1: $z=95\text{mm}$, $z=105\text{mm}$

5% Dose correction 5mm sup and inf of CA
Patient 1: $z=90\text{mm}$

$\sim 10\%$ dose correction
10mm sup of C.A.
Patient 1 – Central Axis (z=100mm)


- White line is the reference distribution and light grey line is the test distribution.

- First pass/fail image shows points Pass 97.72 %
Conclusions

• Icon continues to perform within specification.
• Icon is an excellent system which allows positioning of the patient with sub-millimetre accuracy as required for SRS/SRT. (separate discussion needed for intrafraction motion).
• Icon enables flexible workflows.
• Icon has enabled us to perform end to end checks which has given us confidence in the system.
Acknowledgements

• The Bristol Gamma Knife team
  – Tania McGreene, Alison Cameron, Chris Herbert, Miranda Edens, Ruth Smith, Louise Charlton, Piotr Gieryluk

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  – Alison Stapleton

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  – Jonas Johansson

• Diagnostic Radiology Physics Bristol
  – Ian Negus
  – Gareth Thorne
Thank you for listening