Pre-clinical tests of the Integral Quality Monitor (IQM) System

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• 3 Elekta Synergy/ MLCi2
• Pinnacle³ TPS
• 5 Radiation oncologists & 4 medical physicists
• > 70% VMAT
QA: status quo

• Pre-treatment verification
  – PTW equipment
    • Octavius II/ 2D Array 729/Verisoft 6.2

• $\gamma$-passing rate (3mm/3%) > 95%

• Concerns
  – Not VMAT-specific
  – No full field coverage
  – Workload per day: ~2h
IQM: towards online QA

- Can IQM catch errors before they become clinically relevant?
- Can we improve on efficiency?
- Can we resign pre-treatment QA?
IQM: towards online QA

- Can IQM catch errors before they become clinically relevant?
- Can we improve on efficiency?
- Can we resign pre-treatment QA?
Online patient QA: IQM

• Single large area ion chamber
  – Gantry mounted detector
  – Fully automated
  – Full field coverage
  – Real time online tracking
    • Intra-fraction linac monitoring

• Signal readout
  – Segment-by-Segment
  – Cumulative

• Reference for evaluation
  – Calculated signal
  – Measured signal
Pre-Clinical tests of the IQM system

• Clinical VMAT plans:
  Prostate/ Breast/ H&N

• IQM signal stability
  • inter fraction repeatability
• Detection of geometric errors
• Detection of dosimetric errors
IQM signal stability

- VMAT plans
  - Prostate
  - Breast with SIB
  - H&N
- Signal reproducibility
  - 10 measurements

<table>
<thead>
<tr>
<th></th>
<th>Prostate</th>
<th>Breast with SIB</th>
<th>H&amp;N</th>
</tr>
</thead>
<tbody>
<tr>
<td>measurement uncertainty</td>
<td>1.75%</td>
<td>1.57%</td>
<td>2.01%</td>
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<tr>
<td>calculated vs. measured signal</td>
<td>-2.36%</td>
<td>4.74%</td>
<td>4.19%</td>
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<tr>
<td></td>
<td>0.32%</td>
<td>0.23%</td>
<td>0.43%</td>
</tr>
<tr>
<td></td>
<td>-6.03%</td>
<td>-1.44%</td>
<td>-1.47%</td>
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</table>
IQM signal calculation

• VMAT prostate plan
  – calculated vs. average measured signal

Inclinometer readout & gantry movement

Segment-by-Segment

Cumulative

mean measured value
expected calculated value
relative disagreement [%]
Pre-Clinical tests of the IQM system

- Clinical VMAT plans:
  - Prostate/ Breast/ H&N

- IQM signal stability
- Detection of geometric errors
  - Implementation of systematic & random errors
- Detection of dosimetric errors
Geometric errors

- **systematic** MLC leafbank shift (0.5-8mm)
  - VMAT prostate plan
  - reference: average of 10 measurements

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<th>rel. disagreement</th>
<th>Segm</th>
<th>Cum</th>
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<tr>
<td>Y2+0.5mm</td>
<td>2.2%</td>
<td>1.2%</td>
<td></td>
</tr>
<tr>
<td>Y2+1mm</td>
<td>4.5%</td>
<td>2.6%</td>
<td></td>
</tr>
<tr>
<td>Y2+2mm</td>
<td>8.6%</td>
<td>6.0%</td>
<td></td>
</tr>
<tr>
<td>Y2+5mm</td>
<td>21.1%</td>
<td>15.5%</td>
<td></td>
</tr>
<tr>
<td>Y2+8mm</td>
<td>31.9%</td>
<td>24.2%</td>
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Segment by segment

![Graph showing deviation and IQM signal vs. control point](image_url)
Geometric errors

- **systematic** MLC leafbank shift (0.5-8mm)
  - VMAT prostate plan
  - reference: average of 10 measurements

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- **Cumulative**

- **Deviation %**

- **Control point**

- **IQM Signal**

- **Lake Constance Radiation Oncology Center**
Geometric errors: Histograms

Segment by segment

Cumulative

Y2+2mm

Y2+5mm

Y2+8mm

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Pre-Clinical tests of the IQM System
Geometric errors

- **Random** leafbank errors
  - MLC bank shift: 2/5/8 mm @ 4 control points
  - VMAT prostate plan
Geometric errors

- **Random** leafbank errors

  Tolerance levels

  Segment by segment: **5%**  **11%**

  Cumulative: **1.5%**  **3%**

  2mm  5mm  8mm

  No errors
Geometric errors

- Random leafbank errors
  - 8mm @ 3 control points
  - VMAT for breast with SIB
Geometric errors

- Random leafbank errors
  8mm @ 3 control points
  + consecutive cps
Geometric errors

- Random leafbank shift @ 3 consecutive control points
  - Control points with **low relative weight** (2-10MU/cp)
Geometric errors

- Random leafbank shift @ 3 consecutive control points
  - Control points with high relative weight (16MU/cp)
Pre-Clinical tests of the IQM system

- Clinical VMAT plans:
  Prostate/ Breast/ H&N

- IQM signal stability
- Detection of geometric errors
- Detection of dosimetric errors
Dosimetric errors

- Total #MU changed
  - IQM monitor gives immediate alert
Dosimetric errors

- Random errors @ single control points

VMAT breast: MU errors @ cp10-12

VMAT prostate: MU errors@ cp55-60
Summary

• General
  – Easy & robust workflow, no software crashes
  – User friendly interface
  – Consideration: no lightfield
  – Integration into clinical routine to be discussed

• Segment by segment analysis:
  – Calculated signal not yet clinically applicable
  – Inclinometer refinement necessary (WIP)
  – Averaged signal (eg. 10 measurements) more robust

• Cumulative analysis:
  – High sensitivity: leaf bank shift > 1mm detectable
    systematic & random dosimetric errors detectable
Conclusion

• Can we improve on efficiency?
  – yes

• Can IQM catch errors before they become clinically relevant?
  – Systematic errors: yes
  – Random errors: clinically relevant?

• Can we resign pre-treatment QA?
  – not yet
Thank you!

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