A practical approach to

Dosimetry and Quality Assurance

International Conference on Medical Accelerators and Particle Therapy

Simon Marcelis
Director Particle Therapy
Sept. 5th 2019
Outline

Dosimetry & Quality Assurance

Absolute Dosimetry

Relative Dosimetry

Commissioning

Machine QA

Patient QA
Absolute Dosimetry

What is physical dose in a given point? [Gy]
Absolute Dosimetry

What is physical dose in a given point? [Gy]

- International dosimetric code of practice for absolute dosimetry:
  IAEA TRS-398 (2006)

- Quantify of interest:
  Absorbed dose to water
  \[=\text{energy deposited in a medium by ionizing radiation per unit mass}\]
  [Gy]

- TRS-398 focused on scattering delivery (2006)

- Common detectors:

<table>
<thead>
<tr>
<th>Primary Standard</th>
<th>Clinical Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calorimeters</td>
<td>Ionization Chambers</td>
</tr>
<tr>
<td>Faraday Cups</td>
<td></td>
</tr>
</tbody>
</table>

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Dosimetry

Absolute Dosimetry
What is physical dose in a given point? [Gy]

Primary Standard

Clinical Standard

Calorimeters

Faraday Cups

Ionization Chambers

Plan
### Calorimeters

**Calorimeter**: Measure of the temperature rise in a medium due to energy absorbed from the radiation beam

\[
D_m = c_{p,m} \Delta T k_i
\]

- \( c_p \): specific heat capacity
- \( \Delta T \): temperature rise
- \( k_i \): correction factors

<table>
<thead>
<tr>
<th>( \Delta T/D_m )</th>
<th>+ Pros &amp; - Cons</th>
<th>Illustration</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water 0.24 mK/Gy</td>
<td>+ Dose in Water</td>
<td><img src="image1.png" alt="Illustration" /></td>
<td>• Sarfehnia et al. (2010) Med Phys 37(7) 3541</td>
</tr>
<tr>
<td></td>
<td>- Cumbersome setup</td>
<td></td>
<td>• Renaud et al. (2016) Phys Med Biol 61(18) 6602</td>
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<tr>
<td>Graphite 1.41 mK/Gy</td>
<td>- Dose conversion</td>
<td><img src="image2.png" alt="Illustration" /></td>
<td>• Palmans et al. (2004) Phys Med Biol 49(16) 3737</td>
</tr>
<tr>
<td></td>
<td>+ More portable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Water Calorimeter

Vessel with thermistors

Water (4°C)

Cooling fluid

Air

Beam

Water Calorimeter

Vessel with thermistors

Courtesy of Séverine Rossomme
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Faraday cup

- **Faraday cup**: shielded insulated block which stops the beam and measure the accumulated charge

\[
D_m = \phi \left( \frac{S}{\rho} \right)_m = \frac{N}{A} \left( \frac{S}{\rho} \right)_m
\]

- \( \phi \): fluence
- \( A \): the effective beam area
- \( N \): number of protons collected by the cup
- \( \left( \frac{S}{\rho} \right)_m \): mass stopping power

+ Portable
- Complex design to guarantee accuracy
- Depends on energy spectrum and stopping power

**Pyramid BC-75**


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Ionization chamber

- **Ionization chamber**: measure of charges created due to radiation beam and collected on the electrodes

\[
D_{w,Q} = M_Q N_{D,w,Q_0} k_{Q,Q_0}
\]

- \(M_Q\): corrected response of the ionization chamber for
  - temperature and pressure (\(k_{TP}\))
  - recombination (\(k_s\))
  - polarity (\(k_{pol}\))

- \(N_{D,w,Q_0}\): calibration factor in terms of absorbed dose to water

- \(k_{Q,Q_0}\): correction factor for the radiation quality of the beam

**k_Q (TRS-398)**

<table>
<thead>
<tr>
<th>Ionization chamber type</th>
<th>0.25</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
<th>4.5</th>
<th>5</th>
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<th>10</th>
<th>15</th>
<th>20</th>
<th>30</th>
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<tbody>
<tr>
<td>Markus</td>
<td>1.009</td>
<td>1.005</td>
<td>1.004</td>
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<td>1.003</td>
<td>1.003</td>
<td>1.003</td>
<td>1.002</td>
<td>1.002</td>
<td>1.000</td>
<td></td>
</tr>
</tbody>
</table>

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**Initial recombination**
Ions created in the same ionization track
- Independent on the ionization current
- Theories: Jaffé, Onsager

**Volume recombination:**
Ions created in different ionization tracks
- dependent on the ionization current, thus the dose rate
- Theorie: Boag

**Protons:** total recombination is dominated by volume recombination but initial recombination cannot be neglected

---


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Today’s Challenges: high dose rates

Boag formula (1er order simplification for pulsed beam)

\[ k_{s}^{vol,pulsed} = 1 + \frac{m \cdot d \cdot I_{sat}}{V} \]

- \( m \): depends on the ion recombination coefficient and mobility of the ions in the gas
- \( I_{sat} \): saturation current

How to deal with recombination?

- Increase High voltage (V)
  Limitations: avalanche effect, manufacturing, etc
- Reduce Gap (d)
  Limitations: low signal, manufacturing, etc
- Change gas (m)
- Asymmetrical IC
- …

Prieels et al, PTCOG2011, Philadelphia

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Plan

Absolute Dosimetry
What is physical dose in a given point? [Gy]

Relative Dosimetry
How dose in a given point compares to another? [%]

Primary Standard

Clinical Standard

Calorimeters

Faraday Cups

Ionization Chambers

Depth Dose

Lateral Dose

Water Phantom
+ Ionization Chamber
Diode

…

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All you need is a Water Phantom*!

WP600 (1st computer-controlled Water Phantom, 1973)

* If you have no rush to treat patients and very cheap Medical Physicists

✓ Commissioning
✓ Machine QA
✓ Patient QA
* If you have no rush to treat patients and very patient Medical Physicists
**Outline**

**Dosimetry**

**Absolute Dosimetry**
What is physical dose in a given point? [Gy]

**Relative Dosimetry**
How dose in a given point compares to another? [%]

**Primary Standard**

**Clinical Standard**

**Calorimeters**

**Faraday Cups**

**Ionization Chambers**

**Depth Dose**

**Lateral Dose**

**Water Phantom with Ionization Chamber, diode, …**

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Water Phantom with Ionization Chamber

Dosimetry

Quality Assurance

Commissioning

Machine QA

Patient QA

Main challenge

More efficiency

More efficiency

More efficiency

More affordable Proton Therapy

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Dosimetry

Quality Assurance

Commissioning

Machine QA

Patient QA

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PBS is very simple

It is just a combination of:

- Spots
- Bragg Peaks

Both can easily be measured by a Water Phantom
Spot Measurement
Spot Measurement
Spot Measurement

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>( \approx 45 \text{ s} )</td>
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</tbody>
</table>
Spot Measurement

<table>
<thead>
<tr>
<th>Measurement</th>
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<tbody>
<tr>
<td>X</td>
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<tr>
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<tr>
<td>Y</td>
<td>$\approx 45,\text{s}$</td>
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</tbody>
</table>

© IBA - Simon Marcelis - 2019
Spot Measurement

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<tbody>
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<td>X</td>
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</tr>
<tr>
<td>Y</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Diagonal 1</td>
<td>≃ 45 s</td>
</tr>
</tbody>
</table>

© IBA - Simon Marcelis - 2019
Spot Measurement

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</tr>
<tr>
<td>Diagonal 1</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Diagonal 2</td>
<td>≃ 45 s</td>
</tr>
</tbody>
</table>

*Total per Spot*  ≃ 3 min/spot
Tilted Spot Measurement

10 x 10 spots

<table>
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<th>Measurement</th>
<th>Time</th>
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<tbody>
<tr>
<td>X</td>
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</tr>
<tr>
<td>Y</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Diagonal 1</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Diagonal 2</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Total per Spot</td>
<td>≃ 3 min/spot</td>
</tr>
<tr>
<td>Layer (100 spots)</td>
<td>≃ 300 min/layer</td>
</tr>
<tr>
<td></td>
<td>≃ 5 h/layer</td>
</tr>
</tbody>
</table>
Tilted Spot Measurement

Every 5 MeV (70-230 MeV) = 32 layers

<table>
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<tr>
<td>Y</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Diagonal 1</td>
<td>≃ 45 s</td>
</tr>
<tr>
<td>Diagonal 2</td>
<td>≃ 45 s</td>
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<tr>
<td>Total per Spot</td>
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</tr>
<tr>
<td>Layer (100 spots)</td>
<td>≃ 300 min/layer</td>
</tr>
<tr>
<td>Layer (100 spots)</td>
<td>≃ 5 h/layer</td>
</tr>
<tr>
<td>32 layers</td>
<td>≃ 160 h</td>
</tr>
<tr>
<td></td>
<td>≃ 20 days</td>
</tr>
</tbody>
</table>

+ Multiple Gantry angles!

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Alternatives

- IBA Dosimetry Lynx
- PSI Scintillator
- Logos XRV-3000
Measure as fast as the beam is delivered

Typical delivery time for a 10x10 layer ≃ 1s

→ 32 layers ≃ 30 sec

(vs. 20 days)

/\ geometric corrections
PBS is very simple

It is just a combination of:

Spots & Bragg Peaks

Both can easily be measured by a Water Phantom
Bragg Peaks & SOBPs

Bragg Peaks
SCATTERING
(field delivered at once)

≃ 2 min/field
PBS
(One spot at the time)

\[ \approx 2 \text{ min/field} \]

BUT
The field must be delivered for each measurement point!
PBS
(One spot at the time)

\[ \approx 2 \text{ min/field} \]

BUT

The field must be delivered for each measurement point!

© IBA - Simon Marcelis - 2019
PBS
(One spot at the time)

≃2 min/field

BUT
The field must be delivered for each measurement point!
PBS
(One spot at the time)
\approx 2 \text{ min/field}

BUT
The field must be delivered for each measurement point!
PBS
(One spot at the time)

\[\approx 2 \text{ min/field}\]

BUT
The field must be delivered for each measurement point!
PBS
(One spot at the time)

$\approx 2 \text{ min/field}$

BUT
The field must be delivered for each measurement point!
PBS
(One spot at the time)

For 180 points:
\[180 \times 2\text{min} = 360 \text{min}\]
\[\rightarrow 6\text{h} / \text{field}\]

For 15 fields:
\[15 \times 6\text{h} = 90\text{h}\]
\[\rightarrow 11 \text{days!}\]

Need high resolution
(especially in gradient areas)

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MLIC (Multi Layers Ionization Chambers)

DE.TEC.TOR QUBENEXT

IBA Dosimetry Zebra


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The MLIC will measure as fast as the system can deliver.

Typical number of fields $\approx 15$

$\Rightarrow 15 \times 2 \text{ min/field} = 30 \text{ min}$

(vs .11 days)
Dosimetry

Quality Assurance

Commissioning

Machine QA

Patient QA

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Dosimetry

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Machine QA

Patient QA

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### AAPM TG-224 Proton Machine QA

**TABLE I. Daily QA procedures for proton therapy.**

<table>
<thead>
<tr>
<th></th>
<th>DS/PS</th>
<th>US</th>
<th>PBS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dosimetry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output constancy</td>
<td>±3%</td>
<td>±3%</td>
<td>±3%</td>
</tr>
<tr>
<td>Depth verification:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distal</td>
<td>±2 mm</td>
<td>±1 mm</td>
<td>±1 mm</td>
</tr>
<tr>
<td>Proximal</td>
<td>±2 mm</td>
<td>±2 mm</td>
<td>-</td>
</tr>
<tr>
<td>SOBP width</td>
<td>±2%/±2 mm</td>
<td>±2%/±2 mm</td>
<td>-</td>
</tr>
<tr>
<td>Spot position</td>
<td>-</td>
<td>-</td>
<td>±2%/±1 mm</td>
</tr>
<tr>
<td><strong>Imaging</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-ray isocenter vs Laser isocenter</td>
<td>±2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-ray and proton beam isocenter coincidence</td>
<td>±1 mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Recently published (May 2019)
- B. Arjomandy, P. Taylor, C. Ainsley, S. Safai, N. Sahoo, M. Pankuch, J. Farr, SY. Park, E. Klein, J. Flanz
## Extensive analysis of QA common practices

<table>
<thead>
<tr>
<th>PT Site</th>
<th>DS</th>
<th>US</th>
<th>PBS</th>
<th>Frequence</th>
<th>Test</th>
<th>Tolerance</th>
<th>Device</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site C</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Yearly</td>
<td>Dose Rate</td>
<td>± 30 %</td>
<td>PPC05 + WP</td>
<td>One field per option</td>
</tr>
<tr>
<td>Site A</td>
<td>✓</td>
<td></td>
<td></td>
<td>Yearly</td>
<td>Field Size</td>
<td>&gt; 30×40</td>
<td>Film</td>
<td>Largest Field Size &gt; 30×40</td>
</tr>
<tr>
<td>Site B</td>
<td>✓</td>
<td></td>
<td></td>
<td>Monthly</td>
<td>Test Pattern</td>
<td>y 2%/2mm 98%</td>
<td>Lynx</td>
<td>160MeV 5cm solid water, 226.7MeV 5cm solid water</td>
</tr>
<tr>
<td>Site A</td>
<td>✓</td>
<td></td>
<td></td>
<td>Monthly</td>
<td>Spot Sigma</td>
<td>&lt; 10% or 0.5 mm</td>
<td>Lynx</td>
<td>&lt; 10% or 0.5 mm, whichever is smaller</td>
</tr>
<tr>
<td>Site C</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Yearly</td>
<td>Modulation</td>
<td>± 3mm or ± 3%</td>
<td>PPC05 + WP</td>
<td></td>
</tr>
<tr>
<td>Site A</td>
<td>✓</td>
<td></td>
<td></td>
<td>Daily</td>
<td>Spot Sigma</td>
<td>± 20%</td>
<td>I'mRT MatriXX + Buildup</td>
<td>CPASS ± 10 %</td>
</tr>
<tr>
<td>Site F</td>
<td>✓</td>
<td></td>
<td></td>
<td>Daily</td>
<td>Spot Sigma</td>
<td>± 10%</td>
<td>Daily QA 3</td>
<td>4 spots (220 MeV), Field size diodes</td>
</tr>
<tr>
<td>Site C</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Yearly</td>
<td>Snout Motion</td>
<td>≤ 5 mm</td>
<td>Ruler</td>
<td></td>
</tr>
<tr>
<td>Site C</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Monthly</td>
<td>Modulation</td>
<td>± 3.0 mm or ± 3%</td>
<td>PPC05 + WP</td>
<td>2 ref field + 1 other field (rotation)</td>
</tr>
<tr>
<td>Site C</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>Weekly</td>
<td>Modulation</td>
<td>± 3.0 mm or ± 3%</td>
<td>Zebra</td>
<td>2 ref field + 1 other field (rotation)</td>
</tr>
<tr>
<td>Site A</td>
<td>✓</td>
<td></td>
<td></td>
<td>Daily</td>
<td>Modulation</td>
<td>± 3 mm</td>
<td>I'mRT MatriXX + Buildup</td>
<td>CPASS ± 2 mm</td>
</tr>
<tr>
<td>Site A</td>
<td>✓</td>
<td></td>
<td></td>
<td>Daily</td>
<td>Flatness</td>
<td>± 3 %</td>
<td>I'mRT MatriXX + Buildup</td>
<td>CPASS ± 2 %</td>
</tr>
<tr>
<td>Site A</td>
<td>✓</td>
<td></td>
<td></td>
<td>Daily</td>
<td>Symmetry</td>
<td>± 3 %</td>
<td>I'mRT MatriXX + Buildup</td>
<td>CPASS ± 2 %</td>
</tr>
<tr>
<td>Site D</td>
<td>✓</td>
<td></td>
<td></td>
<td>Daily</td>
<td>Symmetry</td>
<td>± 3 %</td>
<td>Daily QA 3</td>
<td>2 electron energy chambers @ mid-</td>
</tr>
</tbody>
</table>

---

### PT Site DS US PBS Frequence Test Tolerance Device Comment

- Site C ✔ ✔ Yearly Dose Rate ± 30 % PPC05 + WP One field per option
- Site A ✔ Yearly Field Size > 30×40 Film Largest Field Size > 30×40
- Site B ✔ Monthly Test Pattern y 2%/2mm 98% Lynx 160MeV 5cm solid water, 226.7MeV 5cm solid water
- Site A ✔ Monthly Spot Sigma < 10% or 0.5 mm Lynx < 10% or 0.5 mm, whichever is smaller
- Site C ✔ ✔ Yearly Modulation ± 3mm or ± 3% PPC05 + WP
- Site A ✔ Daily Spot Sigma ± 20% I'mRT MatriXX + Buildup CPASS ± 10 %
- Site F ✔ Daily Spot Sigma ± 10% Daily QA 3 4 spots (220 MeV), Field size diodes
- Site C ✔ ✔ Yearly Snout Motion ≤ 5 mm Ruler
- Site C ✔ ✔ Monthly Modulation ± 3.0 mm or ± 3% PPC05 + WP 2 ref field + 1 other field (rotation)
- Site C ✔ ✔ Weekly Modulation ± 3.0 mm or ± 3% Zebra 2 ref field + 1 other field (rotation)
- Site A ✔ Daily Modulation ± 3 mm I'mRT MatriXX + Buildup CPASS ± 2 mm
- Site A ✔ Daily Flatness ± 3 % I'mRT MatriXX + Buildup CPASS ± 2 %
- Site A ✔ Daily Symmetry ± 3 % I'mRT MatriXX + Buildup CPASS ± 2 %
- Site D ✔ Daily Symmetry ± 3 % Daily QA 3 2 electron energy chambers @ mid-
Typical Machine QA times

Yearly Working Days

Daily
≈ 30 min/day

Monthly
3 h
3 h
3 h
3 h
3 h
3 h
3 h
3 h
3 h
3 h

Yearly
≈ 2 days/year

Source: 2015 survey, 14 answers

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Typical Machine QA times

- **Daily**: 30 min/day → 125 h/year (≈ 16 days/year)
- **Monthly**: 3 h/month → 36 h/year
- **Yearly**: 16 h/year

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## DEVICES

### SUMMARY

<table>
<thead>
<tr>
<th>Energy</th>
<th>Spots Positions</th>
<th>Spots Sizes</th>
<th>Spots Symmetry</th>
<th>Output</th>
<th>Imaging System</th>
<th>Beam vs X-ray</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLIC or equivalent</td>
<td>✓</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Scintillator or films</td>
<td>•</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>•</td>
<td>•</td>
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<td>•</td>
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<tr>
<td>Parallel Chamber</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Large Chamber + water phantom</td>
<td>✓</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

### COMMON DAILY PRACTICES:

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Daily QA Device

Placidi et al, Z Med Phys., 28. 10.1016
Marcelis et al, EP3285869B1, Simon Marcelis et al.
Daily QA Device

IN COLLABORATION WITH:

Placidi et al, Z Med Phys., 28. 10.1016
Marcelis et al, EP3285869B1, Simon Marcelis et al.,
Complete Daily QA in one shot

- Energy
- Spots Size
- Spots Position
- Spots Symmetry
- Absolute dose
- X-ray vs Proton
- Lasers
- Uniformity
- Imaging system
- Couch translation

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Energy Measurement
Beam vs. Xray

BB is aligned at isocenter (Xray)

Single beam spot is shot at theoretical isocenter

Lynx measurement

Xray Center

Beam Center

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Daily QA in < 10 min

= 1 more patient/day
Dosimetry

Quality Assurance

Commissioning

Machine QA

Patient QA
Evolution of Patient QA\(^1\)

1973 → 2004

1D Water Phantom

2D Array

\(^1\) Dates reflects the 1\(^{st}\) available commercial solution
Evolution of Patient QA

1973
1D Water Phantom

2004
2D Array

2012
2.5D Arrays in Water

1 Dates reflects the 1st available commercial solution
Evolution of Patient QA\(^1\)

 PSI Water Column Phantom
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 IBA DigiPhant

1 Dates reflects the 1\(^{st}\) available commercial solution
Evolution of Patient QA

1973 - 1D Water Phantom
2004 - 2D MatriXX
2012 - 2.5D DigiPhant
2019 - 3D Hardware ?

1 Dates reflects the 1st available commercial solution

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Evolution of Patient QA

1973
- 1D
- Water Phantom

2004
- 2D
- MatriXX

2012
- 2.5D
- DigiPhant
- Ionizations chambers in Nozzle (spots dose, position, etc)

2019
- 3D
- Logs + MC
- 3D Hardware
- Machine Logs + Monte Carlo Indpt Dose

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Today’s workflow

TPS → 2D Array → Approve/Reject

Analysis

2D Array

≈ 35 min

How much time do you spend on Patient QA per patient?

→ Average ≈ 35 min/patient

Source: Simon Marcelis, PT Facilities survey, Dec 2018, 37 participants
What percentage of patients would you QA using independent dose recalculation (Monte Carlo) only?

→ Average ≈ 50%
What percentage of patients would you QA using independent dose recalculation (Monte Carlo) only?

→ Average ≈ 50%

Source: Online survey, Dec 2018, 37 participants
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### Patient QA Workflows

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D Array</td>
<td>100%</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>≈ 35 min</td>
<td>(35 min)</td>
</tr>
<tr>
<td>Monte Carlo</td>
<td>0 %</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td>= 0 min</td>
<td>(0 min)</td>
</tr>
</tbody>
</table>

What percentage of patients would you QA using independent dose recalculation AND log based QA?

→ Average ≈ 80%
## Patient QA Workflows

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Today</th>
<th>Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D Array (+MC)</strong></td>
<td>100% (35 min)</td>
<td>20% (7 min)</td>
</tr>
<tr>
<td><strong>Monte Carlo</strong></td>
<td>0% (0 min)</td>
<td>50% (0 min)</td>
</tr>
<tr>
<td><strong>Log (Dry Run) (+ MC)</strong></td>
<td>0% (0 min)</td>
<td>30% (3 min)</td>
</tr>
<tr>
<td>Avg. per patient</td>
<td>35 min</td>
<td>10 min</td>
</tr>
<tr>
<td>∑ per week (250pat./year)</td>
<td>175 min (≈3h)</td>
<td>50 min</td>
</tr>
</tbody>
</table>

Save up to 14 shifts (8 hours) per year (>2h/week)

+ Increase the quality of your Patient QA
+ Verify each fraction (log)

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Patient QA Workflow

- Plan, CT, Dose, Structure
- Dose measurement
- Machine Logs (pre-treatment + fractions*)
- TPS dose vs. Indpt. Dose (Monte Carlo)
- TPS dose vs. Detector measurements
- Log Analysis Spots + 3Dy
- Notifications

Request MatriXX / Logs (Dry Run)

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Thank you!