Small Field Dosimetry Challenges for Clinical Physicist

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Indianapolis, Indiana, USA
Treatment Fields

Magna-Fields

200x200 cm²

Traditional Fields

40x40 cm² 4x4 cm²

Advance Therapy Fields

SRS/SRT
Gamma Knife
Cyber-Knife
Tomotherapy
IMRT

Small Field

4x4 cm² 0.3x0.3 cm²
Small Field Dosimetry Problem

Institutional variability in 6 MV Radionics SRS dosimetry

Total scatter factor from different institutions

Cone Factor (St)

Cone Diameter (mm)

Das et al, J Radiosurgery, 3, 177-186, 2000
Dosimetric Variation with Detectors

Das et al, J Radiosurgery, 3, 177-186, 2000
Springfield Hospital Reports Radiation Overdose Administered to 76 Cancer Patients

February 26, 2010

The New York Times reported on a recent report filed by CoxHealth medical facility in Springfield, Missouri where they admitted to over-radiating 76 cancer patients during treatment. The majority of the patients were being treated for brain cancer, and received about a 50% overdose of radiation therapy. A hospital employee improperly calibrated the machine used to administer the radiation.

The error was discovered in September 2009 only after a second physicist received training on the equipment, made by BrainLAB, and the hospital began questioning whether the machine had been installed correctly in 2004, in a process called commissioning.

The overdoses at CoxHealth occurred in a state where there is little or no government oversight of radiation therapy, a fact that Robert H. Bezanson, the hospital’s president and chief executive, chose to emphasize.

On Wednesday, he released a letter that he wrote to the Food and Drug Administration, saying that its recent decision to toughen oversight of diagnostic radiation did not go far enough.

“*The initiative should be broadened to include regulation of medical radiation therapy as well,*” he wrote. “*We have also learned that the incident here at CoxHealth is, unfortunately, not an isolated occurrence. Rather, similar instances of medical overradiation have occurred at other hospitals throughout the country. Without increased regulation and oversight, these instances of medical overdosage will likely continue.*

Wrong detector used for BrainLab cone calibration
A Pinpoint Beam Strays Invisibly, Harming Instead of Healing

By WALT BOGDANICH and KRISTINA REBELO
Published: December 29, 2010

The initial accident report offered few details, except to say that an unidentified hospital had administered radiation overdoses to three patients during identical medical procedures.

It was not until many months later that the full import of what had happened in the hospital last year began to surface in urgent nationwide warnings, which advised doctors to be extra vigilant when using a particular device that delivers high-intensity, pinpoint radiation to vulnerable parts of the body.

Marci Faber was one of the three patients. She had gone to Evanston Hospital in Illinois seeking treatment for pain emanating from a nerve deep inside her head. Today, she is in a nursing home, nearly comatose, unable to speak, eat or walk, leaving her husband to care for their three young daughters.
What is a Small Field?

- Lack of charged particle
  - Dependent on the range of secondary electrons
  - Photon energy
- Collimator setting that obstructs the source size
- Detector is comparable to the field size
CPE & Electron Range

- CPE, Charged Particle Equilibrium
- Electron range = $d_{\text{max}}$ in forward direction
- Electron range in lateral direction
  - Nearly energy independent
  - Nearly equal to penumbra (8-10 mm)
- Field size needed for CPE
  - Lateral range
  - 16-20 mm
Bragg-Gray Cavity: Range and Cavity Size

Dose is calculated only by charged particle crossers in the cavity & Cavity should be non-perturbing

\[
\text{Dose} = \phi . S/\rho = \text{number/cm}^2(\text{MeVcm}^2/g) = \text{MeV/g} = \text{J/kg (Gy)}
\]
Lateral Electronic Equilibrium, LEE

Large Field

Small Field
Definition of Small Fields

Energy Fluence Penumbra/Output

Source sizes
- 0.01
- 0.35
- 0.50

Large field

0.5x0.5 cm²

90%, 70%, 50%, 30%, 10% iso-intensity line

Source Size, Modern Machines

Varian TrueBeam

<table>
<thead>
<tr>
<th>Energy</th>
<th>Mode</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>Dimensions x, y (mm)</th>
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</thead>
<tbody>
<tr>
<td>6 MV</td>
<td></td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>0.9, 0.7</td>
</tr>
<tr>
<td>6 MV</td>
<td>FFF</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>0.8, 0.7</td>
</tr>
<tr>
<td>10 MV</td>
<td></td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>0.9, 0.9</td>
</tr>
<tr>
<td>10 MV</td>
<td>FFF</td>
<td>![Image]</td>
<td>![Image]</td>
<td>![Image]</td>
<td>0.9, 0.8</td>
</tr>
</tbody>
</table>

Sawkey et al, Med Phys, 40, 332, 2013
Dose and Penumbra with Spot Size

Scott et al, Med Phys, 36, 3132, 2009
Dosimetry

- **Absolute**
  - Dose

- **Relative**
  - Depth Dose
    - $[D(r,d)/D(r,\text{dm})]$  
  - TMR
  - Profiles
  - Output, $S_{cp}$ (total scatter factor)
    - $[D(r)/D(\text{ref})]$
IAEA/AAPM Proposed Pathway

Why So Much of Fuss?

- Reference (ref) conditions cannot be achieved for most SRS devices (cyberknife, gammaknife, tomotherapy etc)
- Machine Specific reference (msr) needs to be linked to ref
- Ratio of reading (PDD, TMR, Output etc) is not the same as ratio of dose

\[
\frac{D_1}{D_2} \neq \frac{M_1}{M_2}
\]

\[
\frac{D_1}{D_2} = \frac{M_1}{M_2} \cdot [k_{\text{f_clin}} \cdot f_{\text{msr}}]
\]
Relative Dosimetry

\[ D_{w,Q_{msr}}^f = M_{Q_{msr}} - k_{Q,Q_o} \left( D_{w,Q_{msr}}^f \right) / \left( M_{Q_{msr}} \right) \]

\[ \Omega_{Q_{clin},Q_{msr}} = \frac{M_{Q_{clin}}}{M_{Q_{msr}}} \left( \frac{D_{w,Q_{clin}}^f}{M_{Q_{clin}}} \right) / \left( \frac{D_{w,Q_{msr}}^f}{M_{Q_{msr}}} \right) \]

\[ k_{Q_{clin},Q_{msr}} = \frac{D_{w,Q_{clin}}^f}{D_{w,Q_{msr}}^f} \left( \frac{M_{Q_{clin}}}{M_{Q_{msr}}} \right) = \frac{\text{(Output)}_{rel}}{\text{(Reading)}_{rel}} \]

\[ k_{Q_{clin},Q_{msr}} = \frac{S_{w,air}^f}{S_{w,air}^f} \cdot P_{f_{clin}} \]

\[ = \frac{S_{w,air}^f}{S_{w,air}^f} \cdot P_{msr} \]
Meaning of $k$ in Micro-Chambers

$$k = \frac{f_{clin} \cdot f_{msr}}{Q_{clin}, Q_{msr}}$$

$$= \left\{ \begin{array}{c} \left( \frac{L}{\rho} \right)_{air}^w \cdot P_{fl} \cdot P_{grad} \cdot P_{stem} \cdot P_{cell} \cdot P_{wall} \\ \left( \frac{L}{\rho} \right)_{air}^w \cdot P_{fl} \cdot P_{grad} \cdot P_{stem} \cdot P_{cell} \cdot P_{wall} \end{array} \right\} \begin{array}{c} f_{clin} \\ f_{msr} \end{array}$$
Issues in Radiation Measurements

- Charged particle equilibrium
  - Range of secondary electrons
  - Medium (tissue, lung, bone)

- Photon energy and spectrum
  - Change in spectrum
    - Field size
    - Off axis points like beamlets in IMRT
  - Changes in $(\mu_{en}/\rho)$ from reference field, $f_{ref}$
  - Change in $(L/\rho)$ from reference field, $f_{ref}$

- Detector
  - Volume
  - Density
  - Signal to noise ratio
# Radiation Detectors

<table>
<thead>
<tr>
<th>PTW Semiflex Ionization Chamber</th>
<th>PTW Rigid Stern Ionization Chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTW Farmer Ionization Chamber</td>
<td>PTW Sealed Ionization Chambers</td>
</tr>
<tr>
<td>PTW Pinpoint Ionization Chamber</td>
<td>Dosimetry Diode</td>
</tr>
<tr>
<td>Diamond Detector</td>
<td>Exradin Thimble Chamber</td>
</tr>
<tr>
<td>Soft X-Ray Ionization Chamber</td>
<td>Exradin Microchamber</td>
</tr>
<tr>
<td>Advanced Markus Electron Chamber</td>
<td>Exradin Parallel Plate Chamber</td>
</tr>
<tr>
<td>Rn22 Electron Chamber</td>
<td>Exradin Farmer-Type Chamber</td>
</tr>
<tr>
<td>Scandatronix/Wellhofer Farmer Type</td>
<td>E 2571 0.6 CM³ Farmer Ionization Chamber</td>
</tr>
<tr>
<td>Scandatronix/Wellhofer Parallel Plate Chamber</td>
<td></td>
</tr>
</tbody>
</table>
Detector Response

Sensitivity vs Volume of Detectors

- PFD
- SFD
- A-16
- PinPoint
- Markus
- IC4

Detector Response

- A-16 PinPoint Markus IC4
- 0.125cc
- 0.3cc
- 0.6 cc

Relative sensitivity vs Volume (cm³)
Stopping Power Ratio

Ionization chamber dosimetry of small photon fields: a Monte Carlo study on stopping-power ratios for radiosurgery and IMRT beams

F Sánchez-Doblado, P Andreo, R Capote, A Leal, M Perucha, R Arráns, L Núñez, E Mainegra, J I Lagares, and E Carrasco
### Radiological Parameters

<table>
<thead>
<tr>
<th>Beam quality (TPR20,10)</th>
<th>( S_{W, \text{air}} )</th>
<th>Ratio this work/Andreo (1994)</th>
<th>( S_{PMMA, \text{air}} )</th>
<th>Ratio this work/Andreo (1994)</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6 MV beams</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Elekta SL-18 radiosurgery</td>
<td></td>
<td></td>
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<tr>
<td>10 x 10 cm²</td>
<td>0.690</td>
<td>1.1187</td>
<td>1.000</td>
<td>1.0853</td>
<td>figure 1(a)</td>
</tr>
<tr>
<td>1.0 cm diameter</td>
<td></td>
<td>1.1155</td>
<td>0.997</td>
<td>1.0819</td>
<td>figure 1(b)</td>
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<tr>
<td>0.3 cm diameter</td>
<td></td>
<td>1.1153</td>
<td>0.997</td>
<td>1.0817</td>
<td>figure 1(c)</td>
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<tr>
<td>Siemens Primus MLC</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>10 x 10 cm²</td>
<td>0.677</td>
<td>1.1213</td>
<td>1.001</td>
<td>1.0880</td>
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<td>2 x 2 cm² irregular</td>
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<td>1.1203</td>
<td>0.999</td>
<td>1.0870</td>
<td>figure 1(e)</td>
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<td>on-axis</td>
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<tr>
<td>2 x 2 cm² irregular</td>
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<td>1.1250</td>
<td>1.003</td>
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<td>8 cm off-axis</td>
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<tr>
<td>MLC transmission</td>
<td></td>
<td>1.1300</td>
<td>1.008</td>
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<td>figure 1(i)</td>
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<tr>
<td>IMRT beam</td>
<td></td>
<td>1.1201</td>
<td>0.999</td>
<td></td>
<td>figure 12</td>
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<tr>
<td>(10 x 10 cm² approx)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</table>

*These are the values in the IAEA TRS-398 code of practice (Andreo et al. 2000).*

Cyber Knife Dosimetry

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Table III. $s_{c,p}$ measured with parallel-plate micro-chamber (filled with air and TMS dielectric liquid, alternatively), radiochromic film, radiographic film, MOSFETs, $1 \times 1 \times 1$ mm$^3$ chips of TLD-800 and calculated by Monte Carlo BEAM code. For $s_{c,p}$ measured with the ion chamber and MOSFETs, the experimental values have been corrected by means of the $F$ factor, as described in Section II G.

<table>
<thead>
<tr>
<th>Field diameter (mm)</th>
<th>Extradin pp IC (with air)</th>
<th>Extradin pp IC (with TMS)</th>
<th>Radiochromic film</th>
<th>TLD-800</th>
<th>MOSFETs</th>
<th>Radiographic film</th>
<th>Monte Carlo BEAM code</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$s_{c,p}$ 2σ%</td>
<td>$s_{c,p}$ 2σ%</td>
<td>$s_{c,p}$ 2σ%</td>
<td>$s_{c,p}$ 2σ%</td>
<td>$s_{c,p}$ 2σ%</td>
<td>$s_{c,p}$ 2σ%</td>
<td>$s_{c,p}$ 2σ%</td>
</tr>
<tr>
<td>4.4</td>
<td>(0.45*) 0.5%</td>
<td>&lt;0.8%</td>
<td>(0.45*) 0.5%</td>
<td>0.47 2.4%</td>
<td>0.47 3.7%</td>
<td>(0.48*) &lt;1.8%</td>
<td>0.46 3.0%</td>
</tr>
<tr>
<td>6.7</td>
<td>(0.66*) 0.5%</td>
<td>&lt;0.8%</td>
<td>(0.65*) 0.5%</td>
<td>0.66 2.7%</td>
<td>0.64 1.9%</td>
<td>(0.65*) &lt;3.6%</td>
<td>0.66 2.0%</td>
</tr>
<tr>
<td>10.5</td>
<td>(0.82*) 0.5%</td>
<td>&lt;0.8%</td>
<td>(0.81*) 0.5%</td>
<td>0.81 1.8%</td>
<td>0.80 3.5%</td>
<td>(0.80*) &lt;1.7%</td>
<td>0.81 2.3%</td>
</tr>
<tr>
<td>12.7</td>
<td>(0.85*) 0.4%</td>
<td>&lt;0.6%</td>
<td>(0.85*) 0.4%</td>
<td>0.85 2.5%</td>
<td>0.84 2.8%</td>
<td>(0.84*) &lt;1.4%</td>
<td>0.85 2.5%</td>
</tr>
<tr>
<td>16.0</td>
<td>(0.87*) 0.4%</td>
<td>&lt;0.6%</td>
<td>(0.87*) 0.4%</td>
<td>0.88 2.2%</td>
<td>0.87 3.2%</td>
<td>(0.87*) &lt;2.0%</td>
<td>0.88 2.5%</td>
</tr>
<tr>
<td>19.0</td>
<td>(0.89*) 0.4%</td>
<td>&lt;0.6%</td>
<td>(0.89*) 0.4%</td>
<td>0.89 2.3%</td>
<td>0.89 2.6%</td>
<td>(0.89*) &lt;2.0%</td>
<td>0.89 2.5%</td>
</tr>
</tbody>
</table>

*Experimental values divided by the $F$ factor (Section II G).
Correction Factors

Correction Factor depends on:
- Field size
- Source size (FWHM)
- Detector type

<table>
<thead>
<tr>
<th>Field Size</th>
<th>5 mm coll</th>
<th>7.5 mm coll</th>
<th>10 mm coll</th>
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<tbody>
<tr>
<td>1.4</td>
<td>1.067</td>
<td>1.021</td>
<td>1.008</td>
</tr>
<tr>
<td>1.8</td>
<td>1.087</td>
<td>1.017</td>
<td>1.007</td>
</tr>
<tr>
<td>2.2</td>
<td>1.102</td>
<td>1.020</td>
<td>1.012</td>
</tr>
<tr>
<td>2.6</td>
<td>1.112</td>
<td>1.027</td>
<td>1.010</td>
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<table>
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<th>7.5 mm coll</th>
<th>10 mm coll</th>
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<td>1.4</td>
<td>1.082</td>
<td>1.025</td>
<td>1.017</td>
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<tr>
<td>1.8</td>
<td>1.099</td>
<td>1.024</td>
<td>1.013</td>
</tr>
<tr>
<td>2.2</td>
<td>1.110</td>
<td>1.025</td>
<td>1.013</td>
</tr>
<tr>
<td>2.6</td>
<td>1.124</td>
<td>1.037</td>
<td>1.016</td>
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</table>

<table>
<thead>
<tr>
<th>Detector</th>
<th>5 mm coll</th>
<th>7.5 mm coll</th>
<th>10 mm coll</th>
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<tbody>
<tr>
<td>Diode</td>
<td>0.953</td>
<td>0.966</td>
<td>0.978</td>
</tr>
<tr>
<td>1.4</td>
<td>0.955</td>
<td>0.966</td>
<td>0.978</td>
</tr>
<tr>
<td>1.8</td>
<td>0.957</td>
<td>0.967</td>
<td>0.978</td>
</tr>
<tr>
<td>2.2</td>
<td>0.940</td>
<td>0.967</td>
<td>0.978</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diamond</th>
<th>5 mm coll</th>
<th>7.5 mm coll</th>
<th>10 mm coll</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>1.066</td>
<td>1.001</td>
<td>1.001</td>
</tr>
<tr>
<td>1.8</td>
<td>1.093</td>
<td>1.007</td>
<td>1.000</td>
</tr>
<tr>
<td>2.2</td>
<td>1.107</td>
<td>1.010</td>
<td>0.999</td>
</tr>
<tr>
<td>2.6</td>
<td>1.123</td>
<td>1.012</td>
<td>1.001</td>
</tr>
</tbody>
</table>

Published data on $k_{\text{clin}} \cdot f_{\text{msr}}$ vs $Q_{\text{clin}} \cdot Q_{\text{msr}}$

![Graph showing correction factor vs field size (mm)]

- Siemens; PTW diode 60012
- Elekta; PTW diode 60012
- Siemens; Exradin A16
- Elekta; Exradin A16
- Siemens; Sun Nuclear Dedge
- "Elekta; Sun Nuclear Dedge"
- Siemens; PTW Pinpoint 31014
- Elekta; PTW Pinpoint 31014
- Siemens; PTW microLion
- Elekta; PTW microLion

Francescon et al Med Phys, 38, 6513, 2011
Detector Density Effect

Implementing a newly proposed Monte Carlo based small field dosimetry formalism for a comprehensive set of diode detectors

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(Received 21 April 2011; revised 11 October 2011; accepted for publication 14 October 2011; published 23 November 2011)
Calculation of $k_{\frac{f_{\text{cln}}}{Q_{\text{cln}}}, \frac{f_{\text{msr}}}{Q_{\text{msr}}}}$ for several small detectors and for two linear accelerators using Monte Carlo simulations

P. Francescon, a) S. Cora, and N. Satariano
Department of Medical Physics, ULSS 6 – 36100 Vicenza, Italy

<table>
<thead>
<tr>
<th>Detector</th>
<th>$M_{Q_{\text{clin}}}/M_{Q_{\text{msr}}}$</th>
<th>$k_{Q_{\text{clin}},Q_{\text{msr}}}$</th>
<th>$M_{Q_{\text{clin}}}/M_{Q_{\text{msr}}}$</th>
<th>$k_{Q_{\text{clin}},Q_{\text{msr}}}$</th>
<th>$M_{Q_{\text{clin}}}/M_{Q_{\text{msr}}}$</th>
<th>$k_{Q_{\text{clin}},Q_{\text{msr}}}$</th>
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</thead>
<tbody>
<tr>
<td>A16</td>
<td>0.626 (15)</td>
<td>1.089 (3)</td>
<td>0.811 (10)</td>
<td>1.018 (3)</td>
<td>0.866 (6)</td>
<td>1.010 (3)</td>
</tr>
<tr>
<td>PinPoint</td>
<td>0.620 (17)</td>
<td>1.101 (3)</td>
<td>0.801 (7)</td>
<td>1.024 (3)</td>
<td>0.862 (5)</td>
<td>1.015 (3)</td>
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<tr>
<td>Diode 60008</td>
<td>0.726 (1)</td>
<td>0.943 (3)</td>
<td>0.873 (1)</td>
<td>0.949 (3)</td>
<td>0.912 (1)</td>
<td>0.964 (3)</td>
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<td>Diode 60012</td>
<td>0.705 (1)</td>
<td>0.956 (3)</td>
<td>0.847 (2)</td>
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<td>0.891 (1)</td>
<td>0.978 (3)</td>
</tr>
<tr>
<td>EDGE</td>
<td>0.726 (1)</td>
<td>0.948 (3)</td>
<td>0.864 (1)</td>
<td>0.955 (3)</td>
<td>0.906 (1)</td>
<td>0.966 (3)</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.544 (8)</td>
<td>1.249 (8)</td>
<td>0.785 (12)</td>
<td>1.059 (4)</td>
<td>0.855 (13)</td>
<td>1.019 (3)</td>
</tr>
<tr>
<td>TLD</td>
<td>0.668 (4)</td>
<td>⋯</td>
<td>0.809 (6)</td>
<td>⋯</td>
<td>0.880 (8)</td>
<td>⋯</td>
</tr>
<tr>
<td>EBT films</td>
<td>0.659 (17)</td>
<td>⋯</td>
<td>0.811 (16)</td>
<td>⋯</td>
<td>0.853 (18)</td>
<td>⋯</td>
</tr>
<tr>
<td>Polymer gels$^a$</td>
<td>0.702 (21)</td>
<td>⋯</td>
<td>0.872 (27)</td>
<td>⋯</td>
<td>0.929 (29)</td>
<td>⋯</td>
</tr>
</tbody>
</table>

*Pantelis et al, Med Phy. 37, 2369-2379, 2010*
Tomotherapy $k_{msr}$ Reference Dosimetry

Reference: 5x10 cm$^2$, 85 cm SSD, 10 cm

<table>
<thead>
<tr>
<th>Chamber type</th>
<th>$k_{Q_o}Q_o$ (TRS-398)</th>
<th>$k_{f_{msr}f_{ref}}Q_{msr}Q$</th>
<th>$k_{f_{msr}f_{o}}Q_{msr}Q_{o}$ (MC)</th>
<th>$k_{f_{msr}f_{o}}Q_{msr}Q_{o}$ (previous studies)</th>
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</thead>
<tbody>
<tr>
<td>Exradin A1SL</td>
<td>0.996</td>
<td>1.001</td>
<td>0.997</td>
<td>0.997 (Refs. 5 and 10)</td>
</tr>
<tr>
<td>Exradin A12 Farmer</td>
<td>0.996</td>
<td>1.004</td>
<td>1.000</td>
<td></td>
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<tr>
<td>PTW 30006 Farmer</td>
<td>0.993</td>
<td>1.004</td>
<td>0.997</td>
<td>0.995 (Ref. 6)</td>
</tr>
<tr>
<td>PTW 31010 Semiflex</td>
<td>0.993</td>
<td>1.002</td>
<td>0.995</td>
<td>0.996 (Ref. 10)</td>
</tr>
<tr>
<td>PTW 31014 PinPoint</td>
<td>0.994</td>
<td>0.997</td>
<td>0.993</td>
<td>0.992 (Ref. 10)</td>
</tr>
<tr>
<td>PTW 31018 microLion (parallel)</td>
<td>N/A</td>
<td>N/A</td>
<td>0.993</td>
<td></td>
</tr>
<tr>
<td>NE 2571 Farmer</td>
<td>0.994</td>
<td>1.003</td>
<td>0.997</td>
<td>0.995 (Ref. 6)</td>
</tr>
</tbody>
</table>
CyberKnife data

5 mm cone

Uncorrected output difference (%) with MC

Moignier et al, Med Phys 41(7), 071702, 2014
The influence of linac spot size on scatter factors

D Czarnecki\textsuperscript{1}, J Wulff\textsuperscript{1} and K Zink\textsuperscript{1,2}
Output correction factors for nine small field detectors in 6 MV radiation therapy photon beams: A PENELOPE Monte Carlo study

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Josep Sempau
Institut de Tècniques Energètiques, Universitat Politècnica de Catalunya, Diagonal 647, E-08028, Barcelona, Spain

Pedro Andreo
Department of Physics, Medical Radiation Physics, Stockholm University and Karolinska Institute, SE-171 76 Stockholm, Sweden

Med Phys, 41(4), 041711, 2014
Newer Data on $k_f^{\text{clin}}, f_{\text{msr}}, Q_{\text{clin}}, Q_{\text{msr}}$

New Published data From IAEA

Detector to detector corrections: A comprehensive experimental study of detector specific correction factors for beam output measurements for small radiotherapy beams

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Koari Yajima
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072103-1 Med. Phys. 41 (7), July 2014
Correction Factors

<table>
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<tr>
<th>FS [cm]</th>
<th>0.6</th>
<th>0.9</th>
<th>1.2</th>
<th>1.8</th>
<th>2.4</th>
<th>3.0</th>
<th>4.2</th>
<th>10.0</th>
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</thead>
<tbody>
<tr>
<td>TLD chips</td>
<td>1.00</td>
<td></td>
<td>1.003</td>
<td>1.008</td>
<td>1.004</td>
<td>1.000</td>
<td>1.005</td>
<td>1.010</td>
</tr>
<tr>
<td>TLD micro-cubes</td>
<td>0.998</td>
<td>...</td>
<td>1.000</td>
<td>1.001</td>
<td>1.009</td>
<td>1.000</td>
<td>1.001</td>
<td>1.007</td>
</tr>
<tr>
<td>IBA SFD diode</td>
<td>0.995</td>
<td>...</td>
<td>0.998</td>
<td>1.002</td>
<td>1.006</td>
<td>1.000</td>
<td>0.990</td>
<td>0.969</td>
</tr>
<tr>
<td>IBA PFD diode</td>
<td>0.936</td>
<td>...</td>
<td>0.962</td>
<td>0.985</td>
<td>0.999</td>
<td>1.000</td>
<td>1.000</td>
<td>1.001</td>
</tr>
<tr>
<td>IBA EFD diode</td>
<td>0.961</td>
<td>...</td>
<td>0.983</td>
<td>0.992</td>
<td>1.002</td>
<td>1.000</td>
<td>0.997</td>
<td>0.989</td>
</tr>
<tr>
<td>PTW 6003Diamond</td>
<td>0.995</td>
<td>...</td>
<td>0.983</td>
<td>0.992</td>
<td>1.002</td>
<td>1.000</td>
<td>0.996</td>
<td>0.995</td>
</tr>
<tr>
<td>(Sensitive area ~ 15 mm²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PTW 60019 microDiamond</td>
<td>0.961</td>
<td>...</td>
<td>0.980</td>
<td>0.990</td>
<td>1.001</td>
<td>1.000</td>
<td>0.999</td>
<td>1.000</td>
</tr>
<tr>
<td>RPLD (GDM-302M)</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>0.993</td>
<td>0.998</td>
<td>1.000</td>
<td>0.994</td>
<td>0.997</td>
</tr>
<tr>
<td>Al₂O₃:C</td>
<td>0.980</td>
<td>0.982</td>
<td>0.985</td>
<td>0.991</td>
<td>0.999</td>
<td>1.000</td>
<td>...</td>
<td>0.995</td>
</tr>
<tr>
<td>Scintillator 1</td>
<td>1.022</td>
<td>1.009</td>
<td>1.000</td>
<td>0.996</td>
<td>1.001</td>
<td>1.000</td>
<td>...</td>
<td>0.992</td>
</tr>
<tr>
<td>Scintillator 2</td>
<td>1.028</td>
<td>1.015</td>
<td>1.006</td>
<td>1.000</td>
<td>1.004</td>
<td>1.000</td>
<td>...</td>
<td>0.988</td>
</tr>
<tr>
<td>PTW 31018microLion</td>
<td>0.970</td>
<td>...</td>
<td>0.980</td>
<td>0.990</td>
<td>1.000</td>
<td>1.000</td>
<td>0.999</td>
<td>1.005</td>
</tr>
<tr>
<td>IBA CC01</td>
<td>1.000</td>
<td>...</td>
<td>0.993</td>
<td>0.993</td>
<td>1.000</td>
<td>1.000</td>
<td>0.997</td>
<td>0.990</td>
</tr>
<tr>
<td>IBA CC04</td>
<td>1.096</td>
<td>...</td>
<td>1.007</td>
<td>0.998</td>
<td>1.003</td>
<td>1.000</td>
<td>0.997</td>
<td>0.998</td>
</tr>
<tr>
<td>IBA CC13b</td>
<td>...</td>
<td>...</td>
<td>1.033</td>
<td>1.008</td>
<td>1.005</td>
<td>1.000</td>
<td>0.996</td>
<td>0.996</td>
</tr>
<tr>
<td>Wellhofer IC10b</td>
<td>...</td>
<td>...</td>
<td>1.030</td>
<td>1.005</td>
<td>1.005</td>
<td>1.000</td>
<td>0.996</td>
<td>0.996</td>
</tr>
<tr>
<td>PTW 31014 PinPoint</td>
<td>1.034</td>
<td>...</td>
<td>1.007</td>
<td>1.002</td>
<td>1.000</td>
<td>1.000</td>
<td>0.998</td>
<td>1.002</td>
</tr>
<tr>
<td>PTW 31016 PinPoint 3D</td>
<td>1.078</td>
<td>...</td>
<td>1.013</td>
<td>1.000</td>
<td>1.001</td>
<td>1.000</td>
<td>0.998</td>
<td>0.999</td>
</tr>
<tr>
<td>PTW 31010 Semiflexb</td>
<td>...</td>
<td>...</td>
<td>1.027</td>
<td>1.002</td>
<td>1.004</td>
<td>1.000</td>
<td>0.996</td>
<td>0.997</td>
</tr>
<tr>
<td>PTW 31013 Semiflexa,b</td>
<td>...</td>
<td>...</td>
<td>1.013</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

*This chamber was included in the table for completeness but it is not recommended to use for small field dosimetry in fields smaller than 2.0 × 2.0 cm² because the volume averaging effect is unacceptably high.

*bFor these ionization chambers, corrections for the smallest field were unacceptably high (>20%) for field sizes smaller than 1 × 1 cm² and therefore were excluded from Table V.
Variation of $k_{Q_{\text{clin}}/Q_{\text{mar}}}^{f_{\text{clin}}/f_{\text{mar}}}$ for the small-field dosimetric parameters percentage depth dose, tissue-maximum ratio, and off-axis ratio

Paolo Francesco
Department of Radiation Oncology, Ospedale Di Vicenza, Viale Rodolfi, Vicenza 36100, Italy

Sam Beddar
Department of Radiation Physics, The University of Texas MD Anderson Cancer Center, Houston, Texas 77005

Ninfa Satariano
Department of Radiation Oncology, Ospedale Di Vicenza, Viale Rodolfi, Vicenza 36100, Italy

Indra J. Das
Department of Radiation Oncology, Indiana University School of Medicine, Indianapolis, Indiana 46202
Correction in Profile (OAR)

Francescon et al, Med Phys, 41(10), 101708, 2014
Good News with Modern Microdetectors

Correction-less dosimetry of nonstandard photon fields: a new criterion to determine the usability of radiation detectors

Y Kamio\textsuperscript{1,2} and H Bouchard\textsuperscript{1,2,3}

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\textsuperscript{2} Centre hospitalier de l’Université de Montréal (CHUM), 1560 Sherbrooke est, Montréal, Québec H2L 4M1, Canada
\textsuperscript{3} Acoustics and Ionising Radiation Team, National Physical Laboratory, Hampton Road, Teddington TW11 0LW, UK

<table>
<thead>
<tr>
<th>Detectors</th>
<th>0.50</th>
<th>0.75</th>
<th>1.00</th>
<th>1.25</th>
<th>1.50</th>
<th>1.75</th>
<th>2.00</th>
<th>2.50</th>
<th>3.00</th>
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<tr>
<td>MicroLion</td>
<td>3.1</td>
<td>2.0</td>
<td>1.3</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>N. Diamond</td>
<td>3.8</td>
<td>2.4</td>
<td>1.5</td>
<td>1.0</td>
<td>0.6</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>U. diode</td>
<td>4.9</td>
<td>3.0</td>
<td>1.9</td>
<td>1.2</td>
<td>0.8</td>
<td>0.5</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Alamine</td>
<td>1.4</td>
<td>0.6</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>S. Fiber</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
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</tbody>
</table>

Values are rounded to the nearest 0.1%.

<table>
<thead>
<tr>
<th>Detectors</th>
<th>0.50</th>
<th>0.75</th>
<th>1.00</th>
<th>1.25</th>
<th>1.50</th>
<th>1.75</th>
<th>2.00</th>
<th>2.50</th>
<th>3.00</th>
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<td>MicroLion</td>
<td>2.4</td>
<td>1.8</td>
<td>1.4</td>
<td>1.0</td>
<td>0.8</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>N. Diamond</td>
<td>3.3</td>
<td>2.1</td>
<td>1.5</td>
<td>1.0</td>
<td>0.8</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>U. diode</td>
<td>4.0</td>
<td>2.8</td>
<td>2.1</td>
<td>1.6</td>
<td>1.3</td>
<td>1.0</td>
<td>0.9</td>
<td>0.5</td>
<td>0.3</td>
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<tr>
<td>Alamine</td>
<td>1.5</td>
<td>0.8</td>
<td>0.6</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>S. Fiber</td>
<td>0.7</td>
<td>0.5</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>
In summary, the criterion presented in this work should give the clinical physicist the tools necessary to determine a radiation detector's limits of usability in non-reference condition and thereby perform measurements neglecting correction factors. For small fields, this is accomplished by verifying that the criterion parameter \( \xi_{\text{ref}} \) is sufficiently small for the field of interest. For composite IMRT fields, the reliance on the measurement of \( D_{w,\text{ref}} \) can be assessed by verifying that the beam (or the VSC beam for composite fields) is acceptably uniform over detector's perturbation zone using the indices presented in this work. When a radiation detector is found to be unsuitable for a particular measurement, the simplest option would be to choose a different detector that is more water-equivalent. If such a detector is not available, the same detector can be used to evaluate an integral-dose value, like the dose area product (DAP) which doesn't require a nonstandard field correction factor (Underwood et al 2013a). Furthermore, by using volume-doses instead of point-doses and minimizing the detector’s perturbation with the density compensation method outlined in this work it is possible to use small field detectors to measure nonstandard fields with minimal correction as illustrated by the density-compensated microLion shown in this work. Finally, we showed that the new Exradin scintillating fiber (W1) could measure fields sizes of a few mm with corrections under 1% due to its near-water equivalency. With further improvements, the methods presented could eventually serve as the basis of a correction-less dosimetry protocol for nonstandard fields.
Can small field diode correction factors be applied universally?

Paul Z.Y. Liu\textsuperscript{a,b,\textdagger}, Natalka Suchowerska\textsuperscript{a,b}, David R. McKenzie\textsuperscript{a}

\textsuperscript{a}School of Physics, The University of Sydney; and \textsuperscript{b}Department of Radiation Oncology, Chris O’Brien Lifehouse, Camperdown, Australia

Radiotherapy Oncology, 112, 442-446, 2014
Correction Factor vs Ion Chambers (IMRT, VMAT)

\[ k \frac{f_{\text{clin}}}{f_{\text{msr}}} \]

- Tessier et al.\(^{24}\)
- Wang et al.\(^{25}\)

Fully-rotated delivery

collapsed delivery

Ionization Chamber

Exradin A12
NE2571
Exradin A1SL
Exradin A14
PinPoint\(^{\circledR}\) 31006

Chung et al., Med Phys, 37, 2404-2413, 2010
Validity of Proposed Method

Field Size (cm)

Relative dose at \( d_{\text{max}} \)

- Scanditronix-SFD
- Scanditronix-PIFD
- Extradin-A16
- PTW-Pinpoint
- PTW-0.125cc
- PTW-0.3cc
- PTW-0.6cc
- PTW-Markus
- Wellhofer-IC4
Summary

- Understand the limit of small field
- Focal spot issues
- Detectors that are water equivalent like, MicroLion, MicroDiamond and Plastic Scintillators are best suited
- Use proper correction factors to correct detector response to correct for the dose
- Watch for IAEA and TG-155 guidelines when they are published
Thanks