Disclosures

• I hold a research contract on advanced dose calculation from Elekta/Nucletron

• I am the Chair of the AAPM/ESTRO/ABG Working Group on Model-based Dose Calculation Algorithms.
  ➢ Our WG is working with all brachytherapy TPS vendors.
TG43 and breast brachytherapy

What to expect going to MBDCA
- Tissue heterogeneities
- Scatter condition
- Contrast agent and air

A few things to remember moving forward
TG-43 Dose Calculations
TG-43 Dose Calculations
TG-43 Dose Calculations

From Rivard
One size does not fit all!
### Sensitivity of Anatomic Sites to Dosimetric Limitations of Current Planning Systems

<table>
<thead>
<tr>
<th>anatomic site</th>
<th>photon energy</th>
<th>absorbed dose</th>
<th>attenuation</th>
<th>shielding</th>
<th>scattering</th>
<th>beta/kerma dose</th>
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<td>low</td>
<td>XXX</td>
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</table>

## Rule of thumb

<table>
<thead>
<tr>
<th>Energy Range</th>
<th>What to look for</th>
</tr>
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<tbody>
<tr>
<td>$^{192}\text{Ir}$</td>
<td>interface with air/lung</td>
</tr>
<tr>
<td>$^{103}\text{Pd}/^{125}\text{I}/\text{eBx}$</td>
<td>Adipose vs glandular tissue</td>
</tr>
<tr>
<td></td>
<td>Air and contrast (balloon)</td>
</tr>
<tr>
<td></td>
<td>Applicators and sources (seeds)</td>
</tr>
</tbody>
</table>

Water vs Tissues: Photon Energy

Beaulieu et al (TG-186), Med Phys 39, 2012
$^{103}$Pd Breast Brachytherapy

Tissue effects can be large

Keller et al, IJROBP 2005; Pignol et al, IJROBP 2006

H Afsharpour et al., PMB 2010
Cross sections

Attenuation

\[ \frac{\mu}{\rho} \] _Adipose \over Water

\[ \text{ratio of mass attenuation coefficients} \]

\[ \text{photon energy (keV)} \]

\[ \frac{D_{W,M}}{D_{M,M}} \]

\[ \text{ratio of mass energy absorption coefficients} \]

\[ \text{photon energy (keV)} \]

Dose ratio for a breast case

**Fig. 7.** (a) Ratio of Breast mean-Z $A_{70}/G30$ from a brachytherapy breast implant and $D_{TG-43}$. (b) Ratio of Breast lo-Z over Breast mean-Z.

- **Left:** From water (TG43) to average breast (MC), 30%
- **Right:** Residual compositional uncertainty, $\pm 10\%$

breast electronic brachytherapy study

Shane White, Evelyn de Jong, Guillaume Landry, Frank Verhaegen, Brigitte Reniers
Low Energy Brachytherapy

$^{125}$I and $^{103}$Pd seeds: 28 and 21 keV

Axxent electronic BT source: 27 keV

Xoft Patient TG-186 study

- tissue segmentation using different models presented in TG186
- Manual assignment of skin and contoured geometries
- ICRU 46 compositions
Xoft Patient TG-186 study

Balloon wall

- Contains Barium (Z = 56)
- 0.3 – 0.5mm thick
- Visible on CT
- Attenuates dose by 6% at 1cm from surface
- Dose attenuation larger at distances <1cm
- Cannot be accurately modeled using voxels
- Wall defined as tessellated mesh geometry
TG-186 Heterogeneous Model ($D_{m,m}$)

Dose ratio: Heterogeneous model $D_{mm}/$TG-43 MC

<table>
<thead>
<tr>
<th>DVH</th>
<th>% differences range</th>
</tr>
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<tbody>
<tr>
<td>$D_{90}$</td>
<td>-36% to -33%</td>
</tr>
<tr>
<td>$V_{100}$</td>
<td>-54% to -29%</td>
</tr>
<tr>
<td>$V_{200}$</td>
<td>-97% to -25%</td>
</tr>
<tr>
<td>$D_{0.2cc}$ (Skin)</td>
<td>-19% to 0%</td>
</tr>
</tbody>
</table>

TG-186 < TG-43

- Large DVH decreases in $D_{m,m}$ compared to TG-43
- Higher calculated rib dose
Tissue Heterogeneities

Energy dependant

- Less than 1% for $^{192}$Ir over useful distances
- 10-40% effect for $^{103}$Pd/eBx

- Difference increase with
  - $\downarrow$ energy.
  - $\uparrow$ distance from ref point.
Scatter Condition
TG43 / MC / Acuros-BV MBDCA

Zourari et al 2012
TG43 / MC / Brachy-CC MBDCA

Plamondon, Carlson-Tedgren and Beaulieu, ABS 2013 meeting
Skin Doses: study on 59 patients

TLD skin dose meas.
- TPS-TLD: -13% to 47%
- Average: 16% overestimation
- MC or GBBS: < 5%

Scatter Condition

- Finite dimension of the breast for $^{192}$Ir
  - No important effect on the highest isodoses
  - Reduces skin doses by 5% or more
    - Pentalis et al., IJROBP 2005; Raffi et al, Med Phys 2010

- For lower energy such as $^{169}$Yb
  - Skin and lung doses overestimated by 15-30%
    - Lymperopoulou et al., Med Phys 2006

- For even lower energy
  - Not the most important effect anymore…
Shielding: Contrast Agent
Contrast and air...

Interstitial

Contura

Mammo

SAVI
# Contrast effects on dosimetry of a partial breast irradiation system

Bassel Kassas, a) Firas Mourtada, John L. Horton, and Richard G. Lane  
The University of Texas MD Anderson Cancer Center, Box 94, 1515 Holcombe Boulevard, Houston, Texas 77030

(Received 24 February 2004; revised 6 April 2004; accepted for publication 22 April 2004; published 17 June 2004)

## Table I. Elemental composition by weight of the simulated contrast solutions. Contrast concentration is given by volume.

<table>
<thead>
<tr>
<th>% contrast</th>
<th>% carbon</th>
<th>% hydrogen</th>
<th>% iodine</th>
<th>% nitrogen</th>
<th>% oxygen</th>
<th>Density (g cm$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.91</td>
<td>10.64</td>
<td>3.19</td>
<td>0.35</td>
<td>83.90</td>
<td>1.0203</td>
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<tr>
<td>10</td>
<td>3.75</td>
<td>10.11</td>
<td>6.26</td>
<td>0.69</td>
<td>79.18</td>
<td>1.0406</td>
</tr>
<tr>
<td>15</td>
<td>5.52</td>
<td>9.60</td>
<td>9.22</td>
<td>1.02</td>
<td>74.64</td>
<td>1.0609</td>
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<tr>
<td>20</td>
<td>5.56</td>
<td>9.11</td>
<td>12.06</td>
<td>1.33</td>
<td>70.27</td>
<td>1.0812</td>
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<tr>
<td>25</td>
<td>8.87</td>
<td>8.64</td>
<td>14.80</td>
<td>1.63</td>
<td>66.07</td>
<td>1.1015</td>
</tr>
</tbody>
</table>

## Table II. Percentage reduction ($\Delta\%$) in dose rate at 1 cm from the balloon due to contrast, relative to water, for the various balloon diameters.

<table>
<thead>
<tr>
<th>Balloon diameter (cm)</th>
<th>5% contrast</th>
<th>10% contrast</th>
<th>15% contrast</th>
<th>20% contrast</th>
<th>25% contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>−0.8%</td>
<td>−1.6%</td>
<td>−2.4%</td>
<td>−3.2%</td>
<td>−4.0%</td>
</tr>
<tr>
<td>5</td>
<td>−1.0%</td>
<td>−1.6%</td>
<td>−2.7%</td>
<td>−3.8%</td>
<td>−4.9%</td>
</tr>
<tr>
<td>6</td>
<td>−1.4%</td>
<td>−2.9%</td>
<td>−4.3%</td>
<td>−5.4%</td>
<td>−5.7%</td>
</tr>
</tbody>
</table>
Dosimetric effects of an air cavity for the SAVI™ partial breast irradiation applicator

Susan L. Richardson
Department of Radiation Oncology, Washington University School of Medicine, St. Louis, Missouri 63110

Ramiro Pino
Department of Radiation Oncology, The Methodist Hospital, Houston, Texas 77030 and Texas Cancer Clinic, San Antonio, Texas 78240

(Received 8 July 2009; revised 3 June 2010; accepted for publication 5 June 2010; published 12 July 2010)

0 to +9% differences

Depends on:
• Size of the device
• Number of dwell
• Number of strut
Conclusion

• Significant differences between TG-43 and reality
  • Different concerns for high and low energy

• Commercial MBDCA solution only $^{192}$Ir
  • Low energy have much large dose diff. to solve

• Dose-toxicity relationships and delivered dose levels must be revisited.
  • TG-186 provide strong guidance
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Things to remember

- TG-43 is still the recommended STD for:
  - Prescription dose levels
  - Dose planning/optimization

- MBDCA for dose recalculation
  - Building the necessary dose comparison data for each site
  - Follow TG-186 recommendation
    - for tissue assignments
    - For dose reporting
Merci!

beaulieu@phy.ulaval.ca

http://physmed.fsg.ulaval.ca