Absorbed Dose Standards for Brachytherapy

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Absorbed Dose Standards for HDR Ir-192 Brachytherapy

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HDR $^{192}$Ir Brachytherapy Dosimetry

NIST/ADCL

- Provides chamber calibration factor

Calibrated well type chamber

- Allows measurement of $S_K$

$S_K$

- Using TG-43

$D_w$
HDR $^{192}$Ir Brachytherapy Dosimetry

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  - Provides chamber calibration factor

- Calibrated well type chamber
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- $S_K$

- $\dot{D}_W$

Uncertainty 2.15% (k=2)

Primary absorbed dose standards

- Calorimetry
  - Water
  - Graphite
- Ferrous Sulphate-based (Fricke)
- Ionization chamber based
Water Calorimetry
Rational for absorbed dose to water calibration:

- It is the quantity we like in the first place
- Spectral effects that affect $S_\kappa$ affect $\dot{D}(r_0, \theta_0)$ much less
Water Calorimetry

- Measuring dose to water directly at a point based on

\[ D_w = c_w \cdot \Delta T \]
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$$D_w = c_w \cdot \Delta T$$
Not as easy as a fish tank

- 0.23 mK per each Gy of absorbed dose
- Large source self-heating
- Sharp dose gradient
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Other Setups

PTB (PSDL Germany)

VSL (PSDL Netherland)

Bambynek et al. World Congress on Medical Physics and Biomedical Engineering, September 7 - 12, 2009, Munich, Germany, IFMBE Proceedings Volume 1, 2009, pp 89-92
<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Type A (%)</th>
<th>Type B (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Std error on the mean (meas.)</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>$c_w$</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Absolute temperature</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>$(\Delta R/R)/\Delta V$ calibration</td>
<td>0.04</td>
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<tr>
<td>Thermistor calibration ($\beta$)</td>
<td>0.1</td>
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</tr>
<tr>
<td>$k_p$</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>$k_{hd}$</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>$k_p$</td>
<td>0.1</td>
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<tr>
<td>$k_{ht}$</td>
<td></td>
<td></td>
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<tr>
<td>Conv. model (physical data)</td>
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</tr>
<tr>
<td>Simulation data</td>
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<tr>
<td>Interval extrapolation</td>
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<tr>
<td>Vessel dimension</td>
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<tr>
<td>$k_{dd}$</td>
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<tr>
<td>Source-vessel separation</td>
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<tr>
<td>Probe position wrt vessel</td>
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<tr>
<td>Dwell time</td>
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</tr>
<tr>
<td>Dummy/real source position</td>
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<tr>
<td>Predrift linearization</td>
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</tr>
<tr>
<td>Total uncertainty (1σ) (%)</td>
<td>1.90</td>
<td></td>
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</table>
Graphite Calorimetry
Rational for Graphite Calorimetry?

- 6X the signal for the same dose
- BUT, need to convert from dose to graphite to dose to water
Fricke Dosimetry
Theory:

\[ [Fe^{+2}] \xrightarrow{\gamma} [Fe^{+3}] \]

- So, as long as you know the relationship describing the number of Fe\(^{+3}\) / 100eV (i.e. chemical yield)
- Rational: Not sensitive to source self-heating
## Uncertainties

<table>
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<th>2-sigma Uncertainty</th>
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<tr>
<td>Graphite Calorimetry</td>
<td>1.4 %</td>
</tr>
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<tr>
<td>Gafchromic Film</td>
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<tr>
<td>TG-43</td>
<td>4-5 %</td>
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Conclusion

- Calorimetry, Fricke and Ionization based absorbed dose standards in HDR Ir-192 brachytherapy are feasible.

- Hopefully, once refined, these techniques will be brought to a standard lab near you.

- The uncertainty on dose measurements may be improved in brachytherapy based on absorbed dose primary standards.