GI Dose from Hot Particle

VARSKIN APPLICATION

Peter J. Lee, Ph.D., CHP
Introduction

The current internal dosimetry is not applicable to hot particle.

Apply VARSKIN at depth of stem cell in mucosal layer from ICRP 100.

Compare VARSKIN with MCNP (cylindrical shell of tissue surrounding liquid content).

Assess doses for the risks of ulceration and cancer.
ICRP 100 Target cells depths and masses for adult males

<table>
<thead>
<tr>
<th>Region</th>
<th>Target cell depth, μm</th>
<th>Target cell mass†, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral cavity</td>
<td>190-200</td>
<td>0.23</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>190-200</td>
<td>0.091</td>
</tr>
<tr>
<td>Stomach</td>
<td>60-100</td>
<td>0.62</td>
</tr>
<tr>
<td>Small intestine</td>
<td>130-150</td>
<td>3.6</td>
</tr>
<tr>
<td>Right colon</td>
<td>280-300</td>
<td>1.3</td>
</tr>
<tr>
<td>Left colon</td>
<td>280-300</td>
<td>1.2</td>
</tr>
<tr>
<td><strong>Rectosigmoid</strong></td>
<td><strong>280-300</strong></td>
<td><strong>0.73</strong></td>
</tr>
</tbody>
</table>

†computed from the length and diameter of each section (or radius for stomach) and the depth and thickness of the target cells, assuming a tissue density of 1 g cm\(^{-3}\).

For ingestion of a particle, estimated dose are greatest for the rectosigmoid region of the colon.
### ICRP 100 assumptions for the internal diameter of the large intestine (cm)

<table>
<thead>
<tr>
<th>Segment</th>
<th>Newborn</th>
<th>1 y</th>
<th>5 y</th>
<th>10 y</th>
<th>15 y</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right colon</td>
<td>3</td>
<td>4</td>
<td>4.5</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Left colon</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Rectosigmoid</strong></td>
<td>1.5</td>
<td><strong>2</strong></td>
<td>2.3</td>
<td>2.5</td>
<td>3</td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

### ICRP 100 Reference values for the length of the large intestine (cm)

<table>
<thead>
<tr>
<th>Segment</th>
<th>Newborn</th>
<th>1 y</th>
<th>5 y</th>
<th>10 y</th>
<th>Male 15 y</th>
<th>Female 15 y</th>
<th>Adult Male</th>
<th>Adult Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right colon</td>
<td>14</td>
<td>18</td>
<td>23</td>
<td>28</td>
<td>30</td>
<td>30</td>
<td>34</td>
<td>30</td>
</tr>
<tr>
<td>Left colon</td>
<td>16</td>
<td>21</td>
<td>26</td>
<td>31</td>
<td>35</td>
<td>35</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td><strong>Rectosigmoid</strong></td>
<td>15</td>
<td><strong>21</strong></td>
<td>26</td>
<td>31</td>
<td>35</td>
<td>35</td>
<td><strong>38</strong></td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td>110</td>
<td>100</td>
</tr>
</tbody>
</table>
Correction Factor for VARSKIN GI Dose Assessment

Geometry – cylinder vs. plane
Backscattering - GI content vs. air

More energy deposited at target area of concave surface than flat surface due to higher beta flux - shorter distance and larger solid angle subtended from the hot particle.

The correction factor due to geometry depends on the size of the GI and the range of the beta particle.

For the hollow organ with the size greater than the range of beta particle to some extent, the target area of the concave surface cannot be distinguished from flat surface for the dose assessment.
Correction Factor

CF = energy deposited (MCNP) / energy deposited (VARSKIN)
   = (\rho \times \text{RS inner surface area} \times \text{average dose rate})
     / (\rho \times \text{target area} \times \text{dose rate})

\rho: \text{density thickness of the target layer}

Average RS dose rate derived from Health Implication of Dounreay Fragment.

Select maximum energy deposited from the VARSKIN.

RS: Rectosigmoid
Energy deposited in target area based on VARSKIN (280-300 um)

<table>
<thead>
<tr>
<th>Target area (cm²)</th>
<th>Y-90</th>
<th></th>
<th>Sr-90</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>dose rate (Gy/hr/Bq)</td>
<td>energy deposited (%)</td>
<td>dose rate (Gy/hr/Bq)</td>
<td>energy deposited (%)</td>
</tr>
<tr>
<td>10</td>
<td>1.15E-07</td>
<td>100</td>
<td>4.94E-07</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>1.12E-06</td>
<td>97</td>
<td>9.83E-06</td>
<td>100</td>
</tr>
<tr>
<td>0.5</td>
<td>2.12E-06</td>
<td>92</td>
<td>3.77E-05</td>
<td>76</td>
</tr>
</tbody>
</table>

Maximum energy deposited/ρ (cm² x Gy/hr/Bq):
1.15 E-06 (Y-90), 4.94 E-07 (Sr-90)

Energy deposited = ρ x target area x dose rate
Average RS Dose Rate* from Health Implication of Dounreay Fragment

\[(\text{Gy/hr/Bq})\]

<table>
<thead>
<tr>
<th></th>
<th>Y-90</th>
<th>Sr-90/Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>4.47 E-09</td>
<td>1.67 E-09</td>
</tr>
<tr>
<td>One-year old</td>
<td>1.24 E-08</td>
<td>4.57 E-09</td>
</tr>
</tbody>
</table>

* 3um fuel fragments on contact with the wall

RS inner surface area (cm²) | Energy deposited/ρ (cm² x Gy/hr/Bq)  
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>358</td>
</tr>
<tr>
<td>One-year old</td>
<td>132</td>
</tr>
</tbody>
</table>

Energy deposited = ρ x target area x dose rate
### Energy deposited/\(\rho\) (MCNP)
\[(\text{cm}^2 \times \text{Gy/hr/Bq})\]

<table>
<thead>
<tr>
<th></th>
<th>Y-90</th>
<th>Sr-90/Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>1.60 E-06</td>
<td>5.98 E-07</td>
</tr>
<tr>
<td>One-year old</td>
<td>1.64 E-06</td>
<td>6.03 E-07</td>
</tr>
</tbody>
</table>

### Maximum Energy deposited/\(\rho\) (VARSKIN)
\[(\text{cm}^2 \times \text{Gy/hr/Bq})\]

<table>
<thead>
<tr>
<th></th>
<th>Y-90</th>
<th>Sr-90/Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>1.15 E-06</td>
<td>4.94 E-07</td>
</tr>
<tr>
<td>One-year old</td>
<td>1.15 E-06</td>
<td>4.94 E-07</td>
</tr>
</tbody>
</table>

### Correction Factor (CF)

<table>
<thead>
<tr>
<th></th>
<th>Y-90</th>
<th>Sr-90/Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>1.39</td>
<td>1.21</td>
</tr>
<tr>
<td>One-year old</td>
<td>1.43</td>
<td>1.22</td>
</tr>
</tbody>
</table>
Point-Source Air Backscattering Correction Factor (Mangini’s thesis)

<table>
<thead>
<tr>
<th></th>
<th>P-32/Y-90</th>
<th>Sr-90</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.74 (1.35*)</td>
<td>0.83 (1.20*)</td>
</tr>
</tbody>
</table>

BSCF : air-water/water-water at 280-300 um
*CF : water-water/air-water

Beta energy greater than P-32, the BSCF at depth of 280 um stays the same.
Figure 3.4. Dose rate coefficients for the adult male rectosigmoid for 3 μm (small circles) and 3 mm (large circles) diameter MTR fuel fragments. Radial position of fragment is measured from the axis of the lumen (3 cm diameter). Penetrating (photon) and non-penetrating (beta) components of $^{137}\text{Cs}$ emissions are designated p and np, respectively.
Figure 3.5. Dose rate coefficients for the one year old rectosigmoid for 3 μm (small circles) and 3 mm (large circles) diameter MTR fission fragments. Radial position of fragment is measured from the axis of the lumen (2 cm diameter). Penetrating (photon) and non-penetrating (beta) components of ¹³⁷Cs emissions are designated p and np, respectively.
Air Scatter Correction: $^{90}\text{Sr} \, \beta$-

Fig. 5.50. Literature comparison of air BSCF for $^{90}\text{Sr}$ beta-particles. Black data points are at a normal depth of 0.007 cm. Average beta energy is 0.196 MeV.
Air Scatter Correction: $^{32}$P $\beta$-

Fig. 5.52. Literature comparison of air BSCF for $^{32}$P beta-particles. Black data points are at a normal depth of 0.007 cm. Average beta energy is 0.695 MeV.
Conclusion

For hollow organ with the size greater than the range of the beta to some extent, VARSKIN can perform the dose assessment with the correction of backscattering.

Determine the local dose for ulceration risk when the hot particle is held stationary against the wall for a long period of time.

Determine the average dose for cancer risk, when the hot particle is moving in contact with the wall throughout the transit.