Experimental determination of conversion factors using the RANDO phantom

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Summary

• Aim of this work
  – Determine conversion factors
    » Establish necessary tools
    » Establish a method

• Outcome of this work
  – Positioning system
  – Method for determining conversion factors
Introduction (I)

- Radiation protection quantities

Operational Quantities
- Ambient dose equivalent $H^*(d)$
- Directional dose equivalent $H^*(d,\Omega)$
- Personal dose equivalent $Hp(d)$

Related by calibration and calculation
- Monitored quantities
- Instrument responses

Physical Quantities
- Fluence, $\Phi$
- Kerma, $K$
- Absorbed Dose, $D$

Calculating using $Q(L)$ and sample phantoms (sphere or slab) validated by measurements and calculations

Protection Quantities
- Organ absorbed dose, $D_T$
- Organ equivalent dose, $H_T$
- Effective dose, $E$

Calculated using $w_R$, $w_T$ and anthropomorphic phantoms

Compared by measurement and calculations (using $w_R$, $w_T$, and anthropomorphic phantoms)

ICRP 74
Introduction (II)

- Conversion coefficient (CF)

\[
CF = \frac{\text{Protection quantity OR Operational quantity}}{\text{Physical quantity}}
\]

\[
CF = CF(E_\gamma, \text{geometry})
\]
Introduction (III)

- Examples of irradiation geometries

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Introduction (IV)

- Why determining CF experimentally?

The majority of the currently used CCs are determined using Monte Carlo tools.

Purpose of the current project:
1. Determination of CCs between absorbed dose to man to organ doses, for different types of surface contaminations
2. Determination of CCs between absorbed dose to man to effective dose, for different types of surface contaminations
Material and Methods (I)

- Measurement equipment
  - Risø TL/OSL-DA-15-reader
  - Harshaw 5500 TL-reader
  - LiF:Mg, Cu, P (TLD)

- Anthropomorpic phantom
  - Alerson RANDO

- Laboratory sources
  - $^{60}\text{Co}$, $^{137}\text{Cs}$

- Dedicated dispersion device
  - $^{18}\text{F}$, $^{99m}\text{Tc}$ or $^{24}\text{Na}$
Material and Methods (II)

- Alderson RANDO phantom
  - Human (male) skeleton + tissue simulating plastic
  - 36 slabs (2.5 cm thick), except pelvic slab (9 cm thick)
  - Grid of holes for TLD insertion (in a 3 cm by 3 cm grid)
Material and Methods (III)

- Alderson RANDO phantom
  - Determination of a new sampling scheme by:
    1. CT images,
    2. Literature
    3. Clinical expertise
Material and Methods (IV)
Results

- A complete sampling scheme of the Alderson RANDO phantom was established
  - Positions and associated mass-fractions of the organs at risk

- Adrenals, 2; Brain, 16; Breasts, 4; Esophagus, 3; Gallbladder, 3; Liver, 71; Lower large intestine, 37; Lungs, 34; Testes, 2; Thyroid, 2; Upper large intestine, 27; Urinary bladder, 6; Heart, 8; Kidneys, 15; Lymphatic nodes, 9; Oral mucosa, 4; Pancreas, 9; Prostate, 2; Red bone marrow, 101; Salivary glands, 4; Small intestine, 49; Spleen, 11; Stomach, 20; Thymus, 1.
# Results (example of positioning system, Liver)

<table>
<thead>
<tr>
<th>Rando section</th>
<th>Sample points</th>
<th>Mass fraction</th>
<th>TLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>(6,2.5); (6,5.5); (3,2.5); (3,5.5); (3,8.5)</td>
<td>0.15</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>(3,-0.5); (6,-0.5); (9,2.5); (6,2.5); (3,2.5); (0,2.5); (6,5.5); (3,5.5); (0,5.5); (6,8.5); (3,8.5); (0,8.5); (-3,5.5); (-3,8.5); (-6,5.5); (-9,2.5)</td>
<td>0.29</td>
<td>16</td>
</tr>
<tr>
<td>21</td>
<td>(0,-0.5); (3,-0.5); (3,-3.5); (6,-0.5); (6,-3.5); (9,-0.5); (9,-3.5); (13,-0.5); (0,2.5); (3,2.5); (6,2.5); (9,2.5); (0,5.5); (3,5.5); (6,5.5); (9,5.5); (0,8.5); (3,8.5); (-3,5.5); (-3,8.5)</td>
<td>0.27</td>
<td>20</td>
</tr>
<tr>
<td>22</td>
<td>(3,-0.5); (6,-0.5); (9,-0.5); (12.5,-0.5); (3,-3.5); (6,-3.5); (9,-3.5); (6,-6.5); (9,-6.5); (3,2.5); (6,2.5); (9,2.5); (3,5.5); (6,5.5); (9,5.5); (3,8.5); (0,8.5)</td>
<td>0.17</td>
<td>17</td>
</tr>
<tr>
<td>23</td>
<td>(6,0); (9,0); (12,5,0); (9,-3.5); (6,2.5); (9,2.5); (6,5.5); (9,5.5)</td>
<td>0.09</td>
<td>8</td>
</tr>
<tr>
<td>24</td>
<td>(9,-0.5); (12.5,-0.5); (9,2.5); (9,5.5); (6,2.5)</td>
<td>0.03</td>
<td>5</td>
</tr>
</tbody>
</table>

**Fig.** Sampling points corresponding to the part of the liver in *slab 21* is encompassed by red markings.
Results (irradiation in the laboratory)

- Using the new sampling scheme the first new CCs were established
  - $^{60}$Co (74.8 MBq) irradiation during 48 h

<table>
<thead>
<tr>
<th>Organ</th>
<th>Mean organ dose, $D$ (μGy)</th>
<th>$D/H^*(10)$ (Gy Sv$^{-1}$)</th>
<th>$D/H_p(10)$ (Gy Sv$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RBM</td>
<td>310</td>
<td>0.41</td>
<td>0.65</td>
</tr>
<tr>
<td>Liver</td>
<td>350</td>
<td>0.46</td>
<td>0.73</td>
</tr>
<tr>
<td>Bladder</td>
<td>313</td>
<td>0.41</td>
<td>0.65</td>
</tr>
<tr>
<td>Prostate</td>
<td>302</td>
<td>0.40</td>
<td>0.63</td>
</tr>
</tbody>
</table>
Continuation of the project

- Exposure during *in field* conditions
Summary

• Deviations between calculated and measured CCs have been reported to be about 15% and perhaps even more in specific irradiation situations.

• Determination of CCs in different radiation geometries are needed but complicated/time-consuming.

• A complete sampling scheme for the Alderson RANDO phantom is now available.