Table 1
Estimates of doses for 1%-5% and 25%-50% incidences of clinically detrimental deterministic effects in adults at five years after radiation exposure

[11, R2]

<table>
<thead>
<tr>
<th>Organ</th>
<th>Treatment field</th>
<th>Injury at five years</th>
<th>Approximate dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Effect in 1%-5% of patients</td>
</tr>
<tr>
<td>Bone marrow</td>
<td>Whole</td>
<td>Hypoplasia</td>
<td>2</td>
</tr>
<tr>
<td>Ovary</td>
<td>Whole</td>
<td>Permanent sterility</td>
<td>2-3</td>
</tr>
<tr>
<td>Testis</td>
<td>Whole</td>
<td>Permanent sterility</td>
<td>5-15</td>
</tr>
<tr>
<td>Lens</td>
<td>Whole</td>
<td>Cataract</td>
<td>5</td>
</tr>
<tr>
<td>Kidney</td>
<td>Whole</td>
<td>Nephroclerosis</td>
<td>23</td>
</tr>
<tr>
<td>Liver</td>
<td>Whole</td>
<td>Liver failure</td>
<td>35</td>
</tr>
<tr>
<td>Lung</td>
<td>lobe</td>
<td>Pneumonitis, fibrosis</td>
<td>40</td>
</tr>
<tr>
<td>Heart</td>
<td>Whole</td>
<td>Pericarditis, panniculitis</td>
<td>40</td>
</tr>
<tr>
<td>Thyroid</td>
<td>Whole</td>
<td>Hypothyroidism</td>
<td>45</td>
</tr>
<tr>
<td>Pituitary</td>
<td>Whole</td>
<td>Hypopituitarism</td>
<td>45</td>
</tr>
<tr>
<td>Brain</td>
<td>Whole</td>
<td>Necrosis</td>
<td>50</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>5 cm²</td>
<td>Necrosis</td>
<td>50</td>
</tr>
<tr>
<td>Breast</td>
<td>Whole</td>
<td>Atrophy, necrosis</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Skin</td>
<td>100 cm²</td>
<td>Ulcer, severe fibrosis</td>
<td>55</td>
</tr>
<tr>
<td>Eye</td>
<td>Whole</td>
<td>Panophthalmitis</td>
<td>55</td>
</tr>
<tr>
<td>Oesophagus</td>
<td>75 cm²</td>
<td>Ulcer, stenosis</td>
<td>60</td>
</tr>
<tr>
<td>Bladder</td>
<td>Whole</td>
<td>Ulcer, contracture</td>
<td>60</td>
</tr>
<tr>
<td>Bone</td>
<td>10 cm²</td>
<td>Necrosis, fracture</td>
<td>60</td>
</tr>
<tr>
<td>Ureter</td>
<td>5-10 cm</td>
<td>Stricture</td>
<td>75</td>
</tr>
<tr>
<td>Muscle</td>
<td>Whole</td>
<td>Atrophy</td>
<td>&gt;100</td>
</tr>
</tbody>
</table>

* Based on responses of patients conventionally treated with fractionated therapeutic x- or gamma-irradiation.

Table 2
Estimates of doses for 1%-5% and 25%-50% incidences of clinically detrimental deterministic effects in children at five years after radiation exposure

[11, R2]

<table>
<thead>
<tr>
<th>Organ</th>
<th>Treatment field</th>
<th>Injury at five years</th>
<th>Approximate dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Effect in 1%-5% of patients</td>
</tr>
<tr>
<td>Breast</td>
<td>5 cm²</td>
<td>No development</td>
<td>10</td>
</tr>
<tr>
<td>Cartilage</td>
<td></td>
<td>Arrested growth</td>
<td>10</td>
</tr>
<tr>
<td>Bone</td>
<td>10 cm²</td>
<td>Arrested growth</td>
<td>20</td>
</tr>
<tr>
<td>Muscle</td>
<td></td>
<td>Hypoplasia</td>
<td>20-30</td>
</tr>
</tbody>
</table>

* Based on responses of patients conventionally treated with fractionated therapeutic x- or gamma-irradiation.
Table 3
Effects on the brain in children treated for acute leukaemia detected by computed tomography scans

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Number of patients</th>
<th>Abnormalities</th>
<th>Type of brain abnormalities detected</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiotherapy dose to the brain (Gy)</td>
<td>Chemotherapy</td>
<td>Number</td>
<td>Per cent</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>23</td>
<td>13</td>
<td>56</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>19</td>
<td>11</td>
<td>56</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>24</td>
<td>13</td>
<td>54</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>32</td>
<td>17</td>
<td>53</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>72</td>
<td>35</td>
<td>49</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>14</td>
<td>6</td>
<td>43</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>25</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>30</td>
<td>12</td>
<td>40</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>45</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>19</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>24</td>
<td>IT</td>
<td>44</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>20</td>
<td>IT</td>
<td>27</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>IT</td>
<td>55</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>0</td>
<td>IV+IT</td>
<td>12</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>0</td>
<td>IV+IT</td>
<td>43</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td>0</td>
<td>IV+IT</td>
<td>23</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

* IT = intrathecal methotrexate and IT + IV = intrathecal and intravenous methotrexate.

Table 4
Effects on the brain of radiotherapy to the central nervous system in children

<table>
<thead>
<tr>
<th>Effect</th>
<th>CNS therapy</th>
<th>Comments</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukoencephalopathy</td>
<td>&gt;20 Gy in 1.5-2.0 Gy fractions plus systemic methotrexate, 10 Gy whole-body irradiation</td>
<td>Young children more sensitive</td>
<td>[M6, P3, R4]</td>
</tr>
<tr>
<td>Mineralizing microangiopathy</td>
<td>&gt;15 Gy in 1.5-2.0 Gy fractions</td>
<td>Young children more sensitive</td>
<td>[B4, D5]</td>
</tr>
<tr>
<td>Cortical atrophy</td>
<td>&gt;18 Gy in 1.5-2.0 Gy fractions and intrathecal methotrexate</td>
<td>Severe atrophy in young children</td>
<td>[C3, D3, D5, K2]</td>
</tr>
<tr>
<td>Cerebral necrosis</td>
<td>&gt;54 Gy in 1.8 Gy fractions</td>
<td></td>
<td>[B35, K2]</td>
</tr>
</tbody>
</table>
### Table 5
Average adult heights of individuals exposed in the lower dose groups in Hiroshima and Nagasaki and under 18 years old at the time of bombing [B14]

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age at time of bombing (years)</th>
<th>Average adult height (cm) in dose group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 Gy</td>
<td>0.0-0.09 Gy</td>
</tr>
<tr>
<td>Male</td>
<td>0-5</td>
<td>166.4 *</td>
</tr>
<tr>
<td></td>
<td>6-11</td>
<td>162.3</td>
</tr>
<tr>
<td></td>
<td>12-17</td>
<td>164.3</td>
</tr>
<tr>
<td>Female</td>
<td>0-5</td>
<td>153.3 b</td>
</tr>
<tr>
<td></td>
<td>6-11</td>
<td>152.5</td>
</tr>
<tr>
<td></td>
<td>12-17</td>
<td>152.1</td>
</tr>
</tbody>
</table>

- * Significantly different (p < 0.01) compared with the average of group exposed to > 1.00 Gy.
- b Significantly different (p < 0.05) compared with the average of group exposed to > 1.00 Gy.

### Table 6
Average adult heights of children exposed in the higher dose group in Hiroshima and under 18 years old at the time of bombing [B14]

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age at time of bombing (years)</th>
<th>Average adult height (cm) *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in dose group 1.0-2.0 Gy</td>
<td>in dose group &gt; 2.5 Gy</td>
</tr>
<tr>
<td>Male</td>
<td>0-5</td>
<td>164.2 (12)</td>
</tr>
<tr>
<td></td>
<td>6-11</td>
<td>162.7 (13)</td>
</tr>
<tr>
<td></td>
<td>12-17</td>
<td>163.2 (43)</td>
</tr>
<tr>
<td>Female</td>
<td>0-5</td>
<td>151.8 (11)</td>
</tr>
<tr>
<td></td>
<td>6-11</td>
<td>150.4 (17)</td>
</tr>
<tr>
<td></td>
<td>12-17</td>
<td>152.1 (58)</td>
</tr>
</tbody>
</table>

- * Number of individuals in parentheses.
Table 7
Average height of individuals followed in the Adult Health Study and under age 10 years at the time of bombing [14]

<table>
<thead>
<tr>
<th>Sex</th>
<th>Dose range (Gy)</th>
<th>Average adult height (cm) ± standard deviation *</th>
<th>Hiroshima</th>
<th>Nagasaki</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>&lt; 0.01</td>
<td>164.9 ± 6.02 (57)</td>
<td>163.3 ± 5.72 (53)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01-0.99</td>
<td>166.4 ± 6.18 (91)</td>
<td>164.4 ± 5.43 (31)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.00-2.99</td>
<td>164.4 ± 5.55 (20)</td>
<td>165.1 ± 5.94 (31)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 3.00-6.00</td>
<td>161.0 ± 5.18 (20)</td>
<td>164.3 ± 6.64 (18)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>164.9 ± 6.11 (148)</td>
<td>164.1 ± 5.61 (128)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\chi^2$ statistical test b</td>
<td>1.04 (p &gt; 0.05)</td>
<td>1.90 (p &gt; 0.05)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>&lt; 0.01</td>
<td>153.0 ± 5.54 (74)</td>
<td>152.8 ± 4.81 (53)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.01-0.99</td>
<td>153.6 ± 5.84 (91)</td>
<td>152.1 ± 4.25 (38)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.00-2.99</td>
<td>151.1 ± 5.34 (25)</td>
<td>151.5 ± 5.26 (32)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥ 3.00-6.00</td>
<td>149.9 ± 5.90 (20)</td>
<td>149.8 ± 5.33 (19)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>152.7 ± 5.87 (210)</td>
<td>151.9 ± 4.89 (142)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\chi^2$ statistical test b</td>
<td>2.00 (p &gt; 0.05)</td>
<td>2.00 (p &gt; 0.05)</td>
<td></td>
</tr>
</tbody>
</table>

* Number of individuals in parentheses.

b Homogeneity test of variance for four dose groups; df = 3.

Table 8
Thyroid hypofunction in individuals exposed to fallout radiation in the Marshall Islands [C16]

<table>
<thead>
<tr>
<th>Age at exposure (years)</th>
<th>Incidence of thyroid hypofunction for various estimated doses to the thyroid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 Gy</td>
</tr>
<tr>
<td>&lt;10</td>
<td>1/229 (0.4%)</td>
</tr>
<tr>
<td>≥10</td>
<td>1/371 (0.3%)</td>
</tr>
</tbody>
</table>
### Table 9
Estimates of lowest radiation doses associated with late deterministic effects from exposure in childhood to ionizing radiation, usually in the form of fractionated radiotherapy

<table>
<thead>
<tr>
<th>Organ</th>
<th>Effect</th>
<th>Dose (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testis</td>
<td>Germ cell depletion</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Leydig cell dysfunction</td>
<td>10</td>
</tr>
<tr>
<td>Ovary</td>
<td>Amenorrhea</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td></td>
<td>Infertility</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Abortion</td>
<td>20</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>Hypothyroidism</td>
<td>&gt; 1</td>
</tr>
<tr>
<td>Brain</td>
<td>Cognitive functions</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Isocapathologic changes</td>
<td>18, (10 *)</td>
</tr>
<tr>
<td></td>
<td>Neuroendocrine effects</td>
<td>&gt; 18, (&gt; 1 *)</td>
</tr>
<tr>
<td>Breast</td>
<td>Hypoplasia</td>
<td>2</td>
</tr>
<tr>
<td>Eye</td>
<td>Cataract</td>
<td>2</td>
</tr>
<tr>
<td>Lung</td>
<td>Fibrosis</td>
<td>8-11</td>
</tr>
<tr>
<td>Liver</td>
<td>Fibrosis</td>
<td>12</td>
</tr>
<tr>
<td>Kidney</td>
<td>Reduced creatinine clearance</td>
<td>12</td>
</tr>
<tr>
<td>Skeleton</td>
<td>Skeletal changes</td>
<td>10</td>
</tr>
<tr>
<td>Cardiovascular system</td>
<td>Cardiomyopathy</td>
<td>40</td>
</tr>
<tr>
<td>Bone marrow</td>
<td>Hypofunction</td>
<td>Insufficient data available</td>
</tr>
</tbody>
</table>

* Single whole-body exposure.
Figure 1.
Approximate incidence rates of clinical leukoencephalopathy in patients treated by cranial irradiation, chemotherapy or combination therapies.

Figure II.
IQ score distribution in children treated for acute lymphocytic leukaemia by cranial radiotherapy (RT), intrathecal methotrexate (IT) or intravenous methotrexate (IV).
Figure III.
Maximum growth hormone response to growth-hormone-releasing hormone in children treated for brain tumours by radiotherapy.

[LG]

Figure IV.
Mean standard deviation score of height in children treated for malignant disease by radiotherapy to various sites. Results for those receiving cranial and craniospinal treatment were significantly lower (p < 0.001) at 1-4 years than at the time of initial treatment.

[G2]
Figure V.
Thyroid-stimulating hormone levels in 116 patients aged 16 years or less treated for Hodgkin’s disease by radiotherapy.
[C15]

Figure VI.
Probability of regular menses in women treated for Hodgkin’s disease by total lymph irradiation (TL1) and/or chemotherapy.
[H12]
Figure VII.
Deviation from mean standing and sitting heights in children treated by radiotherapy with <25 Gy or >35 Gy.

[F10]
Figure VIII.
Dose-effect relationship for bone shortening in children treated by radiotherapy that included epiphyseal plate irradiation.

Figure IX.
Difference in breast volume in 53 women treated in childhood for haemangioma by radiotherapy of the breast region.
References


<table>
<thead>
<tr>
<th>Page</th>
<th>Reference</th>
</tr>
</thead>
</table>


N1 Nesbit, M.E., H.N. Sather, L.L. Robison et al. Presymptomatic central nervous system therapy in


