Use of Effective Dose

3rd International Symposium on the System of Radiological Protection
Seoul, October 2015

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UK
Task Group 79: Use of Effective Dose as a Risk-related Radiological Protection Quantity

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Issues

- Equivalent dose and Effective dose, $E$
- $E$ for children and fetus
- $E$ as a measure of risk
Protection of workers and public primarily using constraints and reference levels applying to doses from a single source.

From a single source in normal, emergency, or existing controllable situations by

From all regulated sources in normal situations by

Constraints / reference levels

Limits
Effective Dose

- Enables the summation of all radiation exposures by risk adjustment using simplified weighting factors
- Applies to sex-averaged reference persons, and relates to nominal risk coefficients for uniform external low LET radiation exposure
- Applied without uncertainties, assumes LNT dose-response, chronic = acute, internal = external
Dose Radiation Cancer Risk

Cancer incidence

\[ \sim 100 \text{ mGy} \]

?
# Life-time risk for Euro-American population (% per Gy)

<table>
<thead>
<tr>
<th>Cancer site</th>
<th>Age at exposure, years</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-9</td>
<td>20-29</td>
<td>60-69</td>
</tr>
<tr>
<td>Breast</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Colon</td>
<td>1.5</td>
<td>1.0</td>
<td>0.3</td>
</tr>
<tr>
<td>Liver</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Lung</td>
<td>0.7</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.2</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>1.1</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>All cancers</td>
<td><strong>10</strong></td>
<td><strong>6.2</strong></td>
<td><strong>2.2</strong></td>
</tr>
</tbody>
</table>

*ICRP* INTERNATIONAL COMMISSION ON RADILOGICAL PROTECTION
### Stochastic detriment x $10^{-2}$ per Sv

<table>
<thead>
<tr>
<th>Publication</th>
<th>Cancer</th>
<th>Hereditary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Worker</strong></td>
<td>4.8</td>
<td>0.8</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Public</strong></td>
<td>6.0</td>
<td>1.3</td>
<td>7.3</td>
</tr>
</tbody>
</table>

**Publication 60 (1991)**

<table>
<thead>
<tr>
<th>Publication</th>
<th>Cancer</th>
<th>Hereditary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Worker</strong></td>
<td>4.1</td>
<td>0.1</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Public</strong></td>
<td>5.5</td>
<td>0.2</td>
<td>5.7</td>
</tr>
</tbody>
</table>

**Publication 103 (2007)**
1. Absorbed dose $D_{T,R}$ in human tissues/organs $T$,  
   (averaged organ/tissue absorbed dose) $\text{Gy}$

2. Equivalent dose in tissues/organs, $\text{Sv}$
   $$H_T = \sum_R w_R D_{T,R}$$  
   $w_R$: radiation weighting factor

3. Effective dose, $\text{Sv}$
   $$E = \sum_T w_T H_T$$  
   $w_T$: tissue weighting factor
Proposal

Discontinue use of Equivalent Dose as a separate protection quantity

- Avoids confusion between equivalent dose and effective dose. Eg. iodine-131, $E = 40$ mSv, thyroid dose = 1 Sv.

- Avoids confusion between equivalent dose and dose equivalent, Sv, the operational quantity used as a measure of effective dose for external sources

- Equivalent dose, Sv, currently used to set limits to prevent deterministic effects: eye lens, skin, hands & feet; the more appropriate quantity is absorbed dose, Gy

- No changes required in numerical values of dose limits
ICRP Effective Dose Coefficients

Internal: Sv per Bq intake
External: Sv per fluence or air kerma

- Workers
- Public: Newborn, 1, 5, 10 and 15 y old children, adults
- Radionuclide intakes by pregnant and breast-feeding woman: doses to the fetus and infant
# Tissue weighting factors

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Weighting Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICRP 60</td>
<td>0.01</td>
<td>bone surface, skin</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>bladder, breast, liver, oesophagus, thyroid, remainder</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>bone marrow, colon, lung, stomach</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>gonads</td>
</tr>
<tr>
<td>ICRP 103</td>
<td>0.01</td>
<td>bone surface, skin, brain, salivary glands</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
<td>bladder, liver, oesophagus, thyroid</td>
</tr>
<tr>
<td></td>
<td>0.08</td>
<td>gonads</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>bone marrow, colon, lung, stomach, breast, remainder</td>
</tr>
</tbody>
</table>
Effective dose is not a scientific quantity that is “correct” for a particular age group.

In public dose assessments, usually use three age groups - 1y, 10y and adults - in representative person calculations (Publication 101, ICRP 2006).

For a few radionuclides, consideration of doses to the fetus may be important (isotopes of P, Ca and Sr).

Use of constraints and reference levels that apply to all workers and all members of the public, together with optimisation, provides a pragmatic and workable system of protection.
Use of $E$ in Medicine

- Measured quantities: KAP, ESAK, CTDI$_{\text{VOL}}$, DLP
- Surveys, DRLs in measured quantities
- $E$ useful in comparisons where dose distributions are different
Dose/Risk from Medical Procedures

- Accurate determination of measured quantities
- $E$ a useful risk-adjusted quantity
- Associated risks at low doses are UNCERTAIN
- Effective risk gives a false impression of reliability of risk estimation
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- $E$ a useful risk-adjusted quantity
- Associated risks at low doses are UNCERTAIN
- Effective risk gives a false impression of reliability of risk estimation

BUT can $E$ be used to provide a rough indication of risk?
<table>
<thead>
<tr>
<th>Risks from medical x-ray examinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Organ and effective doses calculated for a range of x-ray examinations</td>
</tr>
<tr>
<td>• Risks from individual procedures calculated using organ doses and age- and sex-specific risk factors</td>
</tr>
<tr>
<td>• Risk per unit effective dose calculated for each procedure as a function of age and sex</td>
</tr>
</tbody>
</table>

Wall *et al* (2011) HPA-CRCE-028
% / Sv risk from X-Ray Examinations

**Females**

- Head (AP+PA+Lat)
- Chest PA
- Abdomen AP
- Lumbar spine (AP+Lat)
- Ba swallow
- Ba enema
- Femoral angiography
- CT chest
- CT abdomen
- CT abdomen + pelvis
- Uniform whole body exposure

**Graph Details:**
- **Y-axis:** Total cancer risk per unit effective dose (%/Sv)
- **X-axis:** Age at exposure (y)
- **Legend:**
  - Head (AP+PA+Lat)
  - Chest PA
  - Abdomen AP
  - Lumbar spine (AP+Lat)
  - Ba swallow
  - Ba enema
  - Femoral angiography
  - CT chest
  - CT abdomen
  - CT abdomen + pelvis
  - Uniform whole body exposure
  - Cervical spine (AP+Lat)
  - Thoracic spine (AP+Lat)
  - Pelvis AP
  - IVU
  - Ba follow
  - Coronary angiography
  - CT head
  - CT abdomen
  - CT chest + abdomen + pelvis
## Cancer Risk Coefficients (% / Sv) for X-Ray Examinations

<table>
<thead>
<tr>
<th>Region</th>
<th>Age group (years)</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>18</td>
<td>13</td>
<td>9.1</td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
<td>11</td>
<td>7.6</td>
</tr>
<tr>
<td>Neck</td>
<td>9.1</td>
<td>6.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Female</td>
<td>20</td>
<td>12</td>
<td>7.2</td>
</tr>
<tr>
<td>Chest</td>
<td>8.3</td>
<td>7.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Female</td>
<td>14</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Abdo &amp; Pelv</td>
<td>12</td>
<td>9.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
<td>8.3</td>
<td>6.6</td>
</tr>
<tr>
<td>Whole body</td>
<td>10</td>
<td>8.0</td>
<td>6.2</td>
</tr>
<tr>
<td>Whole body</td>
<td>14</td>
<td>11</td>
<td>8.5</td>
</tr>
</tbody>
</table>
Proposal

Use $E$ as a rough indicator of possible risk from medical examinations

- MAY apply simple adjustments for age and sex, according to procedure – factors of a few higher in young children and lower at older ages

- BUT UNCERTAINTIES should be recognised

- AND not a substitute for risk analysis using organ doses in Gy – with consideration of uncertainties
Other issues

- Committed effective dose
- Collective effective dose
- Revision of dose coefficients - and previous dose assessments
- Use of specific information on physical and chemical forms of ingested and inhaled radionuclides
- Further consideration of medical applications
Next steps

- Discussion within ICRP Committees
- Revision of report by Task Group
- Reconsideration by Committees and Main Commission
- Public Consultation