Effective Dose and Risk Assessment

ICRP Symposium on Radiological Protection Dosimetry

University of Tokyo
18th February 2016

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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

Constraints / reference levels

From all regulated sources in normal situations by

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:
  - Linear Non-Threshold (LNT) dose-response,
  - Chronic = acute
  - Internal = external
Cancer incidence

Radiation Cancer Risk vs. Dose

~100 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>
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<tr>
<td>Colon</td>
<td>1.5</td>
<td>1.0</td>
<td>0.3</td>
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<tr>
<td>Liver</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
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<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>
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<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>
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<td>6.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Publication</td>
<td>Cancer</td>
<td>Hereditary</td>
<td>Total</td>
</tr>
<tr>
<td>-------------</td>
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<tr>
<td><strong>1991</strong></td>
<td></td>
<td></td>
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<tr>
<td>Worker</td>
<td>4.8</td>
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<tr>
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<td>6.0</td>
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<tr>
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<tr>
<td>Worker</td>
<td>4.1</td>
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<tr>
<td>Public</td>
<td>5.5</td>
<td>0.2</td>
<td>5.7</td>
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</tbody>
</table>
Equivalent and effective dose

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

Consider discontinuing use of Equivalent Dose as a separate protection quantity

- Avoids confusion between equivalent dose and effective dose. Eg. iodine-131, $E = 40 \text{ mSv}$, 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.
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

- **ICRP 60**
  - 0.01 bone surface, skin
  - 0.05 bladder, breast, liver, oesophagus, thyroid, remainder
  - 0.12 bone marrow, colon, lung, stomach
  - 0.2 gonads

- **ICRP 103**
  - 0.01 bone surface, skin, brain, salivary glands
  - 0.04 bladder, liver, oesophagus, thyroid
  - 0.08 gonads
  - 0.12 bone marrow, colon, lung, stomach, breast, remainder
Clarification

• 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$_{VOL}$, 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
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

BUT can $E$ be used to provide a rough indication of risk?
Risks from medical x-ray examinations

- Organ and effective doses calculated for a range of x-ray examinations
- Risks from individual procedures calculated using organ doses and age- and sex-specific risk factors
- Risk per unit effective dose calculated for each procedure as a function of age and sex

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

Males

Total cancer risk per unit effective dose (%/Sv) vs. Age at exposure (y)

- Head (AP+PA+Lat)
- Chest PA
- Abdomen AP
- Lumbar spine (AP+Lat)
- Ba swallow
- Ba enema
- Femoral angiography
- CT chest
- 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

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% / Sv risk from X-Ray Examinations

Females

Age at exposure (y)

Total cancer risk per unit effective dose (%/Sv)

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

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## Cancer Risk Coefficients (% / Sv) for X-Ray Examinations

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<td>6.8</td>
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</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