Quantifying the radiation exposure in medical imaging

Dosimetry and Risk Assessment

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Radiation in medicine
Medical Use of Radiation

Diagnostic radiology
3.6 billion procedures annually* (incl. dental)

Nuclear medicine
33.5 million procedures annually*

Radiotherapy
5.1 million treatment courses annually*

* UNSCEAR 2008 Report
“First, do no harm”

The most important rule of healthcare!!

Especially in radiation medicine, either for diagnosis or for treatment this is even more evident as the “harm” associated with radiation is well-known.

Some tools that modern medicine has to monitor that radiation medicine is performed safely and effectively are:

- Quality Processes,
- Dosimetry
Radiation dose
Radiation Therapy

Is built upon the effects of
RADIATION to MATTER

We take advantage of the energy that beam delivers to the target

Diagnostic Imaging

Is built upon the effects of
MATTER to RADIATION

We take advantage of the attenuation that organs cause to the beam.
Radiation dose in X ray medical imaging is the unavoidable side effect of all procedures and represents the risk.
Dosimetry
Patient dosimetry / risk

1. Patient
2. Measure the dose
3. Calculate a risk related quantity
4. Calculate risk
5. Communicate the risk

?
Diagnostic X ray imaging covers a diverse range of examination types, many of which are increasing in frequency and technical complexity.

This has resulted in the development of new dosimetric quantities, measuring instruments, techniques and terminologies.
In some situations it is desirable to make **direct measurements** of the application specific quantities.

For others it is preferable to make **measurements using a standard phantom** to simulate the patient.
Application specific quantities

- Incident air kerma
- Entrance surface air kerma
- X ray tube output
- Air kerma-area product
- Air kerma-length product
- Quantities for CT dosimetry
Risk-related quantities

Measurements of risk-related quantities

- Risk-related quantities are usually difficult to measure directly.

- Generally estimated from application specific quantities using tables of dose conversion coefficients, determined either by
  - measurements using phantoms
  - Monte Carlo calculation
Effective dose ICRP 103

• “…Effective dose is calculated for a Reference Person and not for an individual.”

• “Effective dose is intended for use as a protection quantity. The main uses of effective dose are the prospective dose assessment for planning and optimisation in radiological protection, and demonstration of compliance with dose limits for regulatory purposes.

• “Effective dose is not recommended for epidemiological evaluations, nor should it be used for detailed specific retrospective investigations of individual exposure and risk.”
Risk-related quantities

Table A.4.1. Summary of sex-averaged nominal risks and detriment.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Nominal Risk Coefficient (cases per 10,000 persons per Sv)</th>
<th>Lethality fraction</th>
<th>Nominal risk adjusted for lethality and quality of life*</th>
<th>Relative cancer-free life lost</th>
<th>Detriment (relating to column 1)</th>
<th>Relative detriment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole population</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oesophagus</td>
<td>15</td>
<td>0.93</td>
<td>15.1</td>
<td>0.87</td>
<td>13.1</td>
<td>0.023</td>
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<tr>
<td>Stomach</td>
<td>79</td>
<td>0.83</td>
<td>77.0</td>
<td>0.88</td>
<td>67.7</td>
<td>0.118</td>
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<tr>
<td>Colon</td>
<td>65</td>
<td>0.48</td>
<td>49.4</td>
<td>0.97</td>
<td>47.9</td>
<td>0.083</td>
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<tr>
<td>Liver</td>
<td>30</td>
<td>0.95</td>
<td>30.2</td>
<td>0.88</td>
<td>26.6</td>
<td>0.046</td>
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<tr>
<td>Lung</td>
<td>114</td>
<td>0.89</td>
<td>112.9</td>
<td>0.80</td>
<td>90.3</td>
<td>0.157</td>
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<tr>
<td>Bone</td>
<td>7</td>
<td>0.45</td>
<td>5.1</td>
<td>1.00</td>
<td>5.1</td>
<td>0.009</td>
</tr>
<tr>
<td>Skin</td>
<td>1000</td>
<td>0.002</td>
<td>4.0</td>
<td>1.00</td>
<td>4.0</td>
<td>0.007</td>
</tr>
<tr>
<td>Breast</td>
<td>112</td>
<td>0.29</td>
<td>61.9</td>
<td>1.29</td>
<td>79.8</td>
<td>0.139</td>
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<tr>
<td>Ovary</td>
<td>11</td>
<td>0.57</td>
<td>8.8</td>
<td>1.12</td>
<td>9.9</td>
<td>0.017</td>
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<tr>
<td>Bladder</td>
<td>43</td>
<td>0.29</td>
<td>23.5</td>
<td>0.71</td>
<td>16.7</td>
<td>0.029</td>
</tr>
<tr>
<td>Thyroid</td>
<td>33</td>
<td>0.07</td>
<td>9.8</td>
<td>1.29</td>
<td>12.7</td>
<td>0.022</td>
</tr>
<tr>
<td>Bone Marrow</td>
<td>42</td>
<td>0.67</td>
<td>37.7</td>
<td>1.63</td>
<td>61.5</td>
<td>0.107</td>
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<tr>
<td>Other Solid</td>
<td>144</td>
<td>0.49</td>
<td>110.2</td>
<td>1.03</td>
<td>113.5</td>
<td>0.198</td>
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<td>Gonads (Heritable)</td>
<td>20</td>
<td>0.80</td>
<td>19.3</td>
<td>1.32</td>
<td>25.4</td>
<td>0.044</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1715</strong></td>
<td><strong>565</strong></td>
<td><strong>574</strong></td>
<td><strong>1.000</strong></td>
<td></td>
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</table>

(A 112) In general, the parameters in these risk models were estimated using incidence data from the studies of the Japanese atomic bomb survivors with follow-up from 1958 through to 1998 for solid cancers (Prest). These models involved a linear dose response allowing exposure age and attained age. These effects were:

(A 110) **Risk modelling.** Within a given exposed population, comparable descriptions of the radiation-associated risk can be made using either excess relative risk (ERR) or excess absolute risk (EAR) models, so long as the models allow for variation in the excess risk with factors such as sex, attained age, and age-at-exposure. When suitably data-rich multiplicative (ERR) or additive (EAR) models lead to vis-
So what can we do?
Challenges

Accurate Dosimetry
Dosimetry in Diagnostic Radiology is straightforward, as long as the following have been properly addressed…
• What is measured/calculated
• How is it measured/calculated
  – Method
  – Equipment
• Who is competent to do it

Risk Communication
• What are we reporting
• How to communicate it properly to the patient
IAEA work on DR dosimetry
IAEA Support on Dosimetry

The **Dosimetry and Medical Radiation Physics Section** is assisting Member States in terms of:

- Development of guidelines
- Calibration services
- Support through TC Projects
- Research through Coordination Activities
Diagnostic Imaging

Justification

Optimization

Benefit

Risk

Diagnostic Radiology
Thank you!