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Tips & Tricks

Paediatric Working Group

Special aspects when using dose quantities in paediatric radiology

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In principle, the same dose quantities are used for adults and children.

Operational (measurable) dose parameters are differed from

protective dose quantities used to protect persons from potential healthy damage.

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Commonly used dose parameters:

- entrance surface dose,
- air kerma at interventional reference point,
- dose area product (DAP),
- volumetric CT dose index ($CTDI_{\mathrm{vol}}$),
- dose length product (DLP).

Commonly used protective dose quantities:

- peak skin dose,
- equivalent (organ) dose H (of eye lenses, of uterus),
- effective dose (D_{eff}).

When dealing with operational dose parameters, the following aspects have to be taken into account whenever children receive a CT scan:

- $CTDI_{vol}$ is measured using a 16 cm- or 32 cm-sized, cylindrical PMMA phantom.
- According to the current international standard IEC 60601-2-44 (2009) and to its amendment 1 (2012), the $CTDI_{vol}$ should be based on the 16 cm-sized phantom for examinations of the head and on the 32 cm-sized phantom for examinations of the body *regardless of patient size or patient age.*
- However, some older scanner models and scanner software versions use the *head phantom* for *paediatric body* examinations. The $CTDI_{vol}$ of the head phantom is (approximately) twice as high as the $CTDI_{vol}$ of the body phantom for identical scans. For accurate interpretations of $CTDI_{vol}$ (and DLP), the phantom of the protocol has to be known by users. In case of doubt, the manufacturer of the CT scanner has to be asked.

Size specific dose estimation for patients who receive a CT scan:

- The dose received by patients from CT scans depends on their size. The $CTDI_{\mathrm{vol}}$ is the dose received by a 32 cm and 16 cm cylindrical phantom and does *not* represent individually absorbed doses of patients. For small patients, interpreting the displayed $CTDI_{\mathrm{vol}}$ as patient dose could lead to underestimating patient dose.
- To take patient size into account, the size-specific dose estimate ($SSDE$) has been introduced to correct for individual profiles.[1]
- The $SSDE$, which depends on the diameter of the patient (anterior-posterior diameter - AP, lateral diameter - LAT, effective diameter - $\sqrt{AP * LAT}$), can be found in a look-up-table that was published by AAPM.
  Example: For CT-abdomen, a 5-years-old patient (effective diameter 18.5 cm) receives almost twice as much dose as displayed on the scanner console.

Protection quantities, such as equivalent and effective dose, are not directly measurable.

- Models of the human body are used to determine the energy deposition in organs and tissues from radiation exposures.

- Considering the diverse sizes of patients, including children of various ages, different virtual and physical anthropomorphic models for adults and children have been developed.

- Different models result in different equivalent and effective doses. Therefore, it is essential to specify the model used for the determination of equivalent dose H and effective dose D_{eff}.

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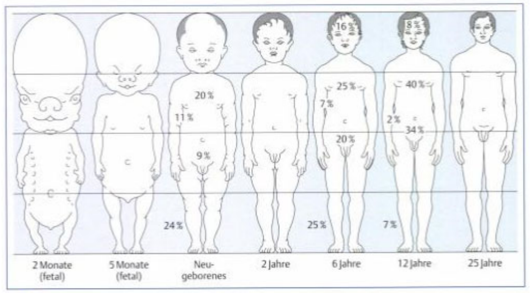
For paediatric models, it has to be taken into account that …



… the proportions of children strongly differ from the proportions of adults;

… the absorption of radiation is smaller in children than in adults because children are thinner and organs are less protected by superficial (fatty) tissue;

… the composition of tissue differs in children compared to adults.

➔ Using the same radiation level as in adults would therefore result in higher equivalent doses.

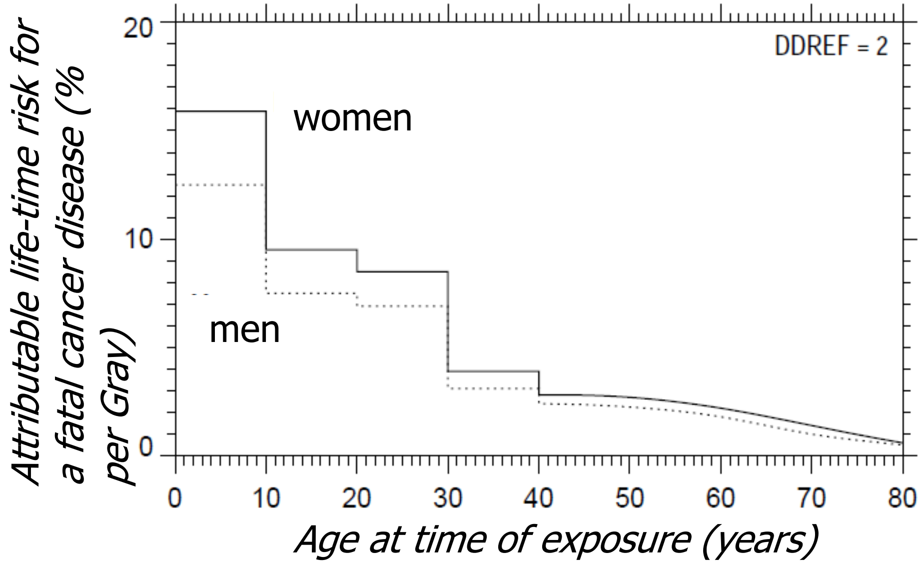
Example: For a CT-examination of the abdomen of an adult ($CTDI_{vol}$ = 15 mGy, German diagnostic reference level), the highest equivalent doses can be found for kidneys (24 mSv), stomach (23 mSv), bladder (23 mSv), and liver (22 mSv). If the same $CTDI_{vol}$ is used for a CT-abdomen of a 5-years-old child, corresponding equivalent doses are increased by approximately 40 %.[2]

Furthermore, compared to adults, ...

- the radiosensitivity of organs and tissues of children and
- the distribution of highly radiosensitive tissue in children

differs.

Example: Averaged over all organs, the radiosensitivity of children is higher than for adults by approximately a factor of 4. This results in a corresponding high risk for the development of cancer several years after the exposure.[3]



The concept of “effective dose” …

The radiosensitivity of tissues is considered by introducing specific tissue weighting factors for organs when the effective dose is computed.

Therefore, the concept of effective dose …

… is used for the approximation of the risk for development of cancer and hereditary diseases many years after the exposure;[3,4]

… is used to support decisions on justification and optimisation of diagnostic and interventional procedures, and evaluations of unintended exposures;

… of doses with official limits expressed, enables comparison in the same dose quantity and, thus, enables the verification of regulatory compliance.

Typical effective doses of radiological standard examinations can be found in many recent publications.[5,6]

Is it valid to determine effective doses for paediatric examinations?

- Strictly speaking, ***«NO»***.
- The effective dose is defined for the internationally accepted reference person (ICRP man, 38 years, height 176 cm, mass 70 kg and ICRP woman, 42 years, height 167 cm, mass 60 kg), only.[7] Internationally accepted models for children are not available, yet.
- Tissue weighting factors are age- and sex-averaged values that conceal differences between cancer risk estimates for women and men at different ages. Thus, the effective dose is not a measure of risk to individual patients or patients of a specific age group or gender.
- However, it is valid to provide equivalent doses (e.g., maximum organ doses) for children who received a radiological examination in order to estimate the risk of developing cancer.

References

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[2] G. Stamm, H. D. Nagel. CT-Expo (version 2.4.1) – a novel program for dose evaluation in CT. Fortschr. Röntgenstr 174 (12) (2002) 1570-1576.

[3] ICRP, 1991. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60.

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