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Tips & Tricks

Paediatric Imaging Working Group

Adaptation of protocol parameters to paediatric patients

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THE PRINCIPLE OF OPTIMISATION OF RADIATION PROTECTION HAS TO BE IMPLEMENTED IN DAILY MEDICAL PRACTICE.

This is required by national laws (e.g., in Germany by § 2c of the X-ray ordinance, Italy: D.LGS. 187/2000) and supported by international recommendations such as ICRP report 103 and the European directive 2013/59/EURATOM (article 56).

- Optimisation of paediatric examinations is of particular importance because the risk of harmful radiation effects is greater in children than in adults.
- Periodic comparisons of dose parameters (e.g., dose area product, DAP, or dose length product, DLP) with diagnostic reference levels (DRLs) help to optimise imaging practice.
- If DRLs are likely to be unjustifiably exceeded, then dose (technical protocol parameters such as exposure-time-product, tube voltage, collimation) has to be better adapted to the medical question and the patient.

OPTIMISATION MEANS THAT TECHNICAL PARAMETERS HAVE TO BE ADAPTED TO THE:

1. MEDICAL QUESTION: The dose administered should be just enough to achieve a diagnostic image of sufficient quality to adequately answer the medical question (ALARA principle).

2. PATIENT'S SIZE:

- The amount of radiation absorption by a patient (i.e. dose) depends on the transmission distance through the patient themself. Since there is reduced absorption in smaller patients (e.g. paediatric patients) relative to adults, adequate image quality can be achieved with lower doses.
- For efficient implementation of the optimisation principle in medical practice, technical protocol parameters have to be adapted to a patient's size. For this, a physical quantity characterising the patient's size has to be considered for optimisation.

DOSE ADAPTATION RELATIVE TO PATIENT DIAMETER

A physical quantity characterising patient's size is the diameter of the body region being examined.

In various studies[1;2] in computed tomography (CT) it was found that:

- *physical image noise* is kept constant if dose is halved per 4 cm decrease in body diameter. However, the dose required to keep subjectively rated image quality constant in smaller patients is not proportional to image noise.
- Instead, the dose required for adequate image quality should be moderately adapted to patient's size: dose should be halved per 8 cm decrease in body diameter. Fatty tissue around the organs of adults improves contrast and thus, explains the moderate dose adaptation to patient's size.
- The size specific dose estimate (SSDE) is the CT dose index $CTDI_{vol}$ adapted to patient's size. If available, it should be used for dose adaptation.

DOSE ADAPTATION RELATIVE TO PATIENT WEIGHT

The International Commission of Radiological Protection (ICRP) recommends adapting the dose to patient's weight for examinations of the body.[3]

In a nationwide survey in Germany on exposure practice in CT, it was found that the CT dose index ($CTDI_{vol}$) for examinations of the abdomen, chest and lumbar spine correlates with patient's weight by[2,3]

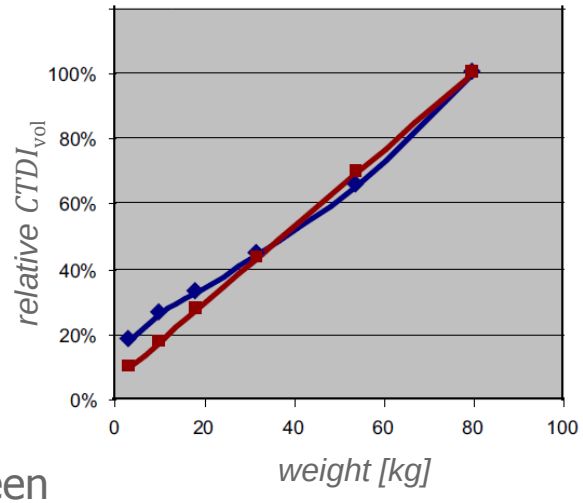
$$CTDI_{\mathrm{vol}} \sim \frac{weight\ (kg)+5}{85} \times f, \quad \text{(Eq. 1)}$$

with f=1 for CT chest, 1.5 for CT abdomen/pelvis/spine and 2-5 CT brain for a constant tube voltage.

- Similar relationships were found between *DLP* and weight[5] as well as between $CTDI_{vol}$ and weight for CT examinations of the head[6].

DOSE ADAPTATION RELATIVE TO PATIENT WEIGHT

- As an outcome of a German study[2], the figure on the right shows the adaptation of the (relative) $CTDI_{vol}$ used in examinations of the abdomen to patient weight normalised by the mean $CTDI_{vol}$ (=100%) used in adult examinations (80kg, blue curve). This relationship can be approximated by Eq. 1 (red curve).



- In plain radiography, relationships were found between dose area product (DAP) and patient thickness/diameter.[7]

➔ These relationships can be considered when dose (i.e. Technical parameters such as the *DAP* or $CTDI_{vol}$) should be adapted to smaller paediatric patients. All adaptation should start with optimised protocols of corresponding adult exams.

➔ A decrease of the *DAP* or $CTDI_{vol}$ can be achieved by decreasing the exposure-time-product.

ADAPTATION OF RADIATION FIELD SIZE AND SCAN LENGTH

In a further study about current CT practice[8], it was found that:

- actual scan lengths are significantly larger than necessary.
- on average, scan lengths have increased by 12% in 10 years. It was concluded that this increase does not result solely from the more frequent use of CT scanners with many detector rows (requiring a larger over-range for image reconstruction) but rather from scanning increasingly large body regions.

➔There is considerable potential for dose reduction when the radiation field size or scan length is adapted to the medical question. In this way, unnecessary exposure providing no clinically relevant information is avoided.

ADAPTATION OF RADIATION FIELD SIZE AND SCAN LENGTH

- The restriction of the radiation field size and scan length is of particular importance for examinations of children where radiosensitive organs are very close to each other compared to organs in adults.

- In addition, immature tissues are more radiation sensitive.

- Different guidelines and studies give an overview in setting the appropriate field size and scan length. For different standard examinations, scan lengths or anatomic landmarks are defined that can assist in the correct set up and acquisition of images.[8-11]

ADAPTATION OF TUBE VOLTAGE RELATIVE TO PATIENT SIZE

In CT, dose is approximately proportional to the power of 2.5th of the tube voltage[4]:

Relative effective dose of the patient vs tube voltage.			
tube voltage [kV]	80	120	140
relative dose [%]	40	100	150

- For smaller patients, children in particular, tube voltage can significantly be reduced without compromising adequate image quality.[13; 14]
- Modern CT scanner types offer features suggesting tube voltage (and exposure-time-product) adapted to the patient.[15]
- Some scanners have an option for acquisition as low as 70 kV. This reduces dose exponentially, with attenuation co-efficients close iodine, thus improving the contrast resolution especially in angiography.

TAKE - HOME MESSAGES

- Optimisation of paediatric examinations is of vital importance. The first step in optimisation is to comply with DRLs and wherever possible, examinations should be optimised below existing DRLs.

- If DRLs are unjustifiably exceeded,
  - the DAP or $CTDI_{\mathrm{vol}}$, i.e. the exposure-time-product, should be adapted to the diameter of the body part being examined or to the weight of the patient,
  - the radiation field size or the scan length have to be adapted (reduced) to correspond with the medical question,
  - in paediatric imaging, tube voltage should be significantly reduced compared to corresponding adult examinations.

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