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Paediatric CT Practice - How safe is imaging in different countries?

Improving patient care in paediatric CT: appropriateness, awareness, optimisation and real-time monitoring

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We present here our experience of implementing radiation protection in paediatric CT, comparing with national reference levels, assessing appropriateness and showing improvements.

1. How radiation protection during paediatric CT is practised in the facility

There are several ways UZ Leuven minimises radiation dose during CT imaging of children:

a) appropriateness;
b) customisation of the CT dose to the child size;
c) use of high-end CT scanners.

The technical innovations listed below are also applied to all our paediatric exams , unless otherwise stated. Specifically, we use:

- fast scanning technique (when appropriate, 10% of the thorax cases);
- dose shaping filter dedicated to children;
- adaptive shielding;
- tube current modulation;
- automatic selection of kV, preferably low (70-80 kV);
- iterative reconstruction techniques.

Additionally we use other principles for paediatric protocol definition:

- patient centring, scanning minimum anatomical area, using shortest rotation time, decreasing baseline mAs according to body diameter; avoiding major overlap of adjacent areas;
- accepting higher noise than in adults.

2. List of the facility's CTDI and DLP for children from different age groups

The tables below I-III report patient $CTDI_{vol}$ and DLP as extracted from the dose reports of 580 paediatric (0-18years) CT exams (head, thorax, abdomen), from November 2012 to September 2013, in UZ Leuven, Belgium.
Table IV reports the national DRLs, as found on http://fanc.fgov.be/nl/page/diagnostische-referentieniveaus-voor-conventionele-onderzoeken-en-ct-onderzoeken-bij-volwassenen/1306. aspx

Table I: $CTDI_{vol}$ and DLP as extracted from 426 paediatric head CT, grouped per age. Protocols used for these examinations were sequential or spiral, one phase (without intravenous contrast medium injection). kV varied between 80 and 120, depending on patient size. Automatic tube current modulation was active. Data reported are for a 16cm phantom.

CT Head Age of the child (y)	$CTDI_{vol}$ (mGy)	DLP (mGy cm)
0 to 1	13.3	239.9
1 to 5	17.4	330.6
6 to 10	21.6	419.1
10 to 16	39.4	750.5
>17	41.2	814.9

Table II: $CTDI_{vol}$ and DLP as extracted from 109 paediatric thorax CT, grouped by age. Protocols used for these examinations were spiral, single phase and without intravenous contrast administration. kV varied between 80 and 120, depending on patient size. Automatic tube current modulation was active. $CTDI_{vol}$ as reported on the scanner is for a 32cm phantom. The conversion factors for $CTDI_{vol}$ to change a 32cm phantom size to a 16cm phantom size for paediatric body protocols is 2.2. So for example the $CTDI_{vol}$ for a child of 1 year for a CT thorax is 0.7x2.2= 1.54 mGy.

CT Thorax Age of the child (y)	$CTDI_{vol}$ (mGy)	DLP (mGy cm)
0 to 1	0.7	13.7
1 to 5	1.2	26.0
6 to 10	1.3	32.8
10 to 16	3.3	100.5
>17	5.6	200.7

Table III: $CTDI_{vol}$ and DLP as extracted from 45 paediatric abdomen CT, grouped by age. Protocols used for these examinations were spiral, single phase and without intravenous contrast. kV varied between 80 and 120, depending on patient size. Automatic tube current modulation was active. $CTDI_{vol}$ as reported on the scanner is for a 32cm phantom. The conversion factor for $CTDI_{vol}$ to change a 32cm phantom size to a 16cm phantom size for peadiatric body protocols is 2.2. So for example the $CTDI_{vol}$ for a child of 1 year for a CT thorax is 1.8x2.2= 3.96 mGy.

CT Abdomen Age of the child (y)	$CTDI_{vol}$ (mGy)	DLP (mGy cm)
0 to 1	1.8	52.1
1 to 5	2.1	63.9
5 to 10	1.8	66.4
10 to 16	3.3	135.3
>17	7.5	314.0

Table IV: National dose reference levels (DRLs) (25th and 75th percentile) for $CTDI_{vol}$ and DLP of paediatric head, thorax and abdomen CT.

	DRL in $CTDI_{vol}$ (mGy)		DRL in DLP (mGy.cm)	
CT exam	25th percentile	75th percentile	25th percentile	75th percentile
Brain	31	75	430	869
Thorax	1.9	5.2	43	140
Abdomen	2.9	6.8	101	316

3. Assessment of the number of paediatric CT examinations that lack appropriateness

The number of paediatric CT examinations that lack appropriateness is not systematically assessed. Typically the radiologist calls the referral clinician and suggests an alternative examination (or rejects the exam if necessary). Empirical data obtained by means of private conversation with radiologists suggest that this is roughly around 15-20%, and the majority of them are trauma and oncology patients.

4. Number of paediatric CT referrals that are reviewed by radiologists before giving appointments

This information is currently not available. However we are planning to address this at our department by implementing a decision support tool in our electronic system, which can used by physicians to request (CT) examinations (e.g. KWS -RIS). Specifically, the idea is to implement the RIZIV (Rijksinstituut voor Ziekte- en Invaliditeitsverzekering) indicated diagnostic procedures for specific clinical symptoms and known diagnosis provided by the patient.

5. Improvements after the implantation of child-tailored radiation protection

In UZ Leuven we started a quality initiative, with the aim of harmonising and optimising CT procedures, with special attention to children. In collaboration with a university spin-off, Qaelum (http://www.qaelum.com/), a software tool is being developed to create a web repository of all CT protocols, as well as track voluntary and involuntary changes and patient-specific dose.

Below, table IV reports patient $CTDI_{vol}$ and DLP of 84 paediatric (0-18 years) head CT exams, from January 2004 to December 2006. Between brackets the dose reduction with respect to current values (as from table I) is reported. On average a dose reduction (CTDIvol) across the years of 27% can be observed for paediatric patients.

Table V: $CTDI_{vol}$ and DLP as extracted from 84 paediatric head CT, grouped by age and for the period 2004–2006. Protocols used for these examinations were sequential, single phase and without contrast. kV varied between 80 and 120 kV, depending on patient size and automatic tube current modulation was NOT active.

CT Head Age of the child (y)	$CTDI_{vol}$ (mGy)	DLP (mGy cm)
0 to 1	26.2 (-29.0%)	385.6 (-29.8%)
1 to 5	30.3 (-28.3%)	441.0 (-23.8%)
5 to 10	35.4 (-33.6%)	516.3 (-24.0%)
10 to 16	42.5 (-17.6%)	636.0 (-10.2%)
>17	46.8 (-22.0%)	702.6 (-12.3%)

Data for thorax and abdomen of the same period were not available.