Improving patient care in paediatric CT: indication, appropriateness and dose real-time monitoring

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Aims and objectives

In the past years, concerns have been raised regarding the risk of cancer induction from computed tomography (CT), especially for children, due to the rapidly increasing number of CT exams [1]. In 2012, a publication appeared in The Lancet [2] about the relation between pediatric head CT scanning and the increasing risk of developing brain cancer and leukemia. In another study, Brenner et al. estimate the number of children that might ultimately die from cancer attributable to radiation from CT exams [3]. These papers along with several campaign like Image Gently and EuroSafe Imaging triggered a worldwide awareness for justification and optimization of pediatric CT exams and doses.

UNSCEAR, in its last report [1], expressed its concern about the fact that dose data collection for children is largely missing and difficult to implement, mainly because examinations are less frequent, procedure are less standardized than for adults and data need to be stratified based on age categories. There still are only few international data on reported doses in a multi-centre set-up [4-10] and previously published dose reference level (DRL) values may no longer be applicable due to technological advancement. An overview of CTDI DRLs in other countries is given in Table 1.

<table>
<thead>
<tr>
<th>Country</th>
<th>New born</th>
<th>0-1</th>
<th>1-5</th>
<th>6-10</th>
<th>11-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>44.5</td>
<td>27</td>
<td>33</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td>27</td>
<td>33</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>UK</td>
<td></td>
<td>25</td>
<td>25</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>France</td>
<td></td>
<td>NA</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
</tbody>
</table>

With this study we aimed at collecting stratified pediatric data in a multicenter setup and for head CT exams only, which represent the majority of the pediatric CT investigation at each center. Collected data were compared across centers in terms of indication, justification and radiation dose.
**Methods and materials**

During 1 year (July 2013-2014) pediatric head CT data were acquired from 3 institutions: one large-size city hospital (A), one university hospital (B) and one periphery hospital (C). The pediatric population consisted of all the patients from 1 day old till the age of 15 years. Five CT-scanners were used for pediatric patients: a Somatom Definition AS + 64 (Siemens, Germany), a Sensation 16 (Siemens, Germany) and three VCT 64 (GE Medical Systems, USA).

Using the same real-time dose-tracking system, DoseWatch (GE Healthcare), we retrieved the following data: (1) patient related data (age and sex); (2) prescriber, clinical indication and justification; (3) exposure related data such as dose length product (DLP), volumetric CT dose index (CTDI\text{vol}), kV and scan length; (4) procedure related information like use of anesthesia and contrast media, availability of child-tailored protocols and repeated exams.

Data were analyzed pooled together and per center, for 4 different age groups separately: (1) 0 - 1 year, (2) 1 - 5 years, (3) 5 - 10 years, (4) 10 - 15 years old. Analysis was performed for the different age groups separately. We described the frequency distributions of the clinical indications and the associated doses per age group. Where appropriate one-way ANOVA was applied to assess statistical difference significance among groups.
Results

A total of 296 pediatric head CT scans were registered, as reported in Table 2. Here the median values for the CTDIvol, DLP and scan length are reported for each center and stratified per age group.

<table>
<thead>
<tr>
<th>Age</th>
<th>Site</th>
<th>Number of exams</th>
<th>CTDI vol (mGy)</th>
<th>DLP (mGycm)</th>
<th>Scan (cm)</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Median</td>
<td>Std dev</td>
<td>Median</td>
<td>Std dev</td>
</tr>
<tr>
<td>&lt; 1 y</td>
<td>A</td>
<td>8</td>
<td>21.3</td>
<td>2.0</td>
<td>314</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>7</td>
<td>17.6</td>
<td>3.5</td>
<td>268</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>15</td>
<td>8.7</td>
<td>1.6</td>
<td>141</td>
<td>68</td>
</tr>
<tr>
<td>1 - 5 y</td>
<td>A</td>
<td>27</td>
<td>23.2</td>
<td>3.5</td>
<td>375</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>20</td>
<td>20.8</td>
<td>5.0</td>
<td>357</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>24</td>
<td>10.7</td>
<td>2.0</td>
<td>189</td>
<td>57</td>
</tr>
<tr>
<td>5 - 10 y</td>
<td>A</td>
<td>23</td>
<td>22.6</td>
<td>1.6</td>
<td>378</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>17</td>
<td>21.6</td>
<td>7.2</td>
<td>402</td>
<td>148</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>20</td>
<td>12.5</td>
<td>2.8</td>
<td>216</td>
<td>61</td>
</tr>
<tr>
<td>11 - 15 y</td>
<td>A</td>
<td>60</td>
<td>34.9</td>
<td>10.1</td>
<td>570</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>39</td>
<td>25.2</td>
<td>7.1</td>
<td>422</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>36</td>
<td>18.1</td>
<td>3.7</td>
<td>298</td>
<td>59</td>
</tr>
</tbody>
</table>

Table 2

In Figure 1, the frequency distribution (in percent) of head CT exams CTDIvol per center is shown. While center B and C have a more Gaussian distribution of the data in center A the majority of the head CT are scanned with one fixed protocol.

In Figure 2, a scatter plot of CTDIvol in function of age is shown, per center. As can be observed, in center C delivered dose is lower with respect to other centers, and the spread of the data is smaller. This is not suprising as in this center a quality process in terms of pediatric protocol optimization was started 10 years ago, while for the centers A and B this is a more recent project. Note that center C is the peripheral hospital, so
it is possible that less complicated procedures and exams are requested, as compared to the university or large hospital.

A further analysis per age-group gave the following distribution: 9% of the exams occurred for the group 0-1 years, 30% for 1-5 years, 23% for the 5-10 years and 38% for 10-15 years. The most common clinical indication was head trauma (80%), and the majority of referring physicians were from Emergency Radiology (ER) (50-80%, depending on the center). Anesthesia was used only in 6% of the cases. Series before and after intravenous contrast administration and re-takes occurred rarely (range: 2-3% and 1.4%-5% respectively).

Adult protocols were erroneously used for children (mostly >10y, range 13%-49% of cases). Technical parameter-variability was in the kV used (range 80-140). Ratios of maximum to minimum CTDIvol and DLP values varied between 2.5-6mGy, and 3.1-9.2mGycm respectively. All hospitals used iterative reconstruction (40-60%) and mAs modulation.

Figure 3 represents the boxplot for CTDIvol grouped per hospital and age group. In spite of the fact that all centers use a multislice CT scanner equipped with iterative reconstruction techniques and tube current modulation functionalities, the variation across the three hospitals is large, with the largest median CTDIvol differences occurring in group 5-10 years (from 1.5 mGy of hospital C to 22.6 mGy of hospital B). Note that all centers have a median CTDIvol below national DRLs of 44.5 mGy. Note also that the 95% confidence interval is much larger in group 10-15 year, probably because it is in this group that the majority of adults protocols are used.

Figure 4 shows boxplots of the scan length, grouped per hospital and stratified per age group. Again, along with a variation across radiology departments, it is interesting to see that in hospital C, which has the lowest CTDIvol per age group (Figure 2), the median scan length is larger in comparison with hospital A and B.
Fig. 1: Frequency distribution (percent) of CTDIvol for pediatric head ct procedures, in each center.

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Fig. 2: Scatterplot of delivered CTDIvol in function of age, for each center.

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Fig. 3: Boxplots of delivered CTDIvol per age-group and per center.

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Fig. 4: Boxplots of performed scan length during pediatric head CT procedures per age group and per center.

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Conclusion

Most pediatric head CT scans were indicated for trauma and ordered by the ER. Unfortunately, several pediatric head CT scans are still performed with inappropriate technical factors (high kV, adult protocols). In the participating hospitals, there was no clinical decision support process to question the indications. In spite of the fact that each centra reported doses below the national DRLs and uses high-end multi-slice scanners, large dose variations have been observed.

An optimisation process should be initiated in order to reduce this spread in dose (appropriate image quality requirements for a given indication). Appropriate DRLs for CT examinations of the brain for the various age groups will be proposed across the center for temporary use in paediatrics until a more extensive survey is organised at national level. In addition, we encourage authorities to propose DRLs by age class, and not only for general pediatric procedures.

Dose-tracking systems are very useful tool for these type of survey, provide increased awareness and help radiologists and CT-technologists to understand radiation dose issues.
Personal information

Questions and/or remarks?

Feel free to contact us:

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