Radiation exposure during paediatric emergency CT: Time we took notice?

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Introduction: Concerns exist about radiation exposure during medical imaging. Comprehensive computerised tomography (CT) dose standards exist for adults, but are incomplete for children. We investigated paediatric CT radiation doses at a NHS Trust in order to define the extent of the risk.

Methods: CT dose indicators (CTDI) were recorded for all scans on paediatric patients from January – December 2011 and benchmarked against American College of Radiologists reference levels (75 mGy for adult head, 25 mGy for adult abdomen, and 20 mGy for paediatric (5-year-old) abdomen). Size-specific dose estimates (SSDE) were calculated based on effective patient diameter as recommended by the American Association of Physicists in Medicine. Student t-test was used to compare CTDI and SSDE values for each anatomical region.

Results: Of 53,648 paediatric emergency presentations, CT was requested in 211 (0.39%). One hundred fifty-four patients underwent 169 scans, with the rest being cancelled for clinical improvement or senior overrule. Indication for CT was trauma in 130/154 (90%), of which 55% were after falls, 19% following road traffic collisions, 12% after sporting injury, and 12% after alleged assault. CTDI values were available for 96/169 (57%) scans, with the rest lacking sufficient data. There was no significant difference between CTDI and derived SSDE values. 3% of head scans exceeded the adult head reference level.

Conclusion: There is wide variation in radiation exposure during paediatric trauma CT, with some scans delivering doses in excess of recommended adult values. There is an urgent need to define standards for radiation dose in paediatric CT for all ages and anatomical regions.

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In 2008, the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), the American Association of Physicists in Medicine (AAPM) and the American Society of Radiologic Technologists (ASRT) founded the ‘Alliance For Radiation Safety in Pediatric Imaging’ as part of the Image Gently campaign [1], in order to focus on the unique needs of paediatric patients when using ionizing radiation [2]. Their aim is to reduce the amount of ionizing radiation that children are exposed to during radiological investigation.

Computerised tomography (CT) scanners normally report two radiation dose indices per scan: CT dose index (CTDI, unit: mGy) and dose length product (DLP, unit: mGycm), calculated by using either 16 cm or 32 cm phantoms. These measurements can be used as Diagnostic Reference Levels (DRLs) in order to compare radiation delivery between scans. However, the real dose to which an individual child is exposed may not be well represented using these rigid measurements due to variance in their size and shape, as well as the possibility that not all energy emitted by the scanner is absorbed by the patient. Because of this, the AAPM Task Group 204 has proposed using size-specific dose estimates (SSDE) based on the effective diameter of the patient [3,4].

Although there are some adult standards for maximum CTDI per CT, the DRLs for paediatric CT are incomplete, with omissions in different age groups and anatomical regions of scans. For example, the ACR have only published one reference CTDI for abdominal CT for 5-year-old patients [5], and the European Commission have only published DRLs for ‘standard 5-year-old patients’ [6]. Our study compares CTDI and SSDE values for all children in one (non-specialist paediatric) UK Foundation Trust in a 365-day period, and benchmarks these against the current ACR guidelines for adults and children. Our aim is to discuss how more detailed and comprehensive consensus standards might be set in order to reduce unnecessary radiation exposure.

1. Methods

All paediatric patients (aged 0–15 years) from 1st January–31st December 2011 who presented to one (non-specialist paediatric) UK Foundation Trust and had CT imaging requested by the emergency departments (ED) were prospectively identified. Patient specific data were used to retrospectively review the clinical course of these patients in order to determine whether the CT was undertaken
following the initial request. Demographic information regarding age and gender was determined and, for those scans that were conducted, the indication for CT, anatomical region, and radiation dose parameters were recorded. Each scan was examined using the digital calipers in the Patient Archiving and Communications in Medicine (PACS) system to determine the lateral and anteroposterior (AP) dimensions. An effective diameter was derived from these measurements using the conversion table described by the AAPM Task Group [4], and the SSDE was calculated for each scan using the formula: 

\[ \text{SSDE} = \text{conversion factor} \times \text{CTDI} \]

Reported CTDI values were compared to the ACR CT Reference levels (Table 1) [5]. A student t-test was used to compare the SSDE and CTDI values for each anatomical region in order to determine whether there was a significant difference. Data are expressed as median (range). A P value of .05 was regarded as significant.

2. Results

During this period there was a total of 247,162 emergency department attendances, of which 53,648 (22%) were emergency paediatric patients. Emergency CTs were requested for 211 (0.39%) of these patients; however, only 154 (73%) patients underwent 169 CT scans, the rest being cancelled for improvement in clinical status or senior overrule. Of the children who underwent CT, there were 104 males (68%), and the median age of all was 10 (0–15) years. The indications for CT included: trauma (n = 130, 90%) of cases; falls (n = 71, 55%); road traffic collisions (RTCs) (n = 25, 19%); sporting injury (n = 16, 12%), alleged assault (n = 16, 12%) and other accidental injuries (n = 2, 2%) (Fig. 1).

CTDI values were available for 96/169 (57%) of scans, the rest having no retrospectively available data regarding radiation dose. Of these scans, the head (76/96) was the most common anatomical region scanned. Of these head CT, 2/76 (3%) of the paediatric scans were above the reference dose for adult head CT. These included one scan for a 13-year-old boy with a dose of 89.8 mGy (SSDE = 83.5 mGy), and one scan for a 9-year-old boy with a dose of 111 mGy (SSDE = 108.8 mGy). Cervical spine CT was conducted for 14/96 of these patients, and upper limb CT for one patient; however, there are no ACR reference levels against which to benchmark these scans. The only abdominal scan was for a 10 year-old boy, and had a CTDI of 5.3 mGy, well below the ACR reference levels for 5 year-old and adult abdominal scans of 20 mGy and 25 mGy respectively.

In order to compare the CTDI and SSDE values for the different anatomical regions, the scans of the trunk were considered together, and included three thorax-abdomen-pelvis, one kidney-ureter-bladder (KUB) and one true abdominal scan. When CTDI and SSDE values were compared for each anatomical region they were not significantly different (Table 2). Statistical analysis was not possible for the upper limb scan since \( n = 1 \).

3. Discussion

Although there is no doubt that when used appropriately CT can be a valuable emergency diagnostic imaging modality, the risks of exposure to radiation must be carefully balanced against these benefits. Brody et al. described a dose of 50–100 mSv to be associated with an increase in risk of fatal cancer in approximately 1 in 2000 paediatric CT scans [7]. Furthermore, Pearce et al. have reported that cumulative doses of 50 mGy may triple the risk of leukaemia, and

![Fig. 1. Number of CTs by indication.](image-url)
60 mGy may triple the risk of brain cancer [8]. Emergency CT scans are being requested and performed in a increasing number each year [9], with approximately 7 million paediatric CT scans conducted annually in the USA [10]. At our NHS Trust, CT scan was requested for just under 0.4% of over 53,000 paediatric presentations, and performed for just under 0.3%. For those patients who had CT requested and subsequently cancelled, all of the scans were either cancelled due to clinical improvement, or following review by a senior clinician who decided that the scan was no longer indicated. We support the practice of senior clinical input and continued clinical review in order to eliminate unnecessary CT scans.

In our cohort of children, 44% of the CT scans performed had missing or unavailable CTDI values, since there were none reported by the CT scanner. This represents a significant omission of data, and hinders the optimisation of scans to ensure minimal radiation exposure. Hartin et al. have reported similar major shortfalls in recorded radiation doses; less than 1% of 1335 paediatric CT scans over a 10-year period at their non-paediatric institution had reported radiation doses [11]. CTDI values ought to be documented and readily available for scrutiny for all CT scans used for scanning paediatric patients in order to audit and improve practice.

Our data show that derived SSDE values were not significantly different to the raw CTDI values reported by the CT scanners. This may suggest that CTDI values – although by no means perfect – may be good enough on their own in determining some paediatric radiation doses. This is an important finding since CTDI values are reported by most CT scanners without any requirement for further calculation. However, our findings may simply suggest that the population of children in this cohort were in good correlation with pre-set scanner configurations, with very few variations in anatomical size and shape from those expected. This is in line with others’ findings; Brady and Kaufman have similarly reported that there was no significant difference between SSDE and CTDI for patients who weighed 36 kg or less when CTDI was calculated using a 16 cm phantom, and when patients weighed 100–140 kg and CTDI was calculated using a 32 cm phantom [12]. We support the continued development and validation of SSDE values in larger studies in order to determine whether they may help in our understanding and practice.

It is difficult to use the available ACR CT Reference Levels to benchmark practice in paediatric CT since there is only one standard for paediatric abdominal CT. The European Commission in 1996 also published DRLs for paediatric CT, but only for ‘standard 5-year old patients’ [6]. In 2003, Shrimpton et al. attempted to propose new national DRLs on the basis of third quartile values of a UK-wide survey of CT doses; however their DRLs are also confined to head and thorax for 0–1, 5 and 10-year olds [13]. Galanski et al. have also used the third quartile range to propose DRLs [14]. The majority of CTs performed during our study were for combinations of regions such as thorax, abdomen and pelvis, and for varying ages of children. Our data also include scans of the cervical spine and upper limb, regions which have no ACR reference levels. More comprehensive and useful guidelines would include specific anatomical categories and would include comprehensive DRLs for every age. Our data demonstrated a wide variability in radiation exposure, a finding that others have also noted [15]. Such variability may be mitigated in the future by using well defined, consistent, and precise DRLs for each scan. Our data also demonstrated that a small proportion of children were exposed to radiation doses during head CT in excess of that recommended even for adults. Although this was rare in our series, it still represents a risk to those individuals, and such risk is surely no longer sustainable.

In conclusion, radiation dose exposure in paediatric CTs is variable, and has incomplete universal, specific standards against which to measure practice. This may result in some children receiving radiation doses even in excess of adult standards. A detailed, comprehensive, and easy to use set of standards for paediatric radiation exposure is needed, and must use values that are readily available from modern CT scanners.

References