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Diagnostic reference levels in plain radiography for paediatric imaging: A Portuguese study

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ABSTRACT

Objective: To determine diagnostic reference levels (DRLs) for the most frequent paediatric plain radiography examinations in Portugal (chest, pelvis and abdomen) and to characterise a standard paediatric patient for each age group used in literature.

Methods: Anthropometric data was collected from 9935 patients. Each age group (<1, 1–<5, 5–<10, 10–<16, ≥16) was categorised by the median values of weight, height and BMI, to define a standard patient. Exposure parameters, kerma-area product (KAP-mGy cm^2) and entrance surface air kerma (ESAK-μGy) were collected. DRLs for KAP and ESAK were defined as the 75th percentile (P75) of dose values and presented by age and weight.

Results: In each age group the P75 of KAP varied from 11 to 77 mGy cm^2 for chest; 23–816 mGy cm^2 for pelvis; 25–979 mGy cm^2 for abdomen. The P75 of ESAK varied from 49 to 67 μGy for chest; 98–1129 μGy for pelvis and 70–1060 μGy for abdomen.

Conclusion: The P75 of dose values determined in this study were lower than those published in literature. When available, weight is the preferred parameter to categorise paediatric patients. The large ranges of dose values found in this study, demonstrates a clear need for the optimisation and harmonisation of practice.

Introduction

Diagnostic reference levels (DRLs) were introduced by ICRP (International Commission on Radiological Protection)[1] as a practical tool for optimisation of radiation dose in diagnostic radiology and nuclear medicine, based on several initiatives taken by the radiation protection authorities from the United States and the United Kingdom in late 1980s.[2] Achieving acceptable image quality or adequate diagnostic information, consistent with the medical imaging task, is the overriding clinical objective. DRLs are used to help manage the radiation dose to patients so that the dose is commensurate with the clinical purpose. DRLs should be used as a form of investigation level to identify unusually high levels, which calls for local review if consistently exceeded. In principle, there could be a lower level also (i.e. below which there is insufficient radiation dose to achieve a diagnostic medical image). DRLs are not for regulatory or commercial purposes, not a dose constraint, and not linked to limits or constraints.[3]

The Council of the European Union has included the DRL concept in the European Basic Safety Standards Directive[4] clearly indicating that "Member States shall ensure the establishment, regular review and use of diagnostic reference levels for radiodiagnostic examinations …".

In 1996, the European Commission published the European Guidelines on Quality Criteria for Diagnostic Radiographic Images in Paediatrics[5] as one of the milestones of several European initiatives regarding radiation protection of the patient and after the development of a similar document for adult radiography.[6]

The decision to develop such guidelines was based on the fact that children have longer life expectancy and therefore a higher risk of detrimental radiation effects.

An UNSCEAR report[7] reviewed 23 different cancer types. Broadly, for about 25 per cent of these cancer types, including leukaemia and thyroid, skin, breast and brain cancer, children were

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found to be clearly more radiosensitive. For some of these cancers, depending on the circumstances, the risks can be considerably higher for children than for adults. Some of these cancer types are highly relevant for evaluating the radiological consequences of accidents and of some medical procedures. In diagnostic medical exposure, children may receive significantly higher doses than adults for the same examination if the technical parameters for delivering the dose are not specifically adapted. For a given radiation dose, children are generally more at risk of tumour induction than adults. Cancers potentially induced by exposure to ionising radiation at young age may occur within a few years, but also decades later. Estimates of lifetime cancer risk for those exposed as children were uncertain and might be a factor of 2–3 times as high as estimates for a population exposed at all ages.[7]

Since the European guidelines were made available, special attention was given to this topic and several papers regarding the establishment of DRLs for paediatric examinations were published in recent years.[8–19] However, by reviewing them, a lack of harmonisation regarding the classification or grouping of patients included in samples becomes evident, creating some difficulties in comparing published data.

To define DRLs some authors group patients according to: a) specific ages (0, 5, 10 and 15 years); b) division between new-borns and infants; c) age groups (<1, 1–<5, 5–<10, 10–<16, ≥16). Other authors[20] consider as a more practical method to present the DRLs as a function of patient projection thickness. When paediatric DRLs are presented as a curve, hospitals can compare their patient doses directly against the graph, without the need for a large number of patients to allow benchmarking. This method was considered by some authors more adequate than the one established by the UK National Radiological Protection Board (NRPB-UK, now part of Public Health England) for setting paediatric DRLs.[21]

'Paediatric population' means that part of the population aged between birth and 18 years,[22] which provides a variety of patients' weight from a few hundred of grams to more than 100 kg. This high heterogeneity of patients combined with the fact that pre-sets installed in radiological equipment are normally not adapted to them, makes defining DRLs and optimisation of X-ray procedures a big challenge for this population.

According to the Portuguese National Institute of Statistics, Portugal has 10,427,301 inhabitants, of which 19.8% are less than 19 years old (www.ine.pt, data from 2013).

Bearing this in mind and taking into consideration that DRLs are not defined and set for individual exposures, but for standard patients, a characterisation of a standard patient in each of the age groups indicated in c), together with DRLs for the most frequent paediatric radiographic examinations in Portugal (chest, pelvis and abdomen) will be presented in this paper.

The main objectives of this study are to establish DRLs for the most frequent paediatric plain radiography examinations, for DR systems and to characterise the paediatric population by defining a standard patient in Portugal for each age group used in literature. According to literature review this is the first prospective study in Europe analysing such a large data collection at the time of the examination. The majority of existing studies were based on retrospective surveys. Results of this study will also contribute to setting European DRLs.

Material and methods

Anthropometric data (weight, height of patient and thickness of the irradiated anatomy) was collected from 9935 patients, referred for a radiography procedure to one of the three dedicated hospitals for children in Portugal. These three health care institutions are the only reference hospitals for paediatric patients in our country and therefore representative of the paediatric population, with practitioners exclusively dedicated to paediatrics pathologies and equipped with up-to-date technology.

Considering that these hospitals mainly use digital radiography systems (DR), with an amorphous silicon Caesium Iodide flat-panel detector, we will present patient dose and propose DRLs for DR systems. Examinations made with mobile units were not included in this study. Institutional Review Board and ethical committee approval was obtained for this study.

For the purpose of this study we have included all examinations of the three most frequent X-rays procedures: chest AP/PA projection; pelvis AP projection; abdomen AP projection; independently of the clinical indication. A standard focus-receptor distance was used to perform the referred examinations (150 cm for chest AP/PA and 110 cm for pelvis and abdomen). All examinations were validated both by the radiographer and radiologist and considered acceptable for the clinical task.

Exposure parameters (kV, mAs and exposure time) as well as kerma-area product (KAP-mGy cm^2) and entrance surface air kerma – K_{ae}, including backscatter (ESAK-μGy)[23] were also recorded.

All devices measuring KAP and ESAK (Diamentor M4-KDK, PTW, Germany) had a valid manufacture calibration certificate, in accordance with IEC 60580,[24] with an accuracy of ±5% and were designed to measure KAP and ESAK according to IEC 61267.[25] Although the radiography equipment had a quality control maintenance provided by the manufacturer, we have also checked equipment constancy using a calibrated RaySafe XI dosimetry system (Sweden; www.raysafe.com).

KAP and ESAK values were collected directly from the equipment console and manually registered in a table, together with patient data, including examination ID number, to allow future analysis in the PACS (Picture Archiving and Communication System).

The measurements of weight, height and anatomical structure thickness of the patients have been made using the same devices. A paediatric measurement rod was used to measure the anteroposterior thickness: from the dorsal region to the middle of the sternum (for chest); from the lumbar region to the umbilicus (for the abdomen); from the sacrum region to the symphysis pubis (for pelvis).

DRLs will be proposed considering several types of paediatric patient categorisation that we have found in the literature:

a) age groups (<1, 1–<5, 5–<10, 10–<16, 16–18);
b) specific weight values (5 kg, 10 kg, 20 kg, 30 kg, 40 kg, 50 kg and 60 kg) with a variation of ±0.5 kg for each value;
c) weight groups (<5 kg; 5–<15 kg; 15–<30 kg; 30–<50 kg; ≥50 kg), proposed in the preliminary report of the PiDRL project (European Guidelines on Diagnostic Reference Levels for Paediatric Imaging).[26]

Patient anthropometric characteristics (weight, height and BMI) were analysed in each age group as a process to define a standard patient for each one of the groups and to allow future comparisons.

Results

We have evaluated the anthropometric characteristics of 9935 paediatric patients referred for a radiography procedure to one of the three dedicated paediatric hospitals in Portugal. Age varied from newborn to 18 years. 50.4% of patients were male and 49.6% female. Table 1 summarises the characteristics of the patients. Taking into consideration that data distribution is not symmetric, the median value will be used as the preferred measure of central