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PAEDIATRIC DIAGNOSTIC REFERENCE LEVELS IN LOW RESOURCE SETTINGS: A GUIDE FOR DEVELOPING COUNTRY PRACTITIONERS WITH EXCERPTS FROM ICRP 135

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ABSTRACT

Background: The practical implementation of Diagnostic Reference Level in paediatric imaging is a complex task due to their unique individuality in terms of high sensitivity to radiation, varying body sizes and presenting pathology. Hence, good knowledge of medical technology, skill to perform patient dosimetry and to analyze image quality is required.

Purpose: To provide a guide on the methodological requirements for the establishment of Paediatric Diagnostic Reference Levels (PiDRLs) based on the revised and updated guidelines from the current ICRP publication 135 on Diagnostic Reference Levels (DRLs).

Materials and method: An extensive review of the ICRP report Publication 135 on Diagnostic Reference levels in medical imaging with a focus on paediatric imaging and other related studies were undertaken.

Results: The ICRP report 135 updates and refines the recommendations of 2001. It highlights that the application of DRLs in paediatrics alone is not sufficient for optimization of protection. Image quality must be evaluated. Quantities used for DRLs should be appropriate to the imaging modality being evaluated, assess the amount of ionizing radiation applied to perform a medical imaging task, and be measured directly. For interventional procedures, complexity of the procedure may be considered in setting DRLs. DRLs shall not be used for individual patients or as trigger (alert or alarm) levels for individual patients. Appropriate weight bands (generally with 5 or 10 kg intervals) are recommended for establishing paediatric DRLs and should be promoted.

Conclusion: The amount of radiation used for examinations of children can vary tremendously due to great variation in patient size and weight from neonates to adult-sized adolescents. This variation in patient radiation dose is appropriate. However, variation in patient doses due to inappropriate technique or failure to child-size the imaging protocol is not appropriate. This forms the basis of the new ICRP guideline and should form the basis of developing PiDRLs.

INTRODUCTION

Children and their parents present a unique individuality to the radiology environment both in terms of their varied levels of psychological development and the radiation safety concerns often expressed by parents [1]. The practical implementation of Diagnostic Reference Levels (DRLs) in paediatric imaging is a complex task due to the high sensitivity of children to radiation and their vulnerability to some certain types of cancers [2], varying body sizes and presenting disease conditions[3]. Therefore, health professionals responsible for imaging children require a basic knowledge of psychology of the child, use of medical technology and requisite skills to perform patient dosimetry and to analyze image quality [4].

Developing country practitioners are faced with myriads of challenges especially, when it comes to establishment of Diagnostic Reference Levels (DRLs) in paediatric imaging [4,5,6] To further highlight this fact, a recent comprehensive survey of data from low -and middle-income countries on DRLs show that paediatric Diagnostic Reference Levels (PiDRLs) constituted approximately one-quarter (14.26 %) of published works covering just 7 % of the entire low- and middle income countries [6].

The few available data on PiDRLs have been hampered by some methodological flaws due to lack of clarity on some of the concepts of diagnostic reference levels. There are several areas where the Commission believes that it will be useful to provide additional guidance on the application of DRLs and the development of DRL values, clarifications of previous recommendations and additional recommendations for newer technologies. Recognizing these facts, several studies have emphasized the need for a harmonized methodological approach to establishing paediatric Diagnostic Reference Levels with regards to the use of appropriate Diagnostic Reference Level quantities and patient groupings [7,8,9] for ease of comparison. The ICRP also saw the need to promote a new guidance document on DRLs in medical imaging with a special section dedicated to paediatrics [3]. This is because the Commission has observed that there is still a lack of knowledge on DRLs within the radiology community [3]. While, the recent guideline would be relevant to all health professionals imaging children worldwide, it will be more relevant for developing country practitioners in countries where established national guidelines for paediatric DRLs are scarce [3,4].

Therefore, this paper focuses on the recent ICRP guideline, publication 135 with particular interest in paediatric radiography which currently accounts for 14.26 % of paediatric Diagnostic Reference Levels data in low- and middle-income countries. Highlighting the reviewed and updated concepts in the new document will be of interest to developing country practitioners.

MATERIALS AND METHODS

While the authors consulted other relevant documents and websites of the ICRP and other agencies that relate to paediatric Diagnostic Reference Levels, the main document that was extensively explored for this publication is the recent ICRP guideline on Diagnostic Reference Levels in medical imaging, publication 135 [10]. Specifically, additional guides reviewed and updated concepts and methodological approaches relevant to paediatric Diagnostic Reference Levels in the new document such as age specific and weight specific requirements were extracted and form the basis of this paper.

RESULTS

New concepts such as DRL quantity and DRL value among others were introduced in the new document. The commission's most recent published guidance on DRLs is over a decade ago [11]. A major change is the use of facility's median value of the DRL for comparison with national or regional DRL value, rather than the facility's mean value of the DRL quantity. The median is considered to be a more robust estimator than the mean, and with data available from larger number of patient examinations due to electronic data collection method, it is seen as providing a quantity more representative of the patient population.

Several terms used in the earlier ICRP publications were not defined clearly [3]. The present publication clarifies and defines some of the terms, such as local, national, regional DRLs and 'consistently exceeded'. In the recent publication, the ICRP provides recommendations on the use of local DRLs, it also introduces the concept of 'typical values' in facilities where different types or levels of technology are used; where the typical value is the median value of the distribution of the values of the DRL quantity for the facility or facilities involved [3].

The majority of published DRL values are based on 'standard' adults. The ICRP in the recent publication guides establishing DRL values and use of DRLs for paediatric patients [3], utilizes work undertaken by the European Commission

[12]. The publication also discusses the use of DRLs in Nuclear Medicine where, DRLs have been assessed in different ways than in X-ray imaging. Highlights were also given on the methodological requirements for the establishment of DRLs in hybrid imaging systems such as PET-CT and SPECT-CT. However, details on these are beyond the scope of this paper.

In the recent publication the ICRP suggests criteria for timing of these revisions (3-5 years). The publication also suggests methods for using automated data collection and registries to provide data for establishing and revising DRL values. The ICRP has not previously advised on appropriate intervals for periodic revision of DRL values as seen in literature. Even though in Europe the new directive on the Basic Safety Standard requires annual review of DRL [13]. These among other points highlighted formed the basis of the new document which will help developing country practitioners establish diagnostic reference levels in paediatric imaging.

DISCUSSION

Optimization is very important in paediatric imaging. This is because, smaller body size of most children compared to adults means more organs are likely to be within or near the primary beam in children, so more precise collimation is both more important and more difficult[14]. It is also important to note that the geometry and spacing of the three sensors of the automatic exposure control (AEC) systems are designed for an adult sized body, which limits the application of the AEC controlled exposure for paediatric patients [7,3].

The quantity of radiation used for examinations of children can vary tremendously due to the great variation in patient weight and size ranging from premature neonates to adult-sized adolescents. This variation in patient radiation dose is appropriate. However, the ICRP as well as other researchers argue that variation in patient radiation dose is not appropriate for two paediatric patients of the same size when the area of the anatomy that is irradiated is the same for the same clinical indication. This may be due to poor technique or failure to adapt the imaging protocol to account for paediatric diseases, patient sizes and body parts [3,8]. Hence, the need to adapt paediatric patient protocols to account for paediatric patient diseases as well as paediatric patient sizes and body parts. Weight-or size-adjusted paediatric DRLs are therefore particularly important as an aid to optimization. Simple adoption of adult imaging protocols to account for paediatric diseases and sizes is not acceptable [3,15].

Several factors need to be considered when discussing development of DRL values for children. Factors common to both adults and children are; choice of DRL quantity, percentile of the distribution of the DRL quantity, choice of whether to collect data from patient examinations or take measurements with phantom, other factors particularly, patient weight and size specifications apply considerably for children.

DRL values for adults are defined based on a standard sized patient but there cannot be a single standard patient for children due to the large size range. Adults vary in body weight by approximately a factor of 4 (40 kg – 160 kg), while, weight in children can vary by a factor of 100, from that of a premature infant (< 1 kg) to that of an obese adolescent (> 100 kg). Within the first 6 months of life, a typical baby's weight doubles, and during the first year, it increases three-fold [3, 10, 14].

The commission has not previously provided guidance on representative child sizes for defining paediatric DRLs. In the past patient age has been used to define groups of children for purpose of establishing a paediatric DRL values. Typically, ages of 0 (neonate), 1, 5, 10 and 15 years have been used [14, 16], mirroring available standard phantoms. Four age groups (<1, >1- 5, >5- 10 and >10 - 15) have frequently been used in the past [17]. However, large variations have been noted even in these groups, and Kleinman et al. [18] demonstrated that individual patient size does not correlate well with patient age even though fitted average patient sizes are age dependent. The study further suggested that it is preferable to use groupings based on paediatric patient body size and that body size should be determined before performing diagnostic imaging examination on children that involves radiation risks. This view is equally shared by other authors [8,9]. The ICRP further recommends that irrespective of variation in patient size, establishment of Diagnostic Reference Level should involve a broad range of practice types. Routine patient doses in academic centres may be different from typical patient doses from non- academic practices due to differences in confidence levels, familiarity with paediatric diseases and body sizes [3].

Weight is a more reliable quantity to link with DRL quantity than age [19,20]. Use of weight bands should be promoted. Some different grouping schemes for patient size and weight exist in

published literature. The European Commission has proposed the weight band in Table 1.0 with an indication of the age bands to which they correspond. However, it is acknowledged that this equivalence will vary substantially across the world.

Table 1.0 Weight grouping for paediatric diagnostic reference levels (DRLs) recommended by the European Guidelines on DRLs for Paediatric Imaging and approximate equivalent ages [12], and age groups used for earlier surveys.

Description	Weight group	Age group based on charts	Most common age on NDRLs
Neonate	< 5 kg	< 1 m	0 y
Infant, toddler and early childhood	5 -< 15kg	1 m - < 4 y	1 y
Middle Childhood	15-< 30 kg	4 y -< 10 y	5 y
Early adolescence	30-<50 kg	10 y - <14 y	10 y
Late adolescence	50-<80 kg	14 y - <18 y	15 y

It is expected that these recommendations should help clarify the appropriate use of DRLs in paediatric imaging, and provide guidance on the application of this tool to a wide variety of imaging modalities and clinical situations. This should help prevent the inappropriate use of DRLs, such as treating a DRL value as a limit, applying DRL values to individual patients, or using quantities that are not easily and directly measurable.

CONCLUSION

The amount of radiation used for examinations of children can vary tremendously due to great variation in patient size and weight from neonates to adult-sized adolescents. This variation in patient radiation dose is appropriate. However, variation in patient doses due to inappropriate technique or failure to child-size the imaging protocol is not. This forms the basis of the new ICRP guideline which should serve as a guide to developing country practitioners in low resource settings. This will reduce methodological variations in establishment of PiDRLs.

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