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ARTICLE ORIGINAL / RESEARCH ARTICLE

Evaluation of entrance surface dose and justification of pediatrics chest radiography in three university-affiliated hospitals at Yaounde - Cameroon

Évaluation de la dose d'entrée de surface et de la justification des radiographies thoraciques de l'enfant dans trois hôpitaux universitaires de Yaoundé - Cameroun

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Mots-clés :
Radioprotection, Justification, Dose d'entrée de surface, enfants, Niveaux de référence diagnostique.

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ABSTRACT

Objective : Evaluate the patient radiation doses and the justification of chest radiography in children, in Yaoundé – Cameroon.

Methods : A cross-sectional study was carried out on 118 children aged from 0 to 15 years in the Radiology units of Yaoundé gyneco-obstetrical and pediatric Hospital, University Hospital Center, and the Medical Centre of CNPS within 5 months (January – Mai 2016). The justification of the chest radiographies was evaluated from the pertinence of the clinical indications. The clinical information were categorized and compared to the recommendations of the Radiology Good practice guide. The Entrance Surface Dose (ESD) was calculated using the Davies formula (ESAK) = O/P × $(kV/80)^2$ × $(100/DFP)^2$ × mAs × BSF ; where the X-Ray tube output (OP) of the radiology equipment was calculated for a voltage of 80 KV and a charge of 20 mAs, with a source to skin distance of 1 metre. The other data collected and analyzed where the qualification of the prescriber, the age, height and Body mass index of the patients.

Results : 21 radiographies where excluded due to poor image quality. The three X-ray machines included in the study were analog radiography, Digital Radiography and Computed Radiography. In our study, 58% of patients were male. The largest age group was children aged 2 to 12 months (38, 1%). The mean age was 39.08 months (± 47.6). The radiography was justified in 82.5% of cases regardless of the qualification of the prescriber. In 74% of cases, the ballots showed no research question. There was no significant correlation between the prescriber and the justification of the radiography. The X-ray tube voltage varied between 50 and 121 kV, while the average charge was 2.78 mAs (± 1.4). The source to skin distance ranged between 104 and 189 centimeters, with an average of 146 cm (± 15). We observed a high variability of the voltage used in infants, between 80 and 100 kV. The lowest charge values (1.3 ± 0.3 mAs) were used in CHE / CNPS, highest values (6.5 ± 3.5) were delivered to new-born in HCY. The values

of the entrance surface doses generally ranged from 21.1 to 304.1 µGy with an average of 117.3 (± 53.1) µGy.
Only the analog radiography equipment of HCY had X-ray filters of at least 2.5 mm Al corresponding to the minimum recommendations of the RP 162 of the European Commission. However, the X-Ray tube output of the HCY's radiography device calculated (18.09 µGy / mAs) was Inferior to the normal according to IAAE. The values of ESD in HGOPY and CHE / CNPS were higher than those recommended by the NRPB and the European Commission. The value of ESD generally increased with age. The study highlighted the fact that the ESD value decreased as the source to skin increased. Meanwhile, the ESD value increased as the voltage and charge increased ($r = 0.407$; $p < 0.001$).
Conclusion: This study was an approach to the evaluation of exposure levels for chest radiography in children in Yaounde. A significant proportion of examinations was unjustified (17.5%). The average recorded doses were significantly higher than those recommended in international DRLs for most age groups; this is certainly linked to the failure to implement international recommendations regarding radiographic technics and the equipment.

RÉSUMÉ

Objectif : Evaluer la dose-patient et la justification des indications de la radiographie du thoracique de face de l'enfant à Yaoundé.
Matériels et méthode : Etude transversale portant sur 118 enfants âgés de 0 à 15 ans, reçus dans les services de Radiologie de l'Hôpital Gynéco-Obstétrique et Pédiatrique de Yaoundé (HGOPY), l'Hôpital Central de Yaoundé (HCY) et du Centre Hospitalier de la CNPS (CHE/CNPS), en 5 mois (Janvier à Mai 2016). La justification des radiographies réalisées était appréciée à partir de la pertinence de l'indication clinique. Les renseignements cliniques étaient catégorisés, puis confrontés à la mention d'indication et aux grades de recommandation du Guide de Bon Usage de la SFR. La Dose d'Entrée de Surface (DES) a été calculée par la formule de Davies : $(ESAK) = O/P \times (kV/80)^2 \times (100/DFP)^2 \times mAs \times BSF$; où le rendement des appareils (O/P) a été calculé pour une tension de 80kV pour 20 mAs à 1 mètre du foyer. Les autres données recueillies et analysées étaient l'âge, la taille, l'IMC des patients et la qualification du demandeur.
Résultats : 21 radiographies ont été exclues pour mauvaise qualité de l'image. Les 3 appareils de radiographie inclus dans l'étude étaient de types analogique, Digital Radiography (DR) et Computed Radiography (CR). 58% des patients étaient de sexe masculin. Le groupe d'âge le plus représenté était celui des enfants de 2 à 12 mois (38,1%). L'âge moyen était de 39,08 mois (± 47,6). L'examen était indiqué dans 82,5% des cas quel que soit la qualification du prescripteur. Dans 74% des cas, les bulletins ne présentaient aucune question de recherche. Il n'y avait pas de corrélation significative entre le prescripteur et la justification de l'examen. La tension du tube radiogène variait entre 50 et 121 kV, tandis que la charge moyenne était de 2,78 mAs (± 1,4). La distance Foyer Peau variait entre 104 et 189 centimètres, pour une moyenne de 146 cm (±15). On observait une grande variabilité de la tension utilisée chez les nouveau-nés, entre 80 et 100 kV. Les valeurs de charge les plus faibles (1,3±0,3 mAs) étaient utilisées au CHE/CNPS, les plus élevées (6,5±3,5) étaient octroyées aux nouveau-nés à l'HCY. Les valeurs des doses d'exposition à la surface variaient globalement de 21,1 à 304,1 µGy avec une moyenne de 117,3 (±53,1) µGy.
Seul l'appareil de radiographie de l'HCY possédait une filtration du tube d'au moins 2,5 mm Al correspondant aux recommandations minimales du RP 162 de la commission européenne. Toutefois, à l'HCY le rendement de l'appareil calculé (18,09 µGy/mAs) était inférieur à la normale selon le RP 162 de la commission européenne. Les valeurs des DES à l'HGOPY et au CHE/CNPS étaient supérieures à celles recommandées par la National Radiological Protection Board (NRPB) et la commission européenne. L'étude a permis de mettre en évidence une influence négative de la Distance foyer-peau sur la valeur de la DES, ainsi qu'une influence positive de la tension et de la charge ($r = 0,407$; $p < 0,001$) utilisée sur la valeur de DES.
Conclusion : Cette étude a constitué une approche de l'évaluation dosimétrique des niveaux d'exposition pour la procédure diagnostique qu'est la radiographie du thorax chez l'enfant à Yaoundé. Une proportion importante d'examens était non indiquée (17,5%). Les moyennes des doses relevées étaient largement plus élevées que celles recommandées dans les NRDs internationaux pour la plupart des groupes d'âges, ceci étant lié assurément au défaut d'application des recommandations internationales, en ce qui concerne la technique radiographique, ainsi que l'équipement.

1. Introduction

Medical imaging is the largest source of exposure to ionizing radiation (IR) of human origin in the world population [1]. Diagnostic procedures represent more than 97% of the exposure of artificial origin and nearly 26% of the total exposure of the human population [2]. Therefore, it is important to evaluate this medical exposure in order to keep this exposure below the limits recommended by the patient radiation protection guidelines [3,4].

In radiopediatrics, justification and optimization of doses deserve special attention because of the greater radiosensitivity of children and their longer life expectancy [5,6]. However, recent studies have shown insufficient optimization of doses in radiopediatrics by radiology technicians [6], related either to the low proportion of examinations performed on children or to a lack of training [7].

In radiodiagnostics, justification of the medical procedure establishes the net superiority of the benefit of the examination as compared to the potential risk related to IR exposure [7]. Studies in Yaounde have shown that in 23% of cases the clinical information did not conform to the type of examination requested [8], and that prescribers had inadequate knowledge on the principles of justification for imaging examinations [9].

Chest X-ray (CT) is the most commonly performed X-ray examination in children [1]. The ease of its request and its accessibility make it an almost banal examination. However, the risks exist because of the irradiation induced by this examination even at low doses. Its prescription therefore requires prior justification. Its implementation must take into account the optimization of doses in relation to the age and weight of the child. The goal is to meet quality criteria, avoid rework, and stay in the field of Diagnostic Reference Levels (NDRs) for age and weight.

In Cameroon, few studies [10,11] have been conducted on dose optimization in radiodiagnostics, and to our knowledge, only one study has been conducted on dose optimization in conventional pediatric radiography [12]. Nevertheless, this study did not dissociate front and lateral chest X-ray, and did not take into account the output of the X-ray tube used. In a context where 31% of radiology personnel have poor knowledge on standards and principles of radiation protection [7] and 79.5% of prescribers have inadequate knowledge of the principle of justification of imaging examinations [9], we undertook to “evaluate the Entrance Surface Dose and justification of chest radiography in children in three university-affiliated hospitals at the Cameroon city capital”.

2. Materials and methods

It was a five months (January – May 2017) cross-sectional study carried out in the Radiology departments of three university-affiliated hospital in Yaounde: Yaounde Gynaeco-Obstetric and Pediatric Hospital (YGOPH), Yaounde Central Hospital (YCH), and the Medical Centre of National Social Insurance Fund (MC-NSIF).

2.1 Study population

We included children aged 0 to 15 years who were referred to the radiology department for a front chest X-ray and whose parents / guardians agreed to participate in the study. Sampling was consecutive, non-probabilistic and exhaustive.

X-ray machines:

At YGOPH: the device was a Digital Radiography (DR), WANDONG® XSI-2, serial number F94-41 / 295, installed in 2013, power: 150kVp, total filtration: 2mm Al / 100kV, no additional filtration; with automatic exposure.

At MC-NSIF: it was a Computed Radiography (CR), General Electrics®, model E7240FX, installed in December 2005, serial number 5M348, Maximum power 150 kW, No automatic exposure; inherent filtration 1.3mm Al / 75 kV equivalent.

At YCH: the machine was an Analog Radiography (AR), SIEMENS®, 576082, serial number 2128, installed in 2003, total filtration 2.5 mm Al / 100 kV equivalent. No automatic exposure.

2.2 Methods and variables

Each x-ray machine was inspected and its information and specifications recorded. A quality control of each device was performed by a medical physicist with more than 10 years of experience. The actual voltage emitted by X-ray tube was measured using a DIAVOLT® PTW dosimeter, calibrated using calibration parameters corresponding to each device taking into account the total filtration of the device. The X-ray tube output (mGy.mAs-1) of each apparatus was calculated at 80 kV, at a distance of 100 cm for 20 mAs.

For each child, the following parameters were identified: indication of the examination, age (date of birth), sex, weight, height, and calculated BMI. For each examination, the exposure parameters kV (voltage), mAs (charge), source to skin distance (SSD) were recorded for the ESD calculation.

The quality criteria for each x-ray were checked according to the European Pediatric Diagnostic Guide [13] and marked on 5 points by a radiologist with more than 10years experience in pediatric radiology. The clinical information provided on the examination request was categorized and then confronted with the clinical imaging guidelines [guide bon usage].
None of the X-ray machines had an integrated device for automatic measurement of the DAP (Dose Area Product).
The Entrance Surface Dose (ESD) was calculated using the Davies formula [14]: ESD (in µGy) = O / P × (kV / 80) 2 × (100 / SSD) 2 × mAs × BSF where O / P is tube output in mGy.mAs-1 and BSF the Backscatter Factor (1.4 in this study as suggested by IAEA [15]). The formula was introduced in Excel to automate calculations.
Statistical analysis:
The collection and analysis of the data was done using the software EpiData®, SPSS 20.0, and R® version 3.2.4. Measures of central tendency such as mean and median and dispersion parameters such as standard deviation and interquartile domains were used for the description of continuous variables. Categorical variables have been described in terms of frequencies and proportions.
The comparison between categorical variables was done using the Fisher's exact test when necessary. The association between two continuous variables was measured using the Pearson and Kendall correlation tests, and materialized where possible by linear regression. The threshold of significance was set at 0.05.

2.3 Ethical considerations

An informed consent, signed by the parents or guardians of the child after explanation was obtained and the study received the authorizations from the administration and Institutional Committee of Ethics for Research.

3. Results

3.1 Demographic and anthropometric data:

During the study period, 135 chest X-rays of children were performed in the three radiology departments. Out of this number, 17 were performed on a device whose output had not been calculated, therefore, were excluded. There were 70 male children (58%), giving a sex ratio of 1.46.
The 75th percentile of the weight and height of the children was 18.1 kg and 1.12 m respectively (**Table I**).

3.2 Justification of child's X-Ray:

In our sample, 68% of the prescribers were general practitioners and 25% were pediatricians. The chest X-ray was justified in 82.5% of the cases independently of the prescriber's qualification (**Table II**).

Table I: Biometric characteristics of the study population

	Min	Average	Std deviation	75th perc	Max
Weight (in Kg)	2 ,20	15,3	13,24	**18,1**	82,6
Height (in meters)	0,48	0,89	0,3	**1,12**	1,68
BMI	0,11	16,68	6,7	**20,21**	39,58
Age (in months)	0	39,08	47,6	**60**	180

Table I: Justification of the chest X-ray according to the referrer

Justification of C X-ray	**Qualification of the referrer**					
	Specialist n(%)	**GP (Generalist)** n(%)	**Resident** n(%)	**Paramedics** n(%)	**Total** n(%)	**P value**
Justified	27(25)	54(50)	6 (5.5)	2 (2)	**88 (82.5)**	0.5
Not justified	2(2)	17(15.5)	0 (0)	0 (0)	**19 (17.5)**	
Total n(%)	**29(27)**	**71 (75.5)**	**6(5.5)**	**2 (2)**	**108 (100)**	

3.3 Radiographic exposure parameters:

The X-ray tube's voltage ranged from 50 to 121 kV, while the average charge was 2.78 mAs (± 1.4). In addition, the skin to surface distance varied between 104 and 189 centimeters (**Table III**).

Table III: Overall Averages of Voltages, charges, and skin to surface distances

	Minimum	Average	Mean	Standard deviation	Maximum
Voltage (U) in kV	50	95,21	100	12,07	121
Charge (Q) in mAs	1	2,78	2,5	1,4	12,5
SSD in cm	104	146	141	15	189

Figure 1 shows the overall variation of the voltages (in kV), the charge (in mAs) used according to the defined age groups.

There is a great variability in the voltage used in neonates, between 80 and 100 kV; and low variability for children between 10 to 15 years (around 100 kV).

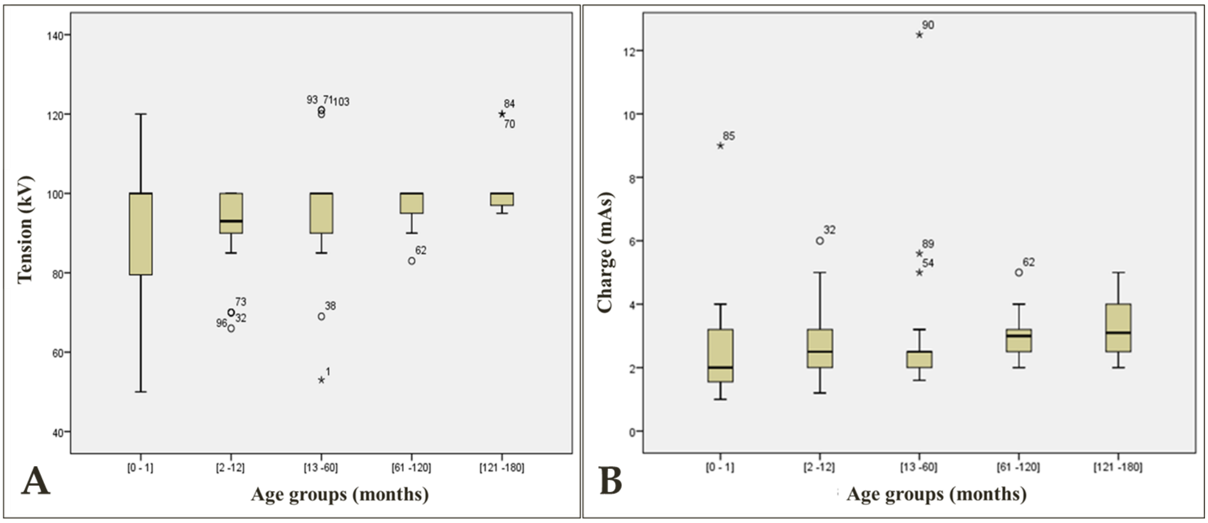

Figure 1: Variation of voltages (A) and charges (B) used by age groups

The lowest charge values were used with Computed Radiography in neonates, while voltage values were highest for extreme ages. The highest charge (6.5 ± 3.5 mAs) were used in neonates with analog Radiography (**Table IV**).

Table IV: Averages of exposure parameters used according to age and hospital

Hospital / machine	Exposition parameters	Age groups (months)				
		[0 ; 1]	**[2 ; 12]**	**[13 ; 60]**	**[61 ; 120]**	**[121 ; 180]**
	kV	92±18	97±7	95±12	97±6	98±2
YGOPH / DR	mAs	2.6±0.6	2.7±0.8	2.5±0,7	2.9±1	3.8±0.8
	SSD (m)	1.45±0.2	1.40±0.03	1.37±0.03	1.33±0.07	1.35±0.01
	kV	110±12	87±9	104±13	100±0.01	110±12
MC-NSIF / CR	mAs	1.3±0.3	2.3±1,4	1.8±0.2	2.5±0.01	2.2±0.3
	SSD (m)	1.79±0.07	1.61±0.2	1.41±0.1	1.53±0.01	1.55±0.2
	kV	54±6	84±8	88±2	94±2	95±0.01
YCH / AR	mAs	6.5±3.5	3.4±0.5	5.5±4.05	3±0.3	3.2±0.01
	SSD (m)	1.19±0.2	1.42±0.2	1.50±0.2	1.4±0.1	1.33±0.01

3.4 Entrance Surface Dose (ESD):

Entrance surface dose values ranged generally from 21.1 to 304.1 µGy with an average of 117.3 ± 53.1 µGy (**Table V**). Half of the patients were exposed to doses of at least 120.5 µGy.

With the analog machine (YCH) the values of ESD were lower than those obtained with the DR and CR machines. **Table VI** gives the 75th percentile of ESD (DRL) according to age groups.

Table V: Overall value of ESD (µGy) according to Yaounde hospitals

Hospital / machine	min – max	mean	75th perc.
YGOPH / DR	36.1 – 304.1	136.4±46,8	145.7
MC-NSIF / CR	40.0 – 187.6	104.1±36	131
YCH / AR	21.9 – 301.4	67.8±62.7	65.5

Table VI: ESD values (µGy) according to age groups and hospitals.

Age groups (months) per Hospital / machine	min – max	mean	75th perc.
MC-NSIF / CR			
[0 ; 1]	56,8 – 86,6	66,58±13,56	**68,6**
[2 ; 12]	40,7 – 135,8	80,69±31,8	**98,2**
[13 ; 60]	97,5 – 134,2	121±13,6	**127,2**
[61 ; 120]	131,6 – 135,4	134,1±2,19	**135,4**
[121 ; 180]	110,2 – 187,6	145,2±32,04	**156,9**
YGOPH / DR			
[0 ; 1]	36,1 – 185	112,5±28,88	**138,9**
[2 ; 12]	81,4 – 178,6	127,5±37,55	**136,9**
[13 ; 60]	49 – 304,1	124,9±41,84	**136,9**
[61 ; 120]	102,7 – 254,3	163±41,08	**203,9**
[121 ; 180]	155 – 286,2	211,7±15,33	**222,3**
YCH / AR			
[0 ; 1]	21,9 – 121,1	67±19,45	**89,55**
[2 ; 12]	24,3 – 87,5	50,06±43	**55,1**
[13 ; 60]	29 – 301,4	96,24±36,29	**65,9**
[61 ; 120]	41,1 – 75,6	55,56±44,89	**58,3**
[121 ; 180]	64,2 - 92,3	78,25±19,8	**85,2**

Table VII: 75th percentile (DRL) of ESD (µGy) according to age groups for the three radiology departments.

Age groups (months)	min – max	mean	75th perc.
[0 ; 1]	21,9 – 185	87,5±47,3	107
[2 ; 12]	24,3 – 178,9	107,5±36,75	134,9
[13 ; 60]	29.0 – 304,1	119,8±56,1	132,2
[61 ; 120]	41,7 – 254,2	126,3±62,5	152,9
[121 ; 180]	64,2 – 286,2	170,5±62,4	205,9

The ESD were very higher with the DR machine for children from 0-12 months than with the CR and AR machines. **Table VII** gives the 75th percentile of ESD (DRL) according to age groups for the three radiology departments combined.

The ESD generally increases with the age of the child. **Table VIII** compares the average values of ESD voltage and charge according to age groups.

3.5 Influence of age and exposure parameters on ESD:

An analysis of the correlation between the ESD and each of the exposure parameters was done by the correlation test of Kendall. **Table IX** shows Kendall's Tau and p-value for the four tests performed. Patients' age and all exposure parameters were correlated with the ESD (p <0.05).

Figures 2 and 3 show the construction of ESD point cloud and the statistical adjustment of ESD by Local Polynomial Regression according to age, charge, voltage, source to skin distance with a range of 95% confidence.

Table IX: Correlation between ESD and Age, Voltage, charge and Source to skin Distance.

	Age	Voltage	Charge	Source - Skin Distance
Tau of Kendall[1]	0,16	0,31	0,27	-0,37
P value	0,01	$8{,}7.10^{-6}$	$6{,}6.10^{-5}$	$5{,}3.10^{-9}$

Table VIII: Comparison of ESD average values and exposure parameters (kV mAs) according to the type of device.

Hospital / machine	[0 ; 1]	[2 ; 12]	[13 ; 60]	[61 ; 120]	[121 ; 180]
MC-NSIF / CR					
Charge	1,3±0,3	2,3±1,4	1,8±0,2	2,5±0,01	2,2±0,3
Voltage	110±12	87±9	104±13	100±0,01	100±12
ESD YGOPH / DR	66,58±13,56	80,69±31,8	121±13,6	134±2,19	145±32,04
Charge	2,6±0,6	2,7±0,8	2,5±0,7	2,9±1	3,8±0,8
Voltage	92±18	97±7	95±12	97±6	98±2
ESD YCH / AR	112,5±28,88	127,5±37,55	124,9±41,84	163±41,08	211±15,33
Charge	6,5±3,5	3,4±0,5	5,5±4,05	3±0,3	3,2±0,01
Voltage	54±6	84± 8	88±2	94±2	95±0,01
ESD	67 ±19,45	50,06 43	96,24±36,29	55,56±44,89	64,2±64,2

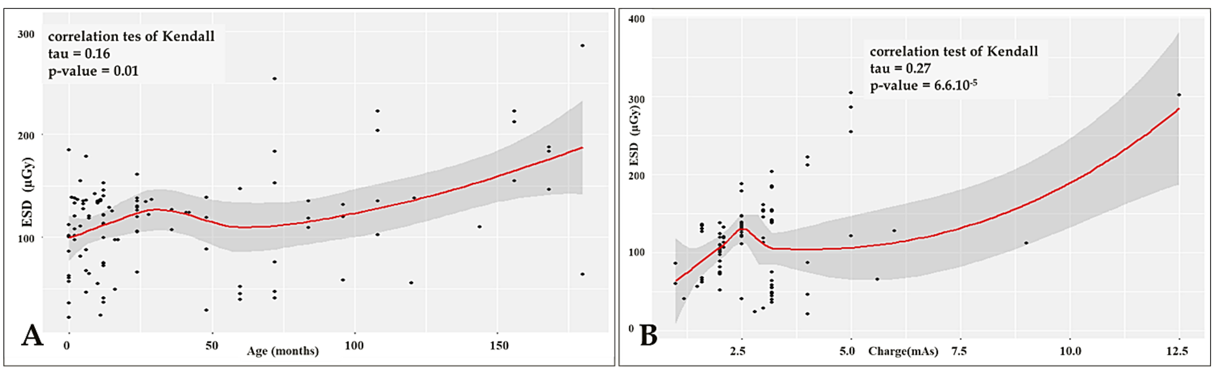

Figure 2: Variation of ESD according to the age of the patients (A) and the charge (B).

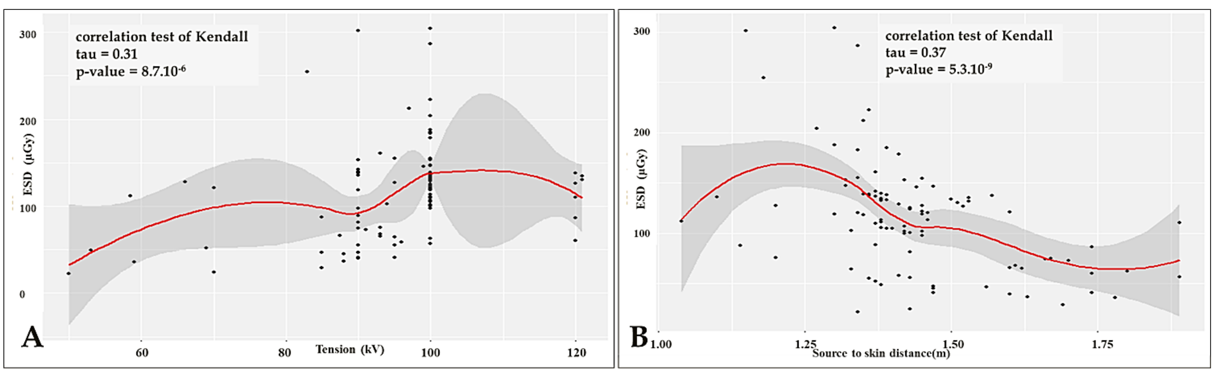

Figure 3: Variation of the ESD according to the voltage (A) and the source to skin distance (B).

4. Discussion

4.1 Demographic data

The size of our population was 118 patients. The most represented age group was 2 to 12 months (38.1%) with an average of 39.08 months. Mbo Amvene et al had collected 117 patients [12], with an average age of 5.4 years, Eljak et al had a study population of 50 children, with an average age of 7 years (± 3.10) [16]. This difference in age with the Eljak et al study is explained by the fact that the age of the target population was 2 to 15 years, compared to 0 to 15 years in our study. In addition, these data from our study are similar to those from Egbe et al In Nigeria, where the average age in the 3 hospitals in the study was 2.13 (± 0.9), 2.57 (± 0.9) and 2.25 (± 0.6) years [17]. This relatively low age should encourage more attention, as many epidemiological studies have shown an increased risk of age-matched cancer following exposure to ionizing radiation.

4.2 X-ray equipment

The output values of the DR and CR devices (47.5 and 58.5 µGy / mAs) corresponded to the IAEA recommendations in the European Commission's publication RP 162, on the criteria for the acceptability of radiological equipment. The output value of the analog device (18.09 µGy / mAs) was below these values, ranging from 25 to 80 µGy / mAs at 80 kV [18].

4.3 Justification of exam indications

In our study, we found that 82.5% of exams were justified. Nevertheless, there is no statistically significant relationship between the prescriber qualification and the justification of the Chest X-rays. This differs from the study by Adambounou et al in Togo, which found that the clinical indications formulated by prescribers for chest x-rays were adapted in 96.5% for specialist physicians, 72% for general practitioners and 12% for paramedics [19]. This discrepancy can be explained by the fact that, in our teaching hospitals, many requests are signed by the general practitioner on the order of the specialist.

4.4 Radiographic exposure parameters

The X-ray tube voltage in our study ranged from 50 to 121 kV, while the average charge ranged from 1 to 12 mAs. In addition, the source – to skin distance varied between 104 and 189 centimeters. These values are quite high compared to those found in the Egbe et al. Study, where volatge ranged from 60 to 84 kV in the UCTH hospital, from 50 to 55 and from 48 to 50 Kv in the FMCO and NAUTH hospitals respectively. [17].

4.5 Entrance surface Doses and diagnostic reference level

In our study, the **02 to 12-month** age group received an average dose of 107.5 µGy with extremes of 24.3-178.9 µGy and a 75th percentile of 134 µGy. Our results were slightly higher than the IRSN recommendation [20] which proposes a dose of 80 µGy for children in the same category. They were nevertheless lower than those of Mbo Amvene et al who found an ESD of 125 µGy for the same category. This difference with IRSN's RDL could be explained by the fact that the recommended source-skin distance was not respected especially for this age group, particularly with the DR (YGOPH) because the radiology device used only allowed to obtain a maximum SSD of 104 cm when the directing beam was vertical. On the other hand, the difference with the results of Mbo Amvene et al could be explained by the fact that the X-ray machines used had filters less than or equal to 1.5 mm Al, meanwhile in our study, the apparatuses used had filters of 2.5, 2, and 1.3 mm Al for analog, DR, and CR respectively.

The **13 to 60 months** age group received an average dose of 119.8 µGy with extremes of 29-304.1µGy and a 75th percentile of 132 µGy. This dose is similar to that of IRSN NRDs which proposes a dose of 100 µGy for children in the same category. Nevertheless, this result remains inferior to that of Mbo Amvene et al who found an ESD of 185 µGy for the same category of children.

The **61 to 120 months** age group received an average dose of 126.3 µGy with extremes of 41.7-254.2µGy and a 75th percentile of 152.9 µGy. This dose is slightly lower than that of IRSN NRDs which proposes a dose of 200µGy for children in the same category. It is also lower than that of Mbo Amvene et al who found an ESD of 250 µGy. Nevertheless, it is similar to the dose found by Van Nieuwenhuyse et al [21] as well as the DRL in Ukraine, which recommends a dose of 120 µGy for children of the same age group.

The **121 to 180 months** age group received an average dose of 170.5 µGy with extremes of 64.2-286.2µGy and a 75th percentile of 205.9µGy. This dose remains lower than that of Mbo Amvene et al who found a dose of 300 µGy. For this same age category in pediatrics, there is currently no DRL recommendation available according to the IRSN.

4.6 Relationship between DES and exposure parameters

The variability of ESD during diagnostic exposures according to the voltage, the charge, and the SSD in this study was described. There was a negative influence of the SSD on the ESD value. This corroborates the results of the UK NRPB for chest X-rays [22]. Don et al had identified a significant influence of DFP on ESD [23], as in our study. The charge was significantly correlated (r = 0.407, p <0.001) with the ESD value. The mean charge for neonates used at CHE (1.3 ± 0.3) mAs was lower than at HGOPY (2.6 ± 0.6) mAs, with a corresponding ESD of 66.58 and 112.5 µGy respectively. Thus, a reduction in the charges used, for instance at the YGOPH could thus favor the lowering of the doses without, however, altering the quality of the image.

The differences between the doses delivered to patients during front Chest X-ray and the DRL of the international recommendations can be explained by differences in the examination protocols and the morphotype. It should be remembered that the irradiation parameters must be adapted, apart the region explored, to the morphotype and weight of the patient, whether or not there is an automatic exposure control. In addition, the differences in dose with those found in the similar study conducted in Cameroon by Mbo Amvene et al could be explained by the calculation of the ESD not taking into account the performance of the X-ray machine, or by the fact that the dose results included both front and side Chest X-rays.

5. Conclusion

A significant proportion of chest X-ray examinations was unjustified (17.5%). Doses were higher than those recommended in international NRDs for most age groups, and the equipment characteristics were not appropriate for pediatric radiography. The training of technicians on the specific aspects of pediatric radioprotection and the adaptation of irradiation parameters to the age and morphotype of children will reduce the patient dose in chest radiography of children.

Conflict of interest.

The authors declare that they have no conflict of interest.

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