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Radiation dose from three-phase X-ray machines: A comparison between different models

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► ***Original article***

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ABSTRACT

Background: The assessment of radiation dose is of great importance in the optimization process. It is crucial to develop strategies for dose estimation in developing countries in lack of dosimeters. ***Material and Method:*** The Entrance Skin Dose (ESD) of 731 patients was calculated using the Davies model. Eight radiological procedures: Chest PA and LAT, lumbar spine AP and LAT, pelvis AP and LAT, skull PA and LAT and three-phase X-ray machines were considered. Based on the mathematical estimation of the radiation output of X-ray machines, a modified Davies model was proposed. The model was compared to others (Edmonds, Tung and Tsai) using their Mean Relative Errors (MRE) with respect to the reference Davies model and the Student's test of comparison of means. The 3rd quartile values were also compared to those found in Cameroon, Nigeria, Iran, France and UK. ***Results:*** The MRE of the proposed model in this work (1.9%) was significantly less than the MRE of the Tung and Tsai model (7.1%), which was in turn significantly less than the MRE of the Edmonds model (55.0%). Results also show that, the 3rd quartile values were mostly higher than reference level in UK. High values of doses are attributable to short Focus to Skin Distance (FSD) and high values of charges. ***Conclusion*:** The model proposed in this study is a better alternative to the Davies model in the case of absence of dosimeter. An adjustment of technical parameters (FSD and charge) could help reduce high doses.

Keywords: *Three-phase X-ray machines, modified Davies model, dose optimization.*

INTRODUCTION

X-rays are frequently used in diagnostic radiology. In developing countries, the extensive demand of X-ray examinations has driven an increasing use of this. It is therefore important to enhance radiation protection of patients and medical personnel since the use of X-rays is not riskless. The main task of radiation protection is to minimise stochastic risks through the principle of justification and optimization. Radiation dose measurement is necessary to enhance the optimization process. In general, Patient dose surveys provide important information on the levels of patient exposure and an insight on the cause of their variations [1].

In diagnostic radiology, the Entrance Skin Dose (ESD) is an important parameter in assessing dose received by a patient in a single radiographic exposure. This quantity can be measured directly with suitable calibrated Thermoluminescent Dosimeters (TLDs) attached to the patient's skin [2,3] or indirectly by using exposure parameters such as: the tube output, the filtration, the Focus to Skin Distance (FSD), the product of tube current (mA) and exposure time(s), the voltage (kV) [4, 5, 6].

A review of radiation dose measured in different countries shows wide variations in patient doses for the same type of examination [7, 8]. These variations indicate that a good imaging technique is necessary to reduce patient

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doses to the lowest practicable levels while maintaining the clinical purpose of medical examination. The International Commission on Radiological Protection (ICRP) recommends the use of Diagnostic Reference Levels (DRLs) to ensure that minimum dose is delivered to patients during examinations. These DRLs also serve as good indicators for practice in need of investigation and help maintain appropriate levels of good practice.

It is therefore crucial for each institution to develop protocols for X-ray examinations that could contribute in the evaluation of the local radiographic practice and also the establishment of Local Diagnostic Reference Levels (LDRLs).

In Cameroon, in spite of the large number of examinations carried out yearly, there is not consistent dose data collection on patient exposure. Studies have provided data for the chest (PA and LAT), abdomen AP and axial skeleton for some purposely selected hospitals in the Center Region of Cameroon [9-11]. The ESD in these studies were calculated using exposure parameters (including but not limited to kV and mAs) and the Davies model. In the latter model the output is an important parameter that needs to be measured using an appropriate dosimeter. This turns out to be a crucial problem in the case of non-availability of dosimeters, particularly in developing countries. To the best of our knowledge dose data for the West Region of Cameroon have not been provided so far. Moreover, no comparable alternative to the Davies model that fixes the issue of non-availability of dosimeter for the output measurement, has been considered in the literature.

Hence, this study focuses on three main purposes. Firstly, the work aims at proposing a new model (a kind of modified Davies model) which can help estimate doses in a three-phase X-ray machines setting, in a context of non-availability of dosimeters. The second goal is to estimate adult patients' doses for the most frequent X-ray examinations (chest PA and LAT, lumbar spine PA and LAT, pelvis AP and LAT, skull PA and LAT) in two hospitals located in the West Region of Cameroon. The third and last purpose of the study is to statistically compare the previous model with some other models in the literature, namely the Tung and Tsai model and the Edmonds model.

MATERIALS AND METHODS

This study was carried out in two hospitals in the West Region of Cameroon: Bafoussam Regional Hospital (BRH) which is a public hospital and the Center of Radiology and Medical Image of West Region (CRIMO) which is a private hospital. These hospitals were selected because they are reference hospitals in the region and they also have high workload of patients. The hospitals were equipped with X-ray machines made of three-phase X-ray generators. BRH had one X-ray machine and CRIMO had two X-ray machines.

Data were collected for adult patients of both sexes (male and female) aged above 15. For each patient, exposure parameters such as voltage (kV), mAs, FSD, examination type and projection (AP, PA, LAT) were recorded. Patient's information including weight, height and age were also recorded. Only films that were considered suitable for diagnosis by the radiologists were included in the present work that is based on the most frequent X-ray examinations carried out in both hospitals: the chest (PA and LAT), lumbar spine AP and LAT, pelvis AP and LAT, skull PA and LAT. Prior to this study, quality control has been performed on all X-ray machines.

The ESD for patients was estimated using equation (1) [12]:

$$ESD = O/P\left(\frac{kV}{80}\right)^2 mAs\left(\frac{100}{FSD}\right)^2 BSF \qquad (1)$$

O/P is the output of the X-ray machine in mGy/(mAs) at 80 kV at a distance of 100cm and normalized to 20 mAs, kV is the tube potential, mAs is the product of tube current and the exposure time, FSD is the Focus-to Skin Distance (in cm), BSF is the backscatter factor. In this wok, the BSF is equal to 1.35 for adults according to the European guidelines [13].

The output of the three X-ray machines was measured in the absence of patient using

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the calibrated Diavolt Universal all-in-one, manufactured by PTW-Freiburg, Germany.

In order to determine the output in equation (1), the model proposed by Harpen was used [14]. He showed that the output depends on the voltage and mAs as:

$$\mathrm{O/P\,(mAs, kV)} = \alpha\left(kV\right)^{\beta} \times mAs \qquad (2)$$

A linearization of Equation (2) yields the following simple linear model.

$$\ln \mathrm{O/P\,(kV)} = \eta + \beta \ln\left(kV\right) \qquad (3)$$

Where; $\eta = \ln\alpha$.

Using the data from measurement, the parameters η and β are estimated by the Ordinary Least Squares (OLS) method, using R software.

For the modified Davies model, we will make use of the model proposed by Simo *et al.* [15] for the estimation of output. Therefore, equation (4) is used:

$$ESD = 0.015\,(kV)^{1.992} \times \frac{1}{T^{0.578}}\left(\frac{kV}{80}\right)^{2} mAs\left(\frac{100}{FSD}\right)^{2} BSF \qquad (4)$$

As we are dealing here with three-phase X-ray machines, mathematical models developed by authors for these specific types of equipment's will also be used for the assessment of ESD. The first equation for ESD estimation for three-phase X-ray machines was published by Edmonds [16]. He showed that the radiation dose can be reduced to a simple function that depends on kVp, mAs, filtration and FSD. His model was challenged by Shrimpton [17]. The author compared the results obtained using Edmonds' formula with that obtained by direct measurement of skin dose using TLD. He noted that Edmonds' formula produces but an estimation of air kerma in the absence of patients. So, for better results, Edmonds' formula needs to be corrected by means of a multiplication by the backscatter factor and the mean energy absorption coefficient of tissue to that of air. Therefore, the corrected Edmonds model given by equation (5) is used in this work.

$$ESD = \frac{836\left(kV\right)^{1,74} mAs}{p\left(FSD\right)^{2}}\left(\frac{1}{T} + 0{,}114\right) \times BSF \times \left(\frac{\mu}{\rho}\right)_{air}^{tissue} \qquad (5)$$

T is the total filtration which includes the inherent and the added filtration in mm Al. $\left(\frac{\mu}{\rho}\right)_{air}^{tissue}$ is the ratio between the absorption coefficients of biological tissue and air which is equal to 1.06 for all energies that are used in radiography [18].

The model proposed by Tung and Tsai [19] for three-phase X-ray machines represented by equation (6) is also used for ESD assessment.

$$ESD = c\left(\frac{kV_p}{FSD}\right)^{2}\left(\frac{mAs}{mm.Al}\right) \qquad (6)$$

mm.AL is the aluminum filtration and *C* is the machine dependent constant which is equal to 0.2775.

The estimated ESDs from the model proposed in this work equation (4), the Edmonds model equation (5) and the Tung and Tsai model equation (6) will be compared in terms of their respective percentage differences or relative errors to the estimated ESDs from the Davies model equation (1). Considering the latter model as the reference comes from the fact that it has been used by several authors to obtain results that compared well with the direct measurement using thermoluminescent dosimeters [12, 20, 21].

Data analysis

Data were collected in each hospital according to the types of examination, and recorded in a computer Microsoft Excel spreadsheet. Excel software was also used for descriptive statistics of radiographic parameters, patients' information and ESD (mean value, percentage error, 3rd quartile, minimum and maximum). The models were compared with one another in terms of their mean relative errors (MRE) given as in equation (7):

$$MRE = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|Davies_i - ESD_i\right|}{Davies_i} \qquad (7)$$

Where; $Daives_i$ is the estimated dose for the i-th observation by the (reference) Davies model; ESD_i is the estimated dose for the i-th observation by the considered model; N is the total number of observations.

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Indeed, the MRE of a given model is the average of the relative deviations between the estimated doses using this model and the estimated doses using the Davies model. It is an indicator of relative performance of models with respect to the Davies model: model 1 performs better than model 2, relatively to the Davies model, if the MRE of model 1 is less than the corresponding one of model 2. In order to investigate whether such results were not due to chance, unilateral Student's t-tests were conducted as well in this study, as follows:

Null hypothesis: H_0: $MRE_1 = MRE_2$
Alternative hypothesis: H_1: $MRE_1 \prec MRE_2$

Where MRE_1 and MRE_2 respectively stand for the mean relative errors of model 1 and model 2 that are chosen among the modified Davies model, the Edmonds model and the Tung and Tsai model. The significance threshold was set at 1%. As such, a p-value less than 1% is interpreted as: the mean relative error of model 1 is significantly less than the mean relative error of model 2. If the p-value is greater than 1%, we fail to conclude that mean relative error of model 1 is significantly less than the mean relative error of model 2.

RESULTS

The present work includes three X-ray machines from BRH and CRIMO hospitals. As was previously mentioned, CRIMO had two X-ray machines. The specific characteristics of each X-ray machine and the obtained value of output at 80kV are shown in table 1. The coefficients α and β are obtained based on the Harpen's equation (2). Their estimated values vary from 0.0027 to 0.025 and from 1.71 to 2.26, respectively. The filtrations of X-ray machines were all greater or equal to the minimum value of 2.5 mm.Al required for good practice [22].

Summary of patients' data (age and weight) and radiographic parameters (kV, mAs and FSD) alongside the ranges in parentheses for both centers are presented in tables 2 and 3. According to the types of examination, the minimum and maximum mean ages of patients were respectively 34.5 and 50.9 in BRH and 33.9 and 68.6 in CRIMO. The mean patient weight ranged between 68.6 kg to 86.2 kg in BRH and 68.2 kg to 95.2 kg in CRIMO. A constant value of 120 kV is used for the chest PA in BRH while in CRIMO, the kV used ranged from 117 to 121 kV. The mean values of kV used in BRH for pelvis AP, skull PA and LAT are comparable to those used in CRIMO. However, the mean kV used in CRIMO for lumbar spine (AP and LAT) are higher than those used in BRH. Moreover, for all examinations, the mAs used in BRH are higher than the values used in CRIMO. The FSD ranged from 84 cm to the 128cm in BRH and from 54.6 cm to 130 cm in CRIMO.

Tables 4 and 5 present the mean values and ranges of the ESD with respect to hospitals and types of examination. For all hospitals and types of examination, the Edmonds model provided the highest mean doses, while the lowest were obtained by the Tung and Tsai model. The overall average dose for the reference Davies model is 4.80mGy, while those for the Modified Davies, the Tung and Tsai and the Edmonds models are respectively 4.75mGy, 4.40mGy and 7.50mGy. Figure 1 shows, for each X-ray device, the MREs per type of examination. The MREs for a given examination vary as we move from one X-ray device to another. For the modified Davies model, the Tung and Tsai model and the Edmonds model, they range respectively from 1.1 to 3.9%, from 2.5% to 21.5%, and from 29.5% to 72%. The results of the unilateral Student's t-test of comparison of means are displayed in table 6. The MRE of the modified Davies model is significantly (p-value less than 1%) lower than the corresponding values for the Tung and Tsai, and the Edmonds model. Besides, the MRE of the Tung and Tsai model is significantly lower than that of the Edmonds model.

Table 7 shows the comparison of 3rd quartiles of estimated doses using the Davies model in this work with other published studies.

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Table 1. Specific characteristics of X-ray machines.

Hospitals	BRH	CRIMO 1	CRIMO 2
Equipment model	**General Electric Healthcare (GEH)**	**General Medical Merate (GMM)**	**Siemens**
Date of manufacture	2011	2014	2008
Date of installation	2012	2015	2009
Total filtration at 80kV	2.5 mm.Al	2.9 mm.Al	3.6 mm.Al
Value of α	0.0027	0.0037	0.025
Value of β	2.26	2.18	1.71
Output (µGy/mAs) at 80kV	53.99	52.11	45.86

Table 2. Patients' data and radiographic parameters in BRH.

Hospital	Examination	Patient Age (years)	Patient weight (kg)	Tube voltage (kV)	Charge (mAs)	FSD (cm)
BRH	Chest PA	45.9 (15-100)	68.6 (47-120)	120	4.7 (2.3-10.4)	128 (83-146)
	Lumbar spine AP	49.8 (17-81)	86.2 (52-184)	74.5 (65-115)	80.7 (40-161)	89.4 (54.5-134.5)
	Lumbar spine LAT	49.5 (17-81)	82.3 (52-184)	78.4 (65-125)	88.4 (40-162)	85.3 (54.5-113)
	Pelvis AP	50.9 (18-84)	73.7 (50-110)	69.7 (65-95)	59.4 (50-160)	84 (72-90)
	Skull PA	34.5 (15-84)	71.3 (50-110)	65.4 (65-75)	71.8 (54-160)	93.5 (84-102)
	Skull LAT	34.5 (15-84)	70.4 (50-110)	65.1 (54-75)	65.8 (63-100)	93.9 (81-100)

Table 3. Patients' data and radiographic parameters in CRIMO.

Hospital	Examination	Patient Age (years)	Patient weight (kg)	Tube voltage (kV)	Charge (mAs)	FSD (cm)
CRIMO 1	Chest PA	46.1 (21-85)	71.5 (45-130)	120.1 (117-121)	2.7 (2.2-4)	130 (119-139)
	Chest LAT	68.6 (46-100)	72 (47-95)	121 constant value used	10 (8-11)	119 (106-133)
	Lumbar spine AP	52.3 (20-35)	79 (50-145)	78.7 (66-98)	51.7 (15.6-63)	81 (72-109)
	Lumbar spine lat	52.9 (20-85)	78.8 (50-145)	87.7 (75-98)	63.0 (15-71)	75.3 (64-89)
	Pelvis AP	34.9 (18-66)	75.7 (56-145)	70.7 (62-77)	46.5 (15-63)	84.3 (74-90)
	Pelvis LAT	33.9 (21-67)	74.9 (56-145)	96.1 (72-102)	66.5 (39-71)	72.8 (65-88)
CRIMO 2	Chest PA	52.5 (24-89)	74.7 (50-120)	120.9 (120-121)	2.8 (1.8-4)	85.3 (79.3-94.5)
	Lumbar spine AP	59.8 (47-70)	83.8 (53-120)	81.4 (79-85)	60.2 (56-63)	57.6 (52.3-64.5)
	Lumbar spine LAT	56.4 (47-67)	95.2 (53-135)	91.2 (87-93)	62.8 (62-63)	54.6 (53-57)
	Skull PA	37.8 (18-70)	68.2 (45-90)	69.4 (63-70)	47.9 (40-50)	55.1 (52-63)
	Skull LAT	37.8 (18-70)	68.2 (45-90)	63.2 (60-70)	39 (36-56)	58.5 (56.5-67)

Table 4. Mean ESD and range with different model in BRH.

Hospital	Types of Examination	Davies *et al.* [12]	Modified Davies *et al.* [4]	Edmonds [16]	Tung and Tsai [19]
BRH	Chest PA	0.48 (0.19-1.46)	0.49 (0.19-1.46)	0.75 (0.29-2.25)	0.47 (0.18-1.41)
	Lumbar spine AP	7.66 (1.70-34.60)	7.75 (1.72-34.98)	13.23 (3.10-57.18)	7.47 (1.65-33.72)
	Lumbar spine LAT	9.49 (2.68-46.39)	9.59 (2.71-46.90)	16.25 (4.90-73.79)	9.25 (2.62-45.21)
	Spine AP	4.82 (2.97-18.65)	4.88 (3.00-18.86)	8.59 (5.41-31.73)	4.70 (2.89-18.18)
	Skull PA	4.02 (2.95-8.01)	4.07 (2.99-8.10)	7.33 (5.39-14.61)	3.9 (2.58-7.81)
	Skull LAT	3.63 (2.28-7.33)	3.66 (2.30-7.41)	6.61 (4.37-13.37)	3.53 (2.22-7.14)

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Table 5. Mean ESD and range with different model in CRIMO.

Hospital	Types of examination	Davies *et al.* [12]	Modified Davies *et al.* [4]	Edmonds [16]	Tung and Tsai [19]
CRIMO 1	Chest PA	0.25 (0.19-0.4)	0.24 (0.19-0.39)	0.36 (0.29-0.59)	0.22 (0.17-0.35)
	Chest LAT	1.12 (0.71-1.40)	1.10 (0.69-1.37)	1.66 (1.04-2.06)	1.00 (0.63-1.24)
	Lumbar spine AP	5.39 (1.56-9.67)	5.30 (1.53-9.50)	8.83 (2.56-15.49)	4.80 (1.39-8.61)
	Lumbar spine LAT	9.38 (1.57-17.17)	9.22 (1.54-16.88)	14.92 (2.59-26.75)	8.35 (1.4-15.28)
	Pelvis AP	3.59 (0.96-5.23)	3.53 (0.94-5.14)	6.05 (1.68-8.75)	3.21 (0.85-4.65)
	Pelvis LAT	13.02 (3.59-18.43)	12.79 (3.53-18.11)	20.18 (6.04-28.34)	11.58 (3.20-16.40)
CRIMO 2	Chest PA	0.53 (0.33-0.91)	0.52 (0.33-0.90)	0.72 (0.45-1.25)	0.41 (0.26-0.71)
	Lumbar spine AP	12.89 (8.24-15.26)	12.25 (8.14-15,71)	18.83 (12.64-23.92)	9.73 (6.47-12.49)
	Lumbar spine LAT	16.91 (14.09-18.62)	17.08(14.23-18.81)	25.51 (21.53-27.97)	13.5 (11.31-14.95)
	Skull PA	7.53 (5.34-8.34)	7.44 (5.28-8.24)	11.94 (8.62-13.19)	5.91 (4.19-6.54)
	Skull LAT	4.54 (2.97-8.00)	4.49 (2.94-7.91)	7.37 (4.87-12.66)	3.57 (2.33-6.28)

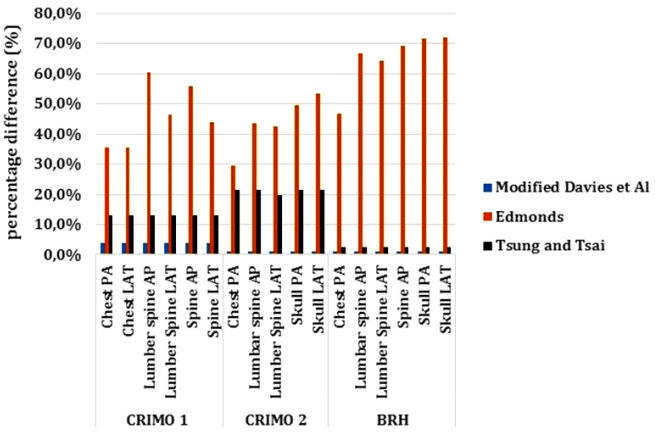


Figure 1. Mean relative errors per type of examination for each X-ray device.

Table 6. Results of the unilateral student's t-test.

Test	Number of observations	Mean	Standard deviation	P-value
Model 1: Modified Davies model	731	1,9%	1,3%	<.01
Model 2: Edmonds model	731	55,0%	12,4%	
Model 1: Modified Davies model	731	1,9%	1,3%	<.01
Model 2: Tung and Tsai model	731	7,1%	6,3%	
Model 1: Tung and Tsai model	731	7,1%	6,3%	<.01
Model 2: Edmonds model	731	55,0%	12,4%	

Table 7. Comparison of 3rd quartile values in this work with those surveyed in other countries.

Type of examination	BRH	CRIMO 1	CRIMO 2	Cameroon (2015) [10]	Cameroon (2016)[9]	Nigeria (2012)[23]	Iran (2015)[6]	UK [24]	France[25]
Chest PA	0.6	0.27	0.56		0,38	0.33	0.74	0.15	0.3
Chest LAT		1.31			1.22	2.49	2.71	0.6	1.2
Lumbar spine AP	7.88	6.43	14.83	13.20			9.57	5	10
Lumbar spine LAT	11.15	10.62	18.24	28.82			18.99	11	25
Pelvis AP	4.99	3.98		8.25			3.72	4	9
Pelvis LAT		15.27							
Skull PA	4.43		8.01	5.19		12.67	3.48	2	
Skull LAT	3.58		4.69	2.45		9.17	2.73	1.3	

DISCUSSION

The present study proposed a modified Davies model for dose estimation in the case of lack of dosimeter. Tables 4 ad 5 show the mean values of ESD obtained using the latter model, the reference Davies model, the Tung and Tsai and the Edmonds models. It is observed that for a given type of examination, the mean value of dose differed from one model to another. Compared to the reference Davies model, the overall MREs obtained for the modified Davies, the Tung and Tsai and the Edmonds models were respectively 1.9%, 7.1% and 55.0% (table

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6). However, Figure 1 shows that for examinations in CRIMO 2 (the chest PA, lumbar spine AP and LAT, skull PA and LAT), the MREs for the Tung and Tsai model tend to be much more larger (up to 21.5%. This could probably be due to the filtration of that X-ray machine: in fact, Tung and Tsai in their model used only X-ray machines with filtration of 2.5 mm.Al, which is lower than the value of 3.6 mm.Al found in CRIMO 2. For the X-ray machine with filtration equal to that value of 2.5mm.Al (in BRH), the MREs do not exceed 3%. This is an indication that the Tung and Tsai model performs well only for X-ray machines with filtration close to that used by the authors.

Despite corrections brought to the Edmonds model, the latter still led to an overestimation of radiation doses received by patients. Doses obtained using the corrected Edmonds formula are higher by a factor of nearly 2 in some cases than those obtained from the reference Davies model. The theoretical spectra due to Birch *et al.* [26] which he has utilized in his formula are likely to overestimate X-ray output of three-phase X-ray machines. Moreover, the calculations in the Edmonds model assume an X-ray tube having tungsten anode with a 17° target [17] while X-ray tubes are manufactured in a range of anode angle.

The results of the unilateral Student's t-test have shown that, relatively to the Davies model, the Tung and Tsai model performs better than the Edmonds model, but the modified Davies model performs better than both the previous models. Hence, the modified Davies model built in this work is the best alternative to the Davies model for estimating doses received by patients, in the case of non-availability of dosimeter.

An inter comparison of radiation doses obtained in different hospitals using the Davies model (tables 4 and 5) shows a variation of patients doses in both health centers for each examination. Such variations may arise not only from differences between patients, but also from differences in radiographic techniques. For example, unlike in CRIMO, the low kV technique (low kV and high value of mAs) is used in BRH for the skull PA. The utilization of a low kVp and high mAs is not recommended for imaging technique due to the decreased penetration of X-rays in such conditions. Therefore, the ideal way to decrease the relative dose is the utilization of a higher kV technique [27]. But the use of low kV technique in BRH for the skull PA combined with large distances has finally produced result of mean ESD (4.02mGy) which is lower compared to the value found in CRIMO 2 (7.53mGy).

The highest values of mean doses for the chest PA, lumbar spine AP and LAT, pelvis AP are found in CRIMO 2, despite the higher filtration of the X-ray device used. Indeed, higher values of filtration are supposed to be conducive to lower estimates of doses. Therefore, the high values of doses registered in CRIMO 2 could be the result of short FSD used for these examinations. The high values of doses found in BRH may be mainly due to the use of high values of charge.

Furthermore, table 7 shows that the 3rd quartile values for skull LAT in this work were higher than those found in published works in Cameroon and Iran [6, 10]. Doses estimated for the chest PA in BRH and CRIMO 2 were also higher than the value found in Nigeria [23]. Nevertheless, doses estimated for the lumbar spine LAT were lower compared with the findings in France [25], indicating that lower doses are possible in Cameroon. UK DRLs are the lowest amongst the above mentioned countries (Cameroon, Iran, Nigeria and France). Except for the pelvis AP, the 3rd quartile values obtained in this work were higher than the established reference level in UK. This should call for dose optimization in Cameroon.

The adoption of the UK reference level is possible for the chest PA and LAT, pelvis AP and LAT, skull PA and LAT. For these types of examination the mean weight is similar to the mean weight reported in UK (65-75kg) [24]. But for the lumbar pelvis AP the mean weight is higher (up to 95.2kg). Differences from our study sample would obviously affect the validity of adopting the UK reference level for these examinations. The use of reference levels has been shown to reduce the overall dose and the range of doses observed in clinical practice. For example, a dose reduction of 30% between 1984

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and 1995 and an average dose reduction of 50% between 1985 and 2000 have been reported in the U.K. [28]. Results of doses in this study will serve as a useful review of dose assessment of patients and also a baseline against which individual X-ray departments may compare their patients' doses. Data will also be useful for the establishment of national guidance levels.

CONCLUSION

The model proposed in this work can be used to accurately estimate radiation doses received by patients. Results have shown that this model performs better than the Tung and Tsai model and the Edmonds model. ESD assessment in this work may call for an increased awareness among professionals of diagnostic radiology in Cameroon about the need for reduction in patient doses. The use of large distances and low values of charge should be an important measure to be taken into account in order to reduce radiation doses received by patients. Training of the personnel could also be helpful as well.

***Conflicts of interest*:** *Declared none.*

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