Local reference dose level evaluation in chest radiography in Yaounde
(Niveau local de référence diagnostique en radiographie thoracique à Yaoundé)

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SUMMARY:

Purpose: Patient radiation doses encountered during conventional X-ray examinations are not exactly known. This study aims to realize a radiation dose audit for chest posterior-anterior (PA) and chest lateral (LAT) examinations, analyze the procedures and establish local diagnostic reference level (LDRL).

Method: A total number of 882 radiographs of 715 patients from seven selected hospitals in Yaoundé were considered in this work. Entrance surface dose (ESD) of adult patients undergoing chest PA and chest LAT examinations is estimated, using a mathematical algorithm and a standard backscatter factor.

Results: Estimated mean ESDs in the hospitals range from 0.28 to 0.73 mGy for chest PA and from 0.39 to 2.08 mGy for chest LAT. For each projection there is a wide variation in patients ESD within hospitals for individual patients and between hospitals. The third quartile ESD value 0.39 mGy for chest PA examinations was found to be above both the Diagnostic Reference Levels (DRLs) reported from similar studies in some African countries and the international established DRLs, while the value 1.33 mGy obtained for chest LAT was within the established international DRLs.

Conclusion: The major contribution to the high dose has been identified in the use of shorter focus-film distance (FFD) and higher charge (mAs). Other factors are both the absence of quality control and the equipment performance. This study shows the need of the implementation of protocol and technics that can reduce patient dose and regular quality control and quality assurance.

Key-words: Chest radiography parameters, LDRL, radiation protection.

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**Objectif:** Les doses reçues durant les examens de radiologie conventionnelle ne sont pas précisément connues. Le but de cette étude était de réaliser un audit de dose pour les examens du thorax postérieur-antérieur (PA) et latéral (LAT), d'analyser les procédures et établir le niveau local de référence diagnostique (NLRD).

**Méthode :** Un nombre total de 715 patients pour 882 radiographies issues de sept institutions sanitaires de la ville de Yaoundé ont participé à cette étude. La dose à la surface d‘entrée (ESD) des patients adultes effectuant les examens de thorax PA et de thorax LAT a été évaluée en utilisant un algorithme mathématique et le facteur de rétrodiffusion standard.

**Résultats :** Les ESDs moyennes variaient de 0,28 à 0,73 mGy pour le thorax PA et de 0,39 à 2,09 mGy pour le thorax LAT. Pour chaque incidence, il a été noté une grande variation des doses aux patients dans un même hôpital et entre les hôpitaux. Le 75ème percentile de la valeur ESD, 0,39 mGy, de l'examen du thorax PA est supérieure au niveaux de référence diagnostiques (NRD) obtenus dans des études similaires dans certains pays d'Afrique et les NRD établis par les organisations internationales. La valeur de 1,33 mGy obtenue à l'examen du thorax LAT est comparable aux NRD établis par les organisations internationales.

**Conclusion :** L'utilisation des courtes distances foyer-film (DFF) et les charges (mAs) élevées ont été identifiée comme les principales causes de dépassement de dose aux patients. Les autres facteurs ont été l’absence du control qualité et la performance des équipements. Cette étude montre la nécessité du respect des protocoles et techniques d’exams radiologiques, de contrôle qualité des équipements et de l’assurance qualité permettant de réduire la dose aux patients dans nos hôpitaux.

**Mot-clés :** Paramètres, radiographie thoracique, NLRD, radioprotection.

**INTRODUCTION:**
The X-ray diagnoses have revolutionized the medical diagnosis and led to a better treatment of many diseases. Most often however, they are being overused in standard routine diagnostic procedures. These procedures were adjusted to obtain a better film result for a better diagnosis without always taking into account the long term effect of those radiations. It is now realized that there are significant variations in patient doses between different radiological departments for the same type of examination.

In report Nr.60 of the International Commission on Radiological Protection (ICRP, 1990) [1], we must notice the recommendation that all medical exposures should be subject to the radiation safety principle of justification, optimization and limitation. Because the ESD provides an indication of the maximum skin for periodic checking of the patient dose, the International Atomic Energy Agency (IAEA, 1996 & 2007) [2, 3], recommended ESD as the dose indicator. To reduce the radiation dose there must be guidance on appropriate level of patient exposure. The ICRP and the European Commission have recommended the use of diagnostic reference levels (DRLs) [1, 4] which is define as the 75th percentile or third quartile of the dose distribution for typical examinations, for groups of standard sized patients or standard phantoms [4, 5]. For single individual, DRL should not be applying because it is not a dose limit. In the case that the measured doses exceed the recommended DRL, then the radiology department should investigate the causative factors contributing to the high doses [4]. During the past decade several surveys for the assessment of dose to patients in diagnostic radiology have been carried out in many countries.
around the world [7-9] including countries of Africa [10-12]. In Cameroon however, not much attention has been given to the patient radiation protection in radiological X-ray examination. Also the implementation of regular quality control of the radiological equipment is not yet effective and doses encountered during radiological examinations are not exactly known. The objective of the present study is to realize a radiation dose audit for chest PA and chest LAT examinations analyze the procedures and use the result of patient dose to establish DRLs for the both chest projections in the centre region of Cameroon in order to follow the international recommendations. The ICRP in its publication 85 (ICRP, 2000) [13] had also recommended to include the absorbed dose in the medical record of patients for certain radiographic procedures such as DRLs measurements. The result of this investigation is to be comparing with similar studies in some African countries and with the international reference dose in order to propose changes to radiography practice with a view to lower patient doses and particularly to optimize procedures.

MATERIALS AND METHODS

Fig 2: The chest examination proportion per hospital. The mean and range of radiographic data used in the X-ray centers and the patient informations for the selected examinations are shown in Table 2. The study sample age ranges

Figures 3a, b contain the histograms of ESDs for individual patients for selected examinations in all health institution together with the drink N Odette et al  J Afr Imag Méd 2015; (7), 3: 152-162 article
(3rd quartile) values, standard deviations and sample sizes (N). The standard deviation evaluated for chest LAT projection is four times more than the one obtained by chest PA projection.

Table 6 gives a comparison of this study with similar studies in some African countries before implementing a quality assurance program.

The determination of the ESDs is carried out through a calculation using the corresponding X-ray tube output (Y(d)) and the following X-ray tube exposure parameters for each patient undergoing the specified diagnostic procedure: kilovolt (kV), charge (mAs), focus-film distance (FFD), focus-skin distance (FSD) and the use of grid. The output of the X-ray tubes were measured at a distance of 100 cm from the tube focus along the beam axis using the calibrated Diavolt universal all-in-one QC Meter L981810 of the Cameroon National Radiation Protection Agency (NRPA). The film type used at the hospitals were Kodak Green sensitive, AGFA "blu" and Fuji with a speed of 400 while a direct view cassette was used for the computer radiograph system. Exposure parameters were registered and the dose evaluation was computed using the Davies et al (1997) [14] formula for calculating ESD as follows:

$$\text{ESD} = Y(d) \times \left( \frac{kV_p}{80} \right)^2 \times \left( \frac{100}{\text{FSD}} \right)^2 \times \text{mAs} \times \text{BSF}$$

Where

- Y(d) in mGy/mAs is the measured output of the radiation unit at 80 kV, at a distance of 100 cm with a 20 mAs using the calibrated Diavolt universal all-in-one QC meter;
- BSF is the backscatter factor. A value for the BSF of 1.35 was used as suggested in the European guidelines (EC, 1996) [15].

For each patient the following parameters were also recorded: sex, age, weight and height in order to carry out the Body Mass Index (BMI), which is an useful classification scheme for the size and shape of a person (Gibson 1990) [16].

The calculation was performed on a sample of 708 ‘adults’ patients with an age above 15 years undergoing chest PA and chest LAT examinations.

**RESULTS:**

A total number of 708 patients of both sexes from the seven health institutions were included in this study with a total number of 882 radiographs. Figure 1 shows that more than 55% of them were from the private owned hospitals (CRM, CMC and CAR) while around 32% were from the government hospitals (CHY, GHY and JHY). The Chest examination proportion per

from 15 to 87 years with a mean BMI of 25. The range of the tube potential for the chest PA examination in all hospitals goes from 100 to 130 kV_p while for chest LAT examination a range from 100 to 166 kV_p was evaluated with for both projections a mean of 110 kV_p. The hospitals considered used high tube potential technique and employed the total filtration list in Table 1. These filtration values were not measured, but given by the radiographers.

The descriptive statistics of radiographic data i.e. mean, minimum (Min), maximum (Max) conducting to the descriptive statistic of ESD with the standard deviation (Std) are presented for each health institution in Table 3. The range factor (Maximum ESD divided by Minimum ESD) within hospitals range between 2.36 and 6.55. Table 4 gives a comparison of the third quartile ESD values of this work with some international established reference dose levels [15, 17, 18]. For the chest PA these values were within or slightly higher than the EC (1996) and the IAEA (2008) recommendations except of GHY, CHY and CRM result while for chest LAT all values were below the EC recommendations except of the CRM and EHC results. Table 5 shows the comparison of some national and International DRLs with the DRL of this work. It appears that our dose reference level for chest PA projection (0.39 mGy) is above the international recommendations while it is within the international recommendations (1.33 mGy) for the chest LAT projection.

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**Table 1:** Radiographic technical data and output values of the X-Rays units.

<table>
<thead>
<tr>
<th>X-ray machine data</th>
<th>GHY</th>
<th>J</th>
<th>CMC</th>
<th>CAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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### Table 2:
Patient information and exposure parameters for selected X-Ray examinations, with Mean values and range (in bracket).

<table>
<thead>
<tr>
<th>X-Ray Examination</th>
<th>Patient data</th>
<th>Radiographic data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of patient</td>
<td>Number of examination</td>
</tr>
<tr>
<td>Chest PA</td>
<td>697</td>
<td>715</td>
</tr>
<tr>
<td>Chest LAT</td>
<td>159</td>
<td>167</td>
</tr>
</tbody>
</table>

PA: Posterior-Anterior; LAT: Lateral.

### Table 3:
Descriptive statistic of the chest PA radiological parameter and the resulting ESD at each health institution.

*Computer Radiography devises. – Not available.*
### Table 4: Comparison of the third quartile ESD value of this study with some international referencedosevalues (mGy).

<table>
<thead>
<tr>
<th>Hospitals/Projections</th>
<th>This work</th>
<th>International Reference DRLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest PA</td>
<td>0.39</td>
<td>0.32</td>
</tr>
<tr>
<td>Chest LAT</td>
<td>-</td>
<td>0.68</td>
</tr>
</tbody>
</table>

– Not available.

### Table 5: The Comparison of some national and international DRLs with the DRL of this work in mGy.

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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Chest PA</td>
<td>0.39</td>
<td>0.3</td>
<td>0.2</td>
<td>0.33</td>
<td>0.41</td>
<td>0.35</td>
</tr>
<tr>
<td>Chest LAT</td>
<td>1.33</td>
<td>1.5</td>
<td>1</td>
<td>-</td>
<td>2.07</td>
<td>0.96</td>
</tr>
</tbody>
</table>

– Not available.

### Table 6: The mean value of ESD before the implementation of quality assurance program from other four African countries and this work.
DISCUSSION

The number of patients does not match with the number of examinations since some patient required both the chest PA and chest LAT examination, but also because some of the examination had to be repeated due to non-exploitable films. The low quality images obtained in such non-exploitable diagnostic radiography lead in one hand to wasting sources and costs and in other hand to causing unnecessary exposure of the patient (Rehani, 1995) [22]. In total 26 (around 3%) of 882 diagnostic radiographies were non-exploitable with 58% of them due to wrong positioning of the patient (most during the chest LAT examination) and 42% of them due to inadequate kV or mAs (most during chest PA examination). The fact that more patient used private owned hospital (Figures 1 and 2) is not because of modern radiography technology (GHY and JHY used Computer Radiography while CRM and CARIM used analogue technology) or the age of the device (see Table 1). Two of the explanations can be the short time of receiving the result of the examination and the patient to patient or physician to patient good publicity made for some radiology department.

Patient height range from 1.32 m to 1.92 m and patient mass fluctuated from a minimum of 36 kg to a maximum of 125 kg slightly similar to the study sample of South Africa (1.41 to 1.92m height and 41 to 127kg mass) (T Nyathi et al, 2009) [23]. The median patient weight was found to be 70 kg for chest PA and 69 kg for chest LAT. This median patient size was similar to that of the standard sized person of 70 kg used by ICRP [1].

According to Table 3 there is a wide variation in individual patients for each examination. The range factor is up to 6.55 at EHC when between hospital it is as high as 12.27 for the chest PA projection. Among the reasons of this dose variation between hospitals, with the performance of the equipment, the type of X-ray generator near the processing system. The large observed range factor (12.27) between hospitals indicate that the dose can still be reduced by harmonizing the radiological procedures for each projection and adhering to guidelines that will correct the operative modalities and which will enable the doses to become lower. Such guidelines on the radiography techniques are suggested in the document: European Guidelines on Quality Criteria for Diagnostic Radiographic Images [15]. The harmonization of procedures, continuing education and informations can be made during radiologist and radiographer conference or meeting that takes place regularly every year or every two years.

The 110 kV mean value found for chest PA and chest LAT confirm the use of the high kilovoltage technique at all center. But this was used with higher mAs and shorter FFD (see Table 3) which led at the GHY to an ESD value up to 1.35 mGy for the chest PA incidence. The South Africa study with similar study sample, using high kilovoltage technique (109-125) kVp and screen film speed of 400, had its mAs varied from 1.0 to 3.2 for Chest AP and from 2.0 to 6.3 for Chest LAT with for both incidences a fixe FFD.
von 180 cm. This study obtained a maximum ESD of 0.20 mGy for chest PA and 0.44 mGy for chest LAT. The use of shorter FFD and higher mAs in our radiology department must be optimized since a direct relationship between shorter FFD, higher patients’ dose and decreased geometric sharpness is well established [24]. Taking into account the technology and the quality of the X-ray devices in our radiology departments and observing the result of our exposure parameter, there is room to optimize the procedure and therefore the patient dose.

The widest dispersion from their mean value is observed in the figure 1b for the chest LAT examination while the smallest dispersion is observed in the chest PA examination (see figure 1a). The figure 1b shows that 25 of the 167 patients undergoing the chest LAT examination (around 15%) have received an entrance surface dose higher than 1.5 mGy.

We can observe in Table 6 that higher mean ESD values for chest PA examinations are found for Nigeria [11, 21] as well as in the present study with a similar patient weight range (35 kg – 116 kg) [11]. In both Nigeria studies low kV technique was used for chest PA examinations. For chest PA examinations the mean ESD values of our study is higher than the one of Sudan, Madagascar and Ghana but lower than the result of Nigeria.

Taking into account the reduction of the patient entrance surface dose obtained in Tanzania [25] and in Iran [26] after the setting of the quality control (QC) and the quality assurance (QA), there is a big expectation that a similar dose reduction could be also obtained in Cameroon by implementing the QC and QA in all radiology departments.

CONCLUSION

This study evaluated the Entrance Surface Dose (ESD) for patients undergoing chest PA and chest LAT X-ray examinations in selected hospitals in the centre region of Cameroon. The mean ESD (0.35 mGy) and the DRL (0.39 mGy) of the chest PA examination were found to be above the DRLs established by the international recommendations (EC, NRCP and IAEA).

According to N Odette et al recommendations the chest LA1 examination mean ESD (0.92 mGy) and DRL (1.33 mGy) is within the expected recommended values. The major contribution to the high dose reported in this work has been identified in the use of shorter FFD and higher mAs. Other factors that contributed to the higher ESD are both the procedures and the equipment performance since some machines are relatively old and the quality control and quality assurance are not been yet implemented.

The study provides evidence of the existing potential for dose reduction. It shows the need in radiological department of regular quality control and quality assurance program and the setting and use of guidelines for each incidence. The radiation safety culture can be improved through the organisation of regular meetings of continuing education and information for radiographer. The result of the present study can be used as a reference upon which future dose measurements may be compared. This can be useful for a possible establishment of the national DRL for professional and national organisations.

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Conflict d’intérêt : Aucun
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