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Determination of Diagnostic reference levels (DRLs) for frontal chest radiology of adult patients at Regional Hospital Center of Daloa, Côte D'Ivoire

Ponaho Claude KEZO [1, 2, *], Akpa Marcel AGNERO [1] and Konan Rene KAMBO [1]

[1] *Laboratory of Environmental Sciences and Technology, University Jean Lorougnon Guede, Daloa, Cote D'Ivoire.*
[2] *Laboratory of Nuclear Physics and Radiation Protection, University Felix Houphouet Boigny, Cote d'Ivoire.*

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Abstract

Although, diagnostic radiology is important in medical field, it significantly contributes to the irradiation of patients. One of the major goals of medical imaging is to minimize the radiation dose to the patient without compromising the image quality needed to produce an accurate diagnosis. Therefore, it is necessary to establish the diagnostic reference levels (DRLs) in radiology in order to achieve this goal. This study aimed to determine the DRLs for the chest radiological examination at the Regional Hospital of Daloa. A DAP meter was used to acquire the dose-area product (DAP) and air kerma data of 127 adult patients (≥ 18 years) undergoing chest examinations in the radiology room. Then the Entrance Surface Dose (ESD) calculated by weighting the dose in air by the BSF backscatter factor and DRLs in DAP and ESD were determined with the 75th percentile statistical method. The key findings showed a variation of 2.69 to 500.47cGy.cm^2 and 0.388 to 10.104 mGy respectively for DAP and ESD with means of 52.314 cGy.cm^2 and 2.279 mGy respectively. The respective values of DRL in DAP and ESD found in this work were 60.91 cGy.cm^2 and 2.658 mGy. The comparison of the DRL values in DAP and ESD found in this work with others values has shown that they were lower than the national and international values of DRLs. This study was essential for RHC of Daloa because it has evaluated the patient doses and indicated that these doses are quietly optimized.

Keywords: Optimization; Chest examination; DAP; ESD; DRLs

1. Introduction

The use of X-rays occupies an important place in the medical device. Today, medical imaging using X-rays is one of the most effective and almost essential methods for diagnosis, thus allowing a better visualization of the internal structure of a tissue or organ [Adji, 2015]. This image formation requires a clear choice of constants of the X-ray tube (mAs, kV) depending on the patient (size, fat percentage, etc.) and the sensitivity of the film. So, there is a possibility of acquisition failures [Boquet, 2021]. These failures are all sources of additional irradiation for the patient and represent a potential risk of possible complications due mainly to repeated exposures favoring cumulative effects of low doses [Chekour, 2015]. It is therefore important to apply measures and radiation protection principles to reduce the risk of exposures from the techniques to the lowest level reasonably achievable (ALARA) while maximizing the benefits of the radiological techniques [Adji, 2015]. Hence, it is necessary of establishing dosimetry indicators that can provide information on material or organizational malfunctions leading to abnormal patient exposure. The establishment of these indicators, called diagnostic reference levels (DRLs), which are not considered as dose limits but as dosimetry indicators, allows not only optimizing doses delivered to patients during the examination procedure, but also identifying situations that require corrective actions [ICRP, 1996]. DRLs as basic tools represent a standard for the identification of abnormal radiation doses (abnormally high or low) for standard diagnostic medical imaging procedures, as well as indicators of typical radiological practice in a hospital, region, or country [Boucif et al., 2022].

* Corresponding author: P C Kezo

In recent years, the establishment of DRLs for different radiological examinations has become a priority for the Ivorian government through the nuclear regulatory authority and scientists of nuclear physics and radiation protection research team in order to protect patients. Many studies were carried out in order to establish DRL for frequent examinations. Monnehan et al in 2009 carried out a study for the determination of DRL values for thorax and abdomen examinations in two regions of Côte d'Ivoire [Monnehan et al., 2009]. Konate et al also have carried out studies to determine DRLs for thorax, lumbar in Western Côte d'Ivoire and Abidjan [Konaté et al., 2017, 2019]. However, there is no DRL data available for lung radiological examination in Côte d'Ivoire.

This study like a preliminary study in the determination of DRL for lung examination in Côte d'Ivoire, aims to determine DLRs for one of the most frequent examinations at the RHC of Daloa, especially the lung examination and establish a data base of DRL for different procedures in Cote d'Ivoire.

2. Materials and methods

2.1. Description of the study area

The city of Daloa with a population of 421,879 inhabitants [ONU-Habitat, 2023] is located in the west central part of Côte d'Ivoire, between longitudes 6°23' and 6°29'W and latitudes 6°49' and 6°56'N. This study was carried out at the RHC of Daloa with geographical coordinates of 6°26'26.2"W and 6°52'59.8"N.

2.2. Materials used

The radiology room complied with the Ivorian standards of at least 25 m^2 of base area and a ceiling height of at least 3.5 m [JOR, 1968] and has been inspected by the competent body. The devices used consisted of the high voltage generator associated with the X-ray tube, the desk, the wall stand, the X-ray viewer and the lead aprons. Also the M4KDK type 11017 DAP meter initially calibrated in the Secondary Calibration Laboratory in Freiburg Germany was used [PTW, 2004].

2.3. Data collection methods

A total of 127 data of adult patients were collected. For this data collection, the assistance of the most experienced radiological technicians was requested in order to avoid all factors that could influence the patient's doses. The collected data were classified into two categories: "patient data" and "examination data".

Patient data which are patient's physical parameters such as: age, height, weight, and gender.

The examination data which are parameters set by the technician on the X-ray viewer at the beginning of the examination such as voltage (kV) and charge (mAs), the distance from the X-ray tube to the patient, but also the displayed data on the DAP-meter at the end of the examination such as the dose area product (DAP) and the kerma (Ka).

2.4. Determination of Entrance Surface Dose (ESD)

The DAP and air kerma (Ka) values directly displayed by the DAP meter of model Diamentor M4-KDK type 11017 were used to determine the ESD values. These values of Entrance Surface Dose (ESD) were calculated by weighting the dose in air (Ka) was by the BSF backscatter factor given by following equation.

$$ESD = Ka \times BSF \quad \text{………..(1)}$$

Where: ESD is Entrance Surface Dose, BSF is the backscattering factor depending on the voltage values, FRD = 1.35 for voltages between 60 kV and 80 kV and BSF = 1.5 for voltages above 80 kV [Leclet, 2011].

2.5. Determination of DRLs in DAP and ESD

The numerical determination of DRLs was based on the so-called 75th percentile statistical method of the distribution of doses measured at the input surface for a given procedure over a large number of patients representative of a country's radiological practice [(IRSN, 2016]. The 75th percentile is therefore an alert level above which practices can be considered non-optimized or even abnormal in terms of the dose delivered to the patient [IRSN, 2016; European Commission, 1999]. In this study, to determine the DRL by the 75th percentile method, the values of DAP and ESD were arranged in ascending order. Then the values of DAP and ESD corresponding to this rank indicate the DRL values.

3. Results and discussion

3.1. Radiological parameters

The values of voltage kV, charge mAs and air kerma (Ka) were shown in Table 1. These values ranged from 70 to 112 kV, 3 to 16 mAs, and 1.1 to 6.736 mGy respectively for voltages (kV), charges (mAs), and air kerma (Ka), with averages of 85.464 kV, 11.735 mAs, and 1.529 mGy, respectively.

The variation in kV observed in this study might be due to the difference in patient's size penetrated by the X-ray beam for patients. Therefore for a patient with a large body size, a higher dose is required, i.e. a higher voltage is needed, unlike those with small size. It is found that the kV values during lung examination at RHC of Daloa are all lower than the minimum voltage value of 115 kV, recommended by French Society of Radiology (SFR) and adopted by the Ivorian government. In fact, the recommended average voltage is 125 kV in a voltage range (115 - 140) kV [SFR, 2014].

As for the mAs, the values measured in this study varied from 3 to 16 mAs with an average of 11.735 mAs. They were significantly higher than those required by the regulation, 1.3 to 3 mAs for radiological examination in Côte D'Ivoire [Monnehan et al., 2009; Konate et al., 2017, 2019].

In addition, it is found that values of air kerma differed for patients of the same sex and age. This might be due to the difference in patient body sizes.

Table 1 Measured voltage, electrical charge and Ka

Parameters	Minimum	Maximum	Average
Voltage (kV)	70	112	85.464
Charge (mAs)	3	16	11.735
Ka (mGy)	1.1	6.736	1.529

3.2. Determination of DAP and Entrance Surface dose (ESD)

DAP and Entrance Surface Dose values are presented in Table 2 below. They ranged respectively from 2.69 to 500.47 $cGy.cm^2$ and from 0.388 to 10.104 mGy, with respective averages of 52.314 $cGy.cm^2$ and 2.279 mGy. The variation of DAP and ESD values in this study could be due to the variation of radiological parameters (kV and mAs).

Table 2 DAP and ESD values for frontal chest radiology examination at RHC of Daloa

	Minimum	Maximum	Average
DAP ($cGy.cm^2$)	2.69	500.47	52.314
Entrance surface dose (mGy)	0.388	10.104	2.279

3.3. DRL in DAP and ESD for frontal chest radiology examination at RHC of Daloa

The DRLs in DAP and ESD are presented in Table 3 below. The DRLs in DAP and entrance surface dose were respectively 60.91 cGy.cm2 and 2.658 mGy and compared with other values obtained in studies conducted around the World.

Table 3 DRL in DAP and ESD for the chest radiological examination at RHC

DRL values	
DAP ($cGy.cm^2$)	60.91
Entrance surface dose (mGy)	2.658

3.4. Comparison of DRL values in DAP and ESD with others studies

The comparison of DRL values obtained in this present study with other values around the World is presented in Table 4 below.

Table 4 Comparison of DRLs in PDS and ESD from present study with DRL values in other works

	Examination	DRLs	
		ESD (mGy)	DAP (cGy.cm^2)
Present study	Chest	2.658	60.91
Abidjan [13].	Thorax	0.22	53.26
Western Cote d'Ivoire [12]	Chest	0.4	54.85
France [9]	Thorax	0.14	59.8
Switzerland [9]	Thorax	0.15	150
England [9]	Thorax	0.15	10
IRSN [9]	Thorax	-	10
IAEA [6]	Chest	0.2	-

According to Table 4, the DRL value in ESD obtained in this study was very higher than values obtained at national level. Konate et al have found in their studies carried out in Abidjan in five medical centers and in the Western Cote d'Ivoire that the DRLs in Entrance Surface Dose were respectively 0.22 mGy and 0.4 mGy. The higher value of DRL found in this study could be explained by the fact of the use of the lower voltage at RHC of Daloa (85.464 kV) while in Abidjan and Western Cote d'Ivoire, the voltage values were relatively higher, with 104 kV and 101 kV respectively. And also by the use of higher electrical charge at RHC of Daloa (11.735 mAs) while in Abidjan and Western Cote d'Ivoire, the voltage values were relatively higher, with mAs and 6 mAs respectively [Konate et al, 2017, 2029]. In fact, the higher voltage and lower electrical charge, the lower is the dose. In addition, the DRL in Entrance Surface Dose found in this study was higher than the ones found in France, Switzerland, England, IRSN and IAEA studies [IRSN, 2012, IAEA, 1996].

As for the DRL in DAP, the values found in this study (60.91 cGy.cm^2) were higher than the one found in Abidjan (53.26 cGy·cm^2) and in but lower than the DAP value obtained in Switzerland (150 Gy.cm^2).

These high DRL values of DAP and ESD could be due to the use of lower voltage (85.464 kV) and higher electrical charge (11.735 mAs) at RHC of Daloa than the one used in Abidjan and Western Cote d'Ivoire. It could also be due to the obsolescence of the X-ray tube installed at the RHC of Daloa. Therefore, the corrective actions like increasing the voltage and reducing the electrical charge are needed to optimize patient dose. These findings indicate a poor optimization of patient's doses, and that could increase the cancer risk for patients undergoing chest radiology examination in RHC of Daloa.

4. Conclusion

This study aims to determine an essential radiological indicator for optimizing patient's dose, especially the diagnostic reference level (DRLs) for the most frequent radiological examination at the Regional Hospital Center of Daloa. The key results have shown that the DRL in ESD was higher than DRL value established by the Ivorian National Authority and those recommended by IRSN and IAEA. These results showed a low optimization of patient dose for this frontal chest examination at RHC of Daloa. Therefore some corrective actions like increasing the voltage and reducing the electrical charge were recommended in order to optimize patient doses during the frontal chest examination.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors have no conflict of interest.

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