

# Application of Radiation Protection of Patients in Medical Diagnostic Radiology (Case of Public Hospitals, Fianarantsoa District, Haute Matsiatra Region, Madagascar)

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**Abstract:** To strengthen patient radiation protection and control of medical exposure, in the Haute Matsiatra region, Fianarantsoa District, Madagascar, we have carried out a study to develop a protocol for dose assessment in diagnostic radiology in order to ensure good radiological practice. In this region, no studies have ever been done in their radiology department. The patient entrance dose ( $D_e$ ) is one of the basic dosimetric quantities for measuring the dose delivered to the patients. Therefore, to assess the patient entrance dose ( $D_e$ ), we have chosen two hospitals such as the Andrainjato University Hospital Center (CHUA) and the Tambavao University Hospital Center (CHUT). We have chosen four most requested radiological examinations (Skull, Thorax, abdomen and pelvis) and we have evaluated the entrance doses of patient and we have compared the result found to the Diagnostic Reference Levels (DRL) recommended by the IAEA for each examination. We found that, the average doses delivered to the patients during their radiographic examinations, were below the reference doses recommended by the IAEA. For this comparison carried out in these two hospitals, we can be confirmed that the values obtained can be useful for the application of regulations on the patient radiation protection and the control of medical exposure in Fianarantsoa.

**Keywords:** Diagnostic Radiology, Patient Entrance Dose, Radiation Protection

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## 1. Introduction

Exposure to ionizing radiation can cause harmful effects not only to the subject who is exposed to it, but also to their descendants. However, the medical use of ionizing radiation must be subject to a significant regulatory framework.

The use of ionizing radiation for medical fields contributes significantly to the exposure of the population. After natural exposure, this practice presents the first source of exposure of artificial origin. A dose limitation applies to workers and the

public; for patients, dose limitation is discussed case-by-case. Internationally, the setting of reference dosimetric values for diagnostic radiology examinations has been proposed. These values, called Diagnostic Reference Levels (NRL) do not constitute dose limits, but a radiological reference threshold, allowing him to locate his technique vis-a-vis the irradiation of the patient.

In Madagascar, the evaluation of the dose delivered to the patients undergoing X-ray radiological examinations was initiated in 2005 as part of the Cooperation project with the IAEA, RAF / 9/033 entitled "Strengthening radiation

protection of patients and control of medical exposure”.

At this end, we have chosen two public hospitals in Fianarantsoa such as the Andrainjato University Hospital Center (CHUA) and the Tambavao University Hospital Center (CHUT) by choosing the four most frequently used examinations (Skull, Thorax, Abdomen and Pelvis).

The objectives of this study are:

- To study the technique used in the two hospitals center chosen to perform four types of radiological examinations common in medical radiography.
- To collect dosimetric data and to compare them with international reference levels.

Finally, to conclude following the discussion of the results, the application of radiation protection of patients in medical diagnostic radiology in Fianarantsoa, Madagascar.

## 2. Methods

### 2.1. Diagnostic Reference Levels (NRL)

The diagnostic reference levels are the dose indicators used to assess the quality of the equipment. In the field of exposure to the ionizing radiations used for medical sectors, the regulatory limit of doses, which is one of the three principles of radiation protection, does not apply to the patient exposures. To strengthen the optimization principle, the concept of diagnostic reference level (NRL) was therefore introduced in publication 73 "Radiological Protection and Safety in medicine" of the International Commission on Radiological Protection (ICRP) [1, 5, 13, 14]. The diagnostic reference levels constitute a tool for optimization. They should not be compared with "dose limits" or "optimal doses". In practice, these levels are established for standardized examinations and typical patients.

**Table 1.** Diagnostic reference level for conventional radiography.

Examination	Position	Dose at the surface by radiography (mGy)
Skull	PA	5
Thorax	PA	0,4
Abdomen	AP	10
Pelvis	AP	10

### 2.2. Kerma (Kinetic Energy Released in Material)

Kerma characterizes the capacity of indirectly ionizing radiation to act on matter [13, 14]. It is the quotient of dE<sub>tr</sub> by dm, where dE<sub>tr</sub> is the sum of the initial kinetic energies of all charged particles released by uncharged ionizing particles in a mass dm of a given material.

$$K = \frac{dE_{tr}}{dm} \quad (1)$$

The unit of kerma is Gy.

Dose in air: Da

In the reference conditions, the dose in air characterizes a radiological facility. Generally, it is measured with an

ionization chamber but it can be calculated. The dose in air Da, expressed in mGy / mAs, is given by formula 2:

$$D_a(d) = k \frac{U^n}{d^2} \quad (2)$$

with  $2 < n < 3$

U: high voltage applied to the tube

d: Tube focus distance at the measurement point

k: Constant depending on the facility

Kerma in air has a relation with the dose in air by formula (3):

$$K_{air} = D_a(d) \cdot It \quad (3)$$

K<sub>air</sub>: Kerma in air expressed in mGy

I: Current flowing through the tube

t: Irradiation time

It: Charge (mAs)

### 2.3. Determination of Entrance Dose [6-14]

The dose in air, Da, must be measured beforehand at a given reference distance d<sub>ref</sub> from the source (eg 100 cm), for the beam dimensions used in practice. The dose at the entrance surface, De, of the patient is then calculated as a function of the source-entrance surface distance (PSD), of the quality of the radiation, for the number of mAs used, for an image according to the formula 4

$$D_e = D_a \cdot \left( \frac{d_{ref}}{d} \right)^2 \cdot mAs \cdot FRD \quad (4)$$

Practical unit of D<sub>e</sub> is: mGy.

### 2.4. Data Collection

To determine the dose in air, the load is fixed but by varying the high voltage for a given distance between the source and the thermoluminescent dosimeter. This distance was set at 100 cm. For kerma in air, we set the high voltage and we vary the charge.



**Figure 1.** Experimental setup for the determination of Da and K<sub>air</sub>.

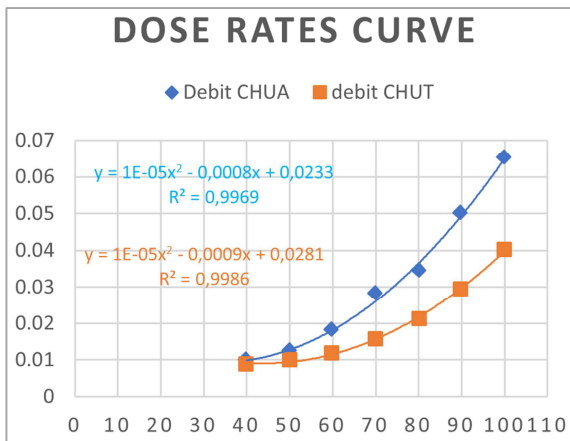
### 3. Results

#### 3.1. Dose in Air [2, 3, 5, 7, 13, 14]

To calculate the dose received by patients during diagnostic radiology examinations, it is necessary to know the dose in air  $D_a$ , the charge, the backscatter factor and the source-patient distance. For the dose in air, we set the charge of 20 mAs and we vary the high voltage with the reference distance 100 cm. The following table gives us the value found in the two hospitals and these values allow us to plot Figure 2.

**Table 2.** Dose rates of the device from both hospitals.

kV	Debit CHUA (mGy/mAs)	debit CHUT (mGy/mAs)
40	0,00988	0,00876
50	0,01239	0,00994
60	0,01831	0,01199
70	0,02794	0,01569
80	0,03452	0,02123
90	0,04978	0,02956
100	0,06523	0,04021



**Figure 2.** Dose rates curve.

#### 3.2. The Surface Dose for the Examinations Considered [2, 3, 12-14]

We selected four examinations, which are considered to be the most frequent in diagnostic radiology. We considered fifteen different parameters for each type of examination. The backscatter factor is 1.35. The distances between the X-rays tube focus and the patient's skin for CHUA are:

1. Thorax face thickness 20 cm: DSP (Skin-source distance) (SSD)=130 cm
2. Abdomen face thickness 20 cm: DSP (Skin-source distance) (SSD)=130 cm
3. Skull face thickness 15 cm: DSP (Skin-source distance) (SSD)=85 cm
4. Pelvis face thickness 20 cm: DSP (Skin-source distance) (SSD)=130 cm.

On the other hand, the distances between the X-rays tube focus and the patient's skin for CHUT are:

1. Thorax face thickness 20 cm: DSP (Skin-source distance) (SSD)=160 cm

2. Abdomen face thickness 20 cm: DSP (Skin-source distance) (SSD)=90 cm
3. Skull face thickness 15 cm: DSP (Skin-source distance) (SSD)=85 cm
4. Pelvis face thickness 20 cm: DSP (Skin-source distance) (SSD)=118 cm.

Tables 3 and 4 show the values of the doses in mGy received by the patients during their diagnostic radiology examinations in the two hospitals. We have calculated the average in order to compare of these fifteen different exams for each type of exam chosen. We will compare these average values with the NRLs and finally to know if the dose received by the patients during their radiological examination is well respected.

**Table 3.** Dose (mGy) received by the patients at CHUA

Examinations	Skull	Thorax	Abdomen	Pelvis
	0.6172	0.1251	0.2638	0.2638
	0.7757	0.1341	0.3316	0.3316
	0.8532	0.1453	0.3647	0.3647
	0.9308	0.1431	0.3979	0.3979
	0.7319	0.1543	0.3128	0.3128
	0.7491	0.1594	0.4171	0.3202
	0.8323	0.1905	0.3202	0.3558
	0.7664	0.1543	0.3558	0.3276
	0.8516	0.1923	0.3276	0.3641
	1.0219	0.1989	0.3640	0.4369
	0.7840	0.2321	0.4369	0.3352
	0.8712	0.2468	0.3352	0.3724
	0.9583	0.2384	0.3724	0.4096
	1.0454	0.2607	0.4096	0.4469
	1.0931	0.2951	0.4469	0.4571
Average	0.8488	0.1913	0.3638	0.3621

**Table 4.** Dose (mGy) received by the patient at CHUT.

Examinations	Skull	Thorax	Abdomen	Pelvis
	0.2768	0.1144	0.2469	0.1221
	0.2284	0.3502	0.2037	0.4454
	0.2575	0.0605	0.2297	0.7640
	0.3219	0.2579	0.2871	0.1336
	2.0284	0.5236	0.4595	0.1670
	0.6819	0.3426	1.8093	0.5346
	1.4422	0.2823	0.5433	1.0525
	0.5929	0.2907	0.2789	0.1415
	1.1421	0.3625	0.5579	0.5662
	2.3984	0.2831	1.1159	0.4677
	0.3127	0.2317	0.2864	1.2113
	0.3211	0.2371	0.3015	0.1538
	0.6762	0.1852	0.6031	0.1580
	0.8452	0.2964	1.2063	0.5071
	2.6626	0.2594	2.3750	0.3332
Average	0.9459	0.2718	0.7003	0.4505

### 4. Discussion

From Table 2, we have presented Figure 2 illustrating the variation of the dose rates of radiological devices as a function of the voltage applied to the X-ray tube for each hospital. The curves obtained are an adjustment of the data to a polynomial function of the second degree, that is to say an equation of the form  $y = ax^2 + bx + c$ . The results confirm that the dose rate in air follows the relationship mentioned in the relationship (2)

[13, 14]. By linear interpolation we will calculate the dose in air  $D_a$  for the intermediate values which will allow us to calculate the  $D_e$  for each different examination.

From relation (4), we have calculated the entrance dose  $D_e$  with the data on the dose rates of the device. The results are given in Table 3 for CHUA and in Table 4 for CHUT.

For the CHUA, the average of the calculated dose, for each type of examination in mGy, it is compared with the NRL values (Skull:  $0.8488 < 5$ ; Thorax:  $0.1913 < 0.4$ ; Abdomen:  $0.3638 < 10$ ; Pelvis:  $0.3621 < 10$ ) is below the NRLs proposed by the IAEA and no examination has exceeded these NRLs. At CHUT, the average dose for each examination (Skull:  $0.9459 < 5$ ; Thorax:  $0.2718 < 0.4$ ; Abdomen:  $0.7003 < 10$ ; Pelvis:  $0.4505 < 10$ ) We found that none of the average scores for these four types of exams at the two hospitals were above the IEA suggested DRLs. On the other hand, we note that a single chest examination was exceeded, which does not mean the overall result.

However, we will be able to confirm a good practice on patient dosimetry in these two diagnostic radiology services. This proves a good application of radiation protection for patients [1-4, 12-14].

## 5. Conclusion

Optimization of doses delivered to the patients is regulated in Madagascar and must be controlled. In this work, we were able to estimate the doses received by the patients who underwent the four radiological examinations chosen in the two hospitals of Fianarantsoa. We have found that the average doses delivered to the patients are below the reference levels recommended by the IAEA [16]. A slight non-significant increase on the examination of the thorax at the Tambavao University Hospital Center (CHUT) is observed. The results obtained prove that radiation protection of patients is applied in these hospitals and follows the regulatory plan of the Law No. 97-041 relating to the protection against the harmful effects of ionizing radiation and radioactive waste management in Madagascar, was enacted on January 2, 1998. These results analyzed according to the influence factors on the dose, that is to say the exposure parameters and the geometric parameters, prove the feasibility and the great interest of a national campaign of dose measurements in radiology, on a larger scale, which would make it possible to establish NRLs specific to Malagasy practice, to provide for their periodic review and to define the appropriate optimization procedures. From this study, we hope to establish a digital radiological monitoring platform ensuring real-time evaluation of the doses received by the patients in the Malagasy territor.

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