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Evaluation of the level of compliance with radiation protection measures and conventional dosimetry in medical imaging structures in the Democratic Republic of Congo (DRC)

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Abstract

Context: The harmful effects of X-rays on health require protection through both collective and individual prevention.
Objective: Assess the level of organization of radiation protection and dosimetry monitoring of medical imaging professionals in the DRC.
Methodology: We conducted a multicenter study in Kinshasa, the capital, and in the provinces of the DRC between March 1 and October 30, 2024. A questionnaire was completed online by consenting medical imaging professionals. The described conditions were evaluated by comparing them to WHO standards.
Results: A total of 186 medical imaging professionals participated in our survey. No personal protective equipment is used by 100% of professionals; the lead apron is used at 95.2%, the lead screen at 68.8%, the safety glasses at 38.7%, the lead gloves at 32.3%, the dosimeter at 16.1%, the protective shoes at 11.3% and the lead helmet at 2.7%. The dosimeter is not worn in 88% of cases and is not read in 91% of cases. Quality control is not ensured in 63.4% of cases. In 94.6%, the participants are unaware of the doses absorbed.
Conclusion: Radiation protection measures and dosimetry monitoring of workers are not respected. The absorbed doses are not known. In the absence of conventional dosimetry, biological dosimetry could be proposed as an alternative to assess the risk of exposure to x-rays.

Keywords: Radiation protection, compliance with safety, dosimetry

Introduction

Humans are exposed to ionizing radiation from natural and artificial sources on a daily basis. Naturally occurring radiation comes from many sources, including more than 60 radioactive materials naturally present in soil, water, and air. Radon is the major natural source of radiation. Every day, humans inhale and ingest radionuclides from air, food, and water [1].
Radiation exposure also comes from artificial sources, ranging from nuclear power plants to medical uses of radiation for diagnosis or treatment. Today, the most common artificial sources of ionizing radiation are medical devices, such as X-ray machines and CT scanners [2].
With the development of the nuclear industry and the more widespread use of nuclear and radiological technologies, more and more people are likely to be exposed to radiation in the course of their work.
According to a 2008 report by the United Nations Scientific Committee on the Effects of Atomic Radiation, some 23 million workers worldwide are exposed to ionizing radiation [3].
For 13 million of them, this radiation comes from natural sources; for the remaining 10 million, it comes from artificial sources. This exposure results mainly from the normal use of the installations, but these workers can sometimes be overexposed in the event of an accident [3, 4].
They may therefore be exposed to artificial radiation or to radioactive materials of natural origin. Concrete measures must be taken to protect them.

Each year in France, approximately 385,000 workers are exposed to ionizing radiation in the workplace [5]

X-rays are ionizing radiations that can pass through the body and have very harmful effects on health for long or repeated exposure periods and/or for high intensities: skin, ophthalmological, hematological, cellular damage that can cause cancers, fetal malformations [6]. The main applications concern medical (radiodiagnosis and radiotherapy), industrial (non-destructive testing, radio metallography) and scientific (laboratories) uses, and the number of x-ray generating equipment is constantly increasing.

The medical sector has the largest number of potentially exposed workers. X-rays can be received directly from the source (primary radiation) or scattered by walls, floors and ceilings (secondary radiation) [3, 6].

In radiological practice, it is essential that the images produced are of the highest quality, as they have a direct impact on the diagnosis, prognosis and treatment of patients. The selection and control of personal protective equipment, the monitoring of personal dosimetry, the drafting of instructions and the periodic training (at least every three years) of workers in radiation protection should thus be ensured [7].

Dosimetry monitoring devices for passive individual dosimetry with deferred reading must be used; as well as those used for active operational dosimetry with direct reading in real time [8].

Therefore, the wearing of passive dosimeters is mandatory for all exposed personnel. It is sent to the body responsible for reading it. These dosimeters provide the opportunity to take appropriate precautions to limit future exposure opportunities so that the cumulative maximum permitted doses are not exceeded [9].

X-ray equipment must be systematically inspected during installation and after any modification. Mobile equipment must be inspected every year and fixed equipment every three years [10].

A number of factors can contribute to workers' exposure to ionizing radiation. These include a lack of appropriate infrastructure, equipment in poor condition, the absence of personal protection or radiation protection advisors, or a lack of medical supervision. Informing workers about occupational exposures and their potential health effects is a legal obligation, as it is part of the general principles of prevention and is one of the main elements of primary prevention [11].

In our first study carried out in 2017 in Kinshasa on radiation protection in radiographic installations [12], as well as in that of Molua A et al. [13], mention was made of the obsolescence of radiological equipment in the structures surveyed. We wanted to inquire about the state of radiation protection and dosimetry monitoring in our country, many years later.

This study aimed to assess compliance with radiation protection procedures through use of personal protective equipment (PPE) and conventional dosimetry by medical imaging professionals in DRC.

Methodology

Type of study

This is a cross-sectional study, with a descriptive and comparative approach, conducted in several radiology structures in Kinshasa and the provinces of the Democratic Republic of Congo.

Framework and period of the study

Our study was multicenter; it involved medical imaging professionals working in health structures with medical imaging equipment in Kinshasa and in the provinces.

We submitted an online form to radiologist technicians, and we only retained the staff of the structures who voluntarily responded to our questionnaire, after consent. Participants from 34 health structures responded to our survey.

The survey lasted five months, from January 1 to May 30, 2024 for data collection, and three months (June, July and August 2024) were devoted to data processing and statistical analysis. Finally, the months of December and January were dedicated to writing and discussion. That is a period of 12 months.

Study population and sampling

We included all full-time medical imaging professionals working in 34 health facilities across the DRC who responded to our survey and completed the survey questionnaire after free and informed consent.

Compliance with radiation protection measures:

- The interposition of protective screens,
- Distance from the source: yes or no
- Reducing exposure time
- Presence of a PCR
- Quality control of radiology equipment
- Equipment maintenance

Variables

The variables of interest were age and sex, the number of years worked, the medical imaging modalities offered, the use of Personal Protective Equipment (PPE), the wearing and reading of dosimeters, and the absorbed dose values.

Statistical analysis

Data were coded and cleaned using Microsoft Office Excel 2010 on a Dell laptop computer. Stata software (Statistics and Data version 18.0) was used for statistical analysis. For descriptive analysis, mean with standard deviation or median with Interquartile Range (IQR) was calculated, depending on the distribution for quantitative data, with or without normal distribution. Normality of data was tested using the Shapiro-Wilks test. Qualitative data are presented as absolute frequencies (numbers) and their relative frequencies are expressed as percentages (%).

In the bivariate analysis, the Student's t-test was used to compare quantitative variables, in particular radiation doses, between two groups. This cross-tabulation of variables was used to test for significant differences between the different groups. The statistical significance level was set at 5%. The results are presented in tables and figures.

Ethical considerations

All participants signed a written free and informed consent form before being included in the study. Each participant's data was de-identified to ensure confidentiality and anonymity. The study protocol was approved by the Ethics Committee of the ISTM-Kinshasa Doctoral School.

Results

During the study period, 186 medical imaging professionals responded to our survey questionnaire and constituted the sample for this study. They represented 34 structures identified in the provinces and in the city of Kinshasa, capital of the DRC.

Demographic Data

Gender of respondents

There were more men (66.7%; N=124) than women (33.3%; N=62) in the present study, giving a sex ratio (M/F) of 2. The Table I shows the frequency of the sex among participants.

Age of respondents

The mean age of the participants was 37.1±11.3 years, with extremes ranging from 21 to 67 years. The age distribution is shown in Table II. The survey showed that the majority of participants were relatively young. The 25-34 age group was the majority with 45.9% of cases, followed by the 35-44 age group (25.9%) and then the 45 and over age group (22.2%). Those under 25 only represented 5.9% of participants.

Provinces where participants are based

Table III shows the different provinces in which the participants in this study are practicing their profession.
Most participants lived in the provinces of Kinshasa (28.5%), North Kivu (17.2%), Congo-Central (15.6%), Kasai Oriental (8.1%) and Kwilu (7.5%). There were fewer participants in the other provinces.

Duration of the exposure

Figure 1 shows that 34% of participants had between 1 and 5 years of exposure or service, and 22% had between 6 and 10 years. A total of 58 participants (31.2%) had 11 or more years of service.

Compliance with radiation safety measures and protective equipment used in operations departments

- **Radiation protection methods used in the assigned service**

In Table IV, we present the means of radiation protection used by the different medical imaging structures.
This survey revealed that none of the personal protective equipment had been fully used. The most used radiation protection equipment was: lead apron (95.2%), lead screen (68.8%), safety glasses (38.7%) and lead gloves (32.3%). The effectiveness of the dosimeter in these institutions was very low, with a rate of 16.1%.

Wearing and reading the dosimeter

Regarding dosimeter wearing and reading habits, the survey showed that dosimeter wearing was only mentioned in 11.8% of cases; and reading these dosimeters was only mentioned in 9.4% of cases (Figure 2).

Quality control

Table V provides information on the existence or not of quality control of the installations of the various medical imaging structures.
Overall, 63% of participants said that periodic and regular quality control of the facilities was not carried out.

- **Knowledge of doses absorbed over the last six months**

Table VI presents the frequencies of knowledge of the doses absorbed by the participants during the last six months of their practice.
This study shows that in 94.6% of cases, medical imaging professionals are not aware of the doses absorbed over the last six months.

Discussion

Sex

Men were in the majority in this study, with a sex ratio of 2. They represented 66.7% of the population studied.
On 1 January 2021, of the 8,907 radiologists registered in France, 3,253 were women, according to data from the Direction de la recherche, des études, de l'évaluation et des statistiques (DREES). In 2021, women accounted for 36.5% of the workforce, compared with 31.8% in 2012. There were 5,654 men.
The medical imaging professions (radiology, scanners, MRI, etc.) have long been dominated by men, due to the history of training and the distribution of roles between the sexes in the medical and technical sciences. Only over time has the profession begun to attract women [14]. Women are in a minority in both the hospital and private sectors, but the proportions are not the same. There are more women and girls in the auditoriums, but professional integration is still a problem.
Gender stereotypes may have influenced career choices. Technical or scientific professions have often been seen as more suitable for men, while caring professions have been seen as more feminine. This may explain why there is a male predominance at certain levels of the occupation [15].
The predominance of boys over girls in educational settings may partly explain this male predominance among medical imaging professionals.

Age

The mean age of the participants was 37.1±11.3 years, with extreme values ranging from 21.3 to 67.9 years. It is reported in the literature that age is a determining factor. The risk of radiation effects occurring in exposed individuals is greater in children and adolescents because they are significantly more sensitive to radiation exposure than adults [16]. In addition, several factors increase the radio sensitivity of a cell: its youth, its low level of differentiation, its high mitotic activity, its good oxygen supply and its phase in the cell cycle (mitosis). Hence the need to recruit perfectly healthy adults [17]. Exposure at an early age increases the risk of cancer incidence and the risk of early mortality from ionizing radiation [16, 17]. The relatively young average age of the population in our study could be a risk factor for sensitivity and susceptibility to the effects of radiation.

Provinces of participant assignment

The majority of participants in this study were professionals working in facilities located in the provinces, representing 71.5% of cases. However, it is important to highlight the high proportion of professionals from Kinshasa, who represented 28.5% of the study sample. In fact, none of the provinces reached the participation rate of professionals from the city of Kinshasa. Professionals in Kinshasa have better access to the Internet network serving the capital. Apart from Kinshasa, which enjoys slightly more reliable Internet coverage, the ecosystem of Internet use in the DRC remains fragmented and fragile. However, a study on the dissemination of information in the North Kivu region showed that, despite the lack of interest in research and the lack of regular Internet access in most provinces except the capital, the inhabitants of North Kivu are interested in information in 78% of cases [18]. The province of Kongo Central, due to its proximity to the capital, was easier to mobilize and seems to have better internet coverage than other provinces. By 2022, almost 65% of the population of the DRC will not have access to the internet [19].

Internet penetration remains low in Africa in general and in the DRC in particular. Overall, the DRC still faces a digital divide, particularly due to the low level of Internet access in rural areas. The problem is more one of affordability [19].

Additional efforts will have to be made in the future to encourage the participation of the other provinces, despite the significant differences in the development of communication links between them.

Duration of the exposure

In the present study, the mean duration of exposure or seniority was 3.06 years 34% of the workers had a seniority or duration of exposure of 1 to 5 years, 22% had a seniority of 6 to 10 years and 31.2% of the participants had a duration of exposure of at least 11 years.

Length of exposure is a very important factor. There is evidence of adverse effects of IR after exposure, but the literature also shows that these effects are dose dependent and influenced by age [20].

A study of micronucleus formation in the PBL DNA of nuclear power plant workers found an increased frequency of micronucleus formation compared with controls, and a highly significant association was found between micronucleus formation and cumulative dose as well as duration of employment [21].

Studies on the incidence of cancer in workers exposed to low doses of IR, even in radiodiagnostics, are controversial. However, in their study, Latarjet et al. [22] reported that exposure to low doses, whether occupational or medical, significantly increased the incidence of cancer. As a precaution, it is assumed that any dose, however low, may lead to an increased risk of cancer [23, 24].

Frequency of using protective equipment in working areas or compliance with radiation protection measures and practice

This study reported the use of lead apron in 95.2% of cases, lead shield in 68.8% of cases, lead goggles in 38.7% of cases, lead gloves in 32.3% of cases and dosimeters in 16.1% of cases. The use of this equipment reduces radiation exposure during examinations or when handling radioactive sources, thus ensuring individual and collective radiation protection in the workplace.

In terms of radiation protection, personal protective equipment must be worn and checked, personal dosimetry must be monitored, instructions must be drawn up and workers must receive regular radiation protection training (at least every three years) [8]. All radiology facilities must strictly adhere to these standards to protect medical imaging personnel. Healthcare workers remain the main target of the harmful effects of ionizing radiation. Workers should normally be reminded of radiation protection rules at regular intervals of three years [25].

Frequency of wearing the dosimeter

Overall, 88% of the people surveyed in this study did not wear a dosimeter at work. An individual dosimeter is essential because it allows radiological monitoring to check that the doses received are within regulatory limits, i.e. it allows the effective dose received by the human body during external exposure to ionizing radiation to be estimated.

Radiation protection regulations are strict and are based on the recommendations of international bodies such as the ICRP and the IAEA. They stipulate that workers must benefit from individual monitoring of irradiation and contamination [26].

Dosimeter reading and knowledge of absorbed doses

In this study, dosimeters were not read as regularly, with 91% of participants reporting that dosimeters were not read. The study also showed that a very small proportion of respondents, 5.4% were aware of their absorbed doses over the previous ten months.

The results of absorbed dose checks must be accurately recorded on the irradiation form in the worker's medical file. These results are communicated to the labour inspector and to the person concerned.

Workers exposed to radiation must have a medical file kept by the occupational physician; this consists of an irradiation form indicating the nature of the work, the type of radiation and the duration of the periods of irradiation.

A further irradiation record is required, giving the dates and results of the equivalent doses received, to ensure adequate dosimetric monitoring [27].

Equipment quality control

Regarding the control of radiological equipment (quality control), more than half of the respondents (63%) reported that regular periodic quality control of equipment was not performed.

Quality control ensures the performance and reliability of radiological equipment, thereby helping to minimise exposure and ensure the safety of workers and patients [28]. Quality control is mandatory for all medical imaging equipment using ionising radiation. It is carried out by the operator under the responsibility of the regulatory body.

The procedures and frequency are specified in the regulations.

Finally, good practice should reduce unnecessary exposure and ensure the training and education of the personnel involved. An effective radiation protection programme must therefore be put in place, with a multidisciplinary approach involving doctors, radiographers, RCPs, medical physicists, occupational physicians and facility managers [29].

The literature also states that if internal quality controls are not carried out at the specified intervals or in the specified manner, the quality control body will remind the operator of the obligation to comply [25]. This is what takes so long to happen in our environment.

This is why we believe that, in the absence of conventional dosimetric monitoring with measuring devices that are not available, biological dosimetry can be used to ensure that health professionals are not harmed by radiation through the indirect effect of ionising radiation and thus to ensure their safety at work.

Tables

Table 1: Distribution of participants by gender

Sex	Number of employees N=186	%
Men	124	66.7
Women	62	33.3

Table 2: Distribution of participants by age group

Age group	N	%
< 25 years old	11	5.9
25 to 34 years old	85	45.9
35 to 44 years old	49	25.9
≥ 45 years old	41	22.2
Total	186	100

Table 3: Participants' provinces of assignment

Provinces	N	%
Kinshasa	53	28,5
Nord-Kivu	32	17,2
Kongo-Central	29	15,6
Kasaï Oriental	15	8,1
Kwilu	14	7,5
Haut-Katanga	10	5,4
Lualaba	8	4,3
Sud-Kivu	4	2,2
Kasaï central	3	1,6
Equateur	2	1,1
Kwango	2	1,1
Mai Ndombe	2	1,1
Sankuru	2	1,1
Tshopo	2	1,1
Haut-Lomami	2	1,1
Ituri	2	1,1
Bas-Uéle	1	0,5
Maniema	1	0,5
Sud-Ubangi	1	0,5
Tanganyika	1	0,5
Total	186	100

Table 4: Distribution of the study population according to the means of protection used

Materials	Workforce (N=186)	%
Protective shoes	5	11.3
Leaded helmet	21	2.7
Dosimeter	30	16.1
Protective glasses	60	38.7
Leaded gloves	72	32.3
Leaded screen	128	68.8
Leaded aprons	177	95.2

Table 5: Regular periodic quality control of installations

Modality	Effective	%
No	118	63.4
Yes	68	36.6
Total	186	100

Table 6: Participants' level of knowledge about doses absorbed over the last six months

Modality	Effective	%
No	176	94.6
Yes	10	5.4
Total	186	100

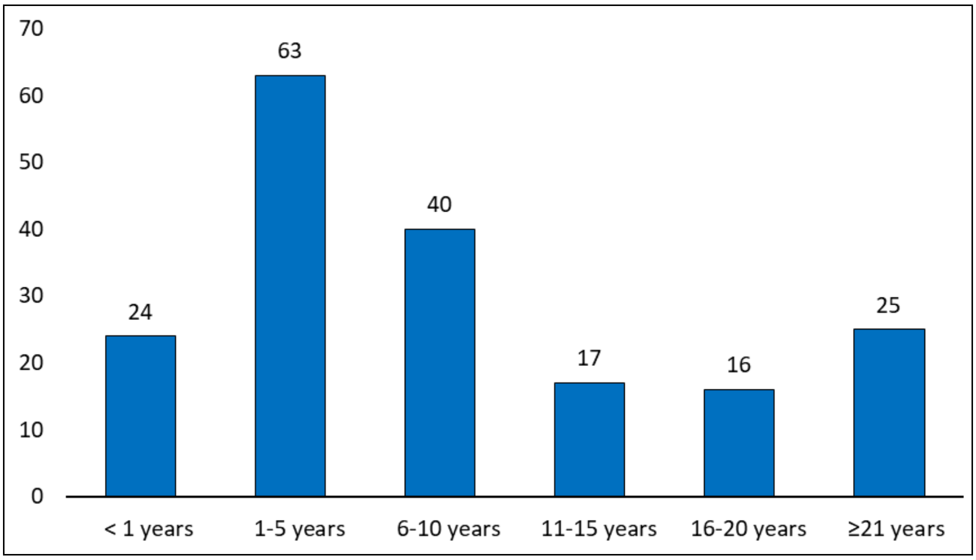

Fig 1: Duration of the exposure of the participants

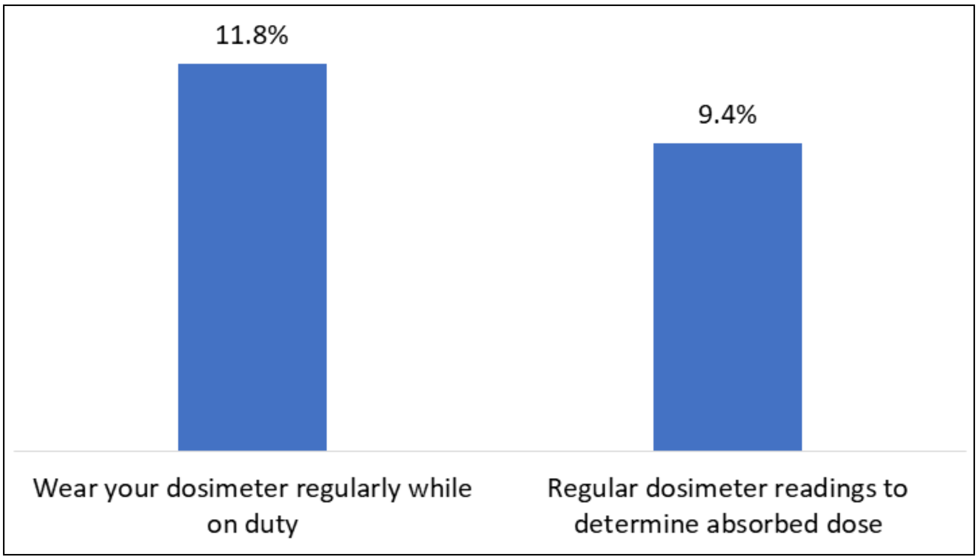

Fig 2: The frequency of dosimeter wearing and dosimeter readings

Conclusion

The results of this study show that compliance with workplace radiation protection measures in healthcare facilities is poor because

- The inadequate use of personal protective equipment (PPE) in our medical facilities, none of which has been accredited for 100% use the very low frequency with which dosimeters are worn and read, which shows that workers' dosimetry is not monitored the low frequency with which quality control of radiological equipment is carried out.
- The frequency of quality control of radiological installations is below average.

The relevant regulations should be made more widely known, in particular when authorizing the opening of installations using ionizing radiation and when monitoring workers' dosimeters and the safety of radiological installations in the DRC.

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Any conflict of interest related to the work.

Conflict of Interest

Not available

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Not available

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