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Establishment of local diagnostic reference levels in terms of dose area product (DAP) in conventional radiology at the Regional Hospital Center of Souss Massa, Morocco

S. Semghouli[1,*], M. El Fahssi[2], A. Dahbi[3] and B. Amaoui[4]

[1] Team Health Techniques (ETechS), Research Laboratory in Health and Environmental Sciences (LabReSSE), Higher Institute of Nursing Professions and Health Techniques (ISPITS), Agadir, Morocco.
[2] Faculty of Medicine and Pharmacy, Mohammed V University, Rabat, Morocco.
[3] Ministry of Health and Social Protection, Higher Institute of Nursing Professions and Health Techniques (ISPITS), Agadir, Morocco.
[4] Biotechnology and Medicine (BioMed) Laboratory, Faculty of Medicine and Pharmacy, Ibn Zohr University, Agadir, Morocco.

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Abstract – Introduction: The effectiveness of diagnostic reference levels (DRLs) in reducing the doses delivered to patients has been demonstrated. Establishing DRLs in terms of the dose surface product (DSP) is an essential step in the management of radiation doses in conventional radiology. **Objective:** This retrospective study aimed to assess local diagnostic reference levels (LDRLs) for four types of X-ray examinations in terms of DAP at the Regional Hospital Center of Souss Massa. **Materials and methods:** Data from 120 adult patients, 30 per location (thorax (PA), pelvis (AP), lumbar spine (AP) and abdomen (AP)) were collected. Patient parameters such as gender, age, BMI, clinical indications, and examination acquisition parameters such as kV, mAs, patient source distance (PSD), and exposure field dimensions were recorded for each patient. The calculation of DRLs is based on a statistical method known as the 75th percentile of the distribution of DAP. The data were statistically analysed by SPSS software V 21.0. Pearson's parametric test was used to explore the relationship between the different quantitative variables. **Results:** The mean ESDs for the thorax (PA), lumbar spine (AP), abdomen (AP), and pelvis (AP) were 0.17, 2.55, 2.16, and 2.63 mGy, respectively. The mean DAP values for the thorax (PA), lumbar spine (AP), abdomen (AP), and pelvis (AP) were 16.53, 213.11, 230.55, and 265.19 cGy.cm2, respectively. The DRLs in terms of ESD for the thorax (PA), lumbar spine (AP), abdomen (AP), and pelvis (AP) were 0.17, 2.77, 2.64, 2.87 mGy, respectively. In terms of DAP, they were 16.58, 245, 291.83, and 300.45 cGy.cm^2, respectively. The results show a significant relationship between DAP and tension, charge, and ESD for all examinations. In addition, there was a significant relationship between DAP and BMI for abdomen X-ray, and no significant relationship for the three other X-ray examinations. **Conclusion:** It is possible to reduce the dose delivered to patients in the Regional Hospital Center of Souss Massa through the continuous training of radiology workers, implementation of a quality assurance program for equipment, and institutionalization of DRL as an approach to reducing patient doses and health service costs.

Keywords: Conventional radiology / entrance skin dose (ESD) / dose area product (DAP) / Local diagnostic reference levels (LDRLs) / Souss Massa / Morocco

1 Introduction

Ionising radiation has many beneficial applications in a number of fields, including medical diagnosis. However, the risks associated with its use must be assessed and, if necessary, controlled (IAEA, 2014). Medical exposure to ionizing radiation represents the largest contribution to population dose from artificial sources, and diagnostic X-rays make up the majority of this contribution (approximately 90%) due to the increasing number of X-ray examinations carried out each year (IAEA, 2007). In addition, direct epidemiological evidence has been demonstrated linking exposure to ionising radiation to the risk of radiation-induced cancer (ICRP, 1999). In this context, the results of the Life Span Study (1950–1990) showed that 334 of the 7578 people who died of solid tumours could be attributed to exposure to ionising radiation (UNSCEAR, 2000). This situation demonstrates the importance of

*e-mail: ssemghouli@gmail.com

justification and optimisation as two essential principles of radiological protection in medical imaging. The principle of justification means that the individual or societal benefit resulting from medical exposure to ionising radiation must be sufficient to compensate for the harm caused. The principle of optimisation means that individual doses of exposure must be kept as low as reasonably achievable, considering economic and societal factors (ICRP, 2007).

Diagnostic reference levels (DRLs) have proven effective in optimizing patient protection during medical imaging procedures. In this context, in the UK, where data have been collected approximately every five years since the mid-1980s, the DRL values determined from the 2005 survey results were 16% lower than the corresponding values from the 2000 survey and approximately half the corresponding values from the mid-1980s survey (ICRP, 2017). In addition, the DRL concept represents a tool that will be used primarily by equipment operators to effectively identify X-ray diagnostic and interventional procedures that may require optimization. However, the DRL concept is currently insufficiently known and implemented in many facilities (Schegerer *et al.*, 2019).

In the Souss Massa Region in Morocco, a particular attention has been paid to patient radiation protection in hospital settings in terms of (1) the perception of professionals (Amaoui *et al.*, 2023; EL Fahssi *et al.*, 2024a), (2) dose optimization (Amaoui *et al.*, 2019; Semghouli *et al.*, 2022a; El Fahssi *et al.*, 2023) and (3) radiological risks estimation (Semghouli *et al.*, 2022b, 2024a). Furthermore, the equipment's for the most prescribed modality are not equipped with a system for displaying the dose-area product (DAP) values for each X-ray examination. To the best of our knowledge, no study relating to the establishment of LDRLs in terms of DAP has been conducted in this region. The aim of this study was to assess the DRLs for four types of X-ray examination in terms of DAP at the Regional Hospital of Agadir. The establishment of DRLs in terms DAP is motivated by the need to have dosimetric measurements, especially in the absence of a national or local approach to optimizing doses delivered to patients. The results of the present study will be used to compare the values obtained with those established by previous studies and as a basis for future local or national studies.

2 Materials and methods

2.1 Populations studied

This was a retrospective study conducted at the regional hospital of Souss Massa between January and March 2023, and included adult patients (age ≥ 18 years) receiving a radiographic examination in the radiology department of the hospital. In total, data from 120 adult patients, 30 per location (thorax (PA), pelvis (AP), lumbar spine (AP) and abdomen (AP)) were collected.

Patient parameters such as gender, age, BMI, clinical indications, and examination acquisition parameters such as kV, mAs, patient source distance (PSD), and exposure field dimensions were recorded for each patient.

The X-ray equipment used in this study was type IAE X50H, serial number B8383, manufactured in KOREA. It has a permanent filtration of 1.5 mm A1 and a maximum voltage of 150 kV.

2.2 Dose estimation

2.2.1 Estimation of dose-area product (DAP)

The DAP is the product of the average dose absorbed in the air in a straight section of the X-ray beam in the absence of the scattering medium and the surface area of this section. The DAP was calculated using the following formula (ICRU, 2005):

$$\mathrm{DAP} = \frac{ESD\mathrm{x}A}{BSF}, \tag{1}$$

where DAP: is the dose-area product, A: is the surface area of the exposed section, BSF: is the backscatter factor.

The backscatter factor FRD depends on the constants, particularly the kilo voltage. It ranges from 1.2 to 1.5. We used a value of 1.35 between 60 and 80 kV (this is the case for three examinations in this study: lumbar spine, abdomen and pelvis) and 1.5 at high kV (120–140 kV, in the case of the thorax).The DAP is expressed in cGy cm^2.

The ESD was calculated by the following empirical formula (Adambounou *et al.*, 2022):

$$\mathrm{ESD(mGy)} = 0.15\mathrm{x}\left(\frac{\mathrm{U}}{100}\right)^2 xQx\left(\frac{1}{SFD}\right)^2, \tag{2}$$

where U: Tube voltage in kV; Q: electrical charge in mAs; FSD: The focus-to-skin distance in m.

2.2.2 Estimation of DRLs

The calculation of DRLs is based on a statistical method known as the 75th percentile of the DAP distribution according to the formalism of the International Commission on Radiological Protection (ICRP, 135).

2.3 Data analysis method

The data were statistically analysed by SPSS software V 21.0. After checking the normality of the variables, Pearson's parametric test was used to explore the relationship between the different quantitative variables.

3 Results

Of the 120 patients examined, 48% were male and 52% were female, with a male/female ratio of 0.92. All patients are adults over the age of 18.

According to Table 1, the average voltage for the four radiographic examinations ranged from 69.23 to 87 kV, with a maximum value of 109 kV for the thorax (PA) and a minimum value of 60 kV for the pelvis (AP) and abdomen (AP). The average charge for the four X-ray examinations ranged from 3.35 to 34.9 mAs, with a maximum value of 51 mAs for the abdomen (AP) and a minimum value of 2.5 mAs for the thorax (PA).

Table 1. Acquisition parameters for the four radiographic procedures studied.

Radiographic examination	kV				mAs			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Thorax (PA)	70	109	87	7.84	2.5	5	3.35	0.49
lumbar spine (AP)	68	76	71.06	2.03	31	41	33.96	4.03
Abdomen (AP)	60	80	69.23	4.36	20	51	34.9	6.71
Pelvis (AP)	60	87	71.3	4.52	20	40	34	5.29

Table 2. Entrance dose and dose-area product for the four radiographic procedures studied.

Radiographic examination	ESD (mGy)				DAP (cGy cm^2)			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Thorax (PA)	0.09	0.40	0.17	0.06	09.08	39.57	16.53	6.35
Lumbar spine (AP)	1.63	3.37	2.55	0.38	141.58	332.21	213.11	40.30
Abdomen (AP)	1.28	4.30	2.16	0.65	101.66	447.64	230.55	75.66
Pelvis (AP)	1.08	4.54	2.63	0.65	57.51	427.53	265.19	74.96

Table 3. Comparison of the 3rd quartiles of DAP from this study with previous studies.

Radiographic examinations	This study	France 2018	Germany 2019	Austria 2019	Saudi Arabia 2021
	DAP (cGy cm^2)				
Thorax (PA)	16.58	20	15	13.9	8.48
lumbar spine (AP)	245	270	200	195.2	253.78
Abdomen (AP)	291.83	340	230	209.9	197.85
Pelvis (AP)	300.45	380	250	212.1	172.79

Table 4. DRLs calculated for the four radiographic examinations.

	Thorax (PA)	Lumbar spine (A/P)	Abdomen (A/P)	Pelvis (A/P)
ESD (mGy)	0.17	2.77	2.64	2.87
DAP (cGy cm^2)	16.58	245	291.83	300.45

According to Table 2, the mean ESDs for the thorax (PA), lumbar spine (AP), abdomen (AP), and pelvis (AP) were 0.17, 2.55, 2.16, and 2.63 mGy, respectively. The mean DAP values for the thorax (PA), lumbar spine (AP), abdomen (AP), and pelvis (AP) were 16.53, 213.11, 230.55, and 265.19 cGy.cm^2, respectively.

The diagnostic reference levels, which represent 75 percentile entrance doses and dose-area product, were estimated on the basis of the results of the four radiographic examinations studied. Table 3 shows the DRLs for the four examinations.

According to Table 4, the DRLs in terms of ESD for the thorax (PA), lumbar spine (AP), abdomen (AP), and pelvis (AP) were 0.17, 2.77, 2.64, 2.87 mGy, respectively. In terms of DAP, they were 16.58, 245, 291.83, and 300.45 cGy cm^2, respectively.

According to Table 5, there is a significant relationship between DAP and tension, charge, and ESD for all examinations. In addition, there was a significant relationship between DAP and BMI for abdomen X-ray, and no significant relationship for the three other X-ray examinations. Table 5 also shows no significant relationship between DAP and patient age.

4 Discussion

The results show that most patients studied were female (52%). The majority of patients were 46–60 years of age (33.33%). The choice of acquisition parameters is based on several criteria, including BMI, region examined, and type of examination, which justify the variation observed in image acquisition parameters even for the same type of examination. The variation of acquisition parameters for the same examination at the same hospital is mainly due to a non-standardization of radiological procedures (El Fahssi *et al.*, 2023). The results show

Table 5. Correlation between BMI, age, tension, charge, ESD and the DAP.

		Tension (kV)	Charge (mAs)	ESD	Age	BMI
DAP (cGy cm^2)	Thorax (PA)	.005	.000	.000	.512	.876
	lumbar spine (AP)	.000	.000	.000	.634	.159
	Abdomen(AP)	.006	.001	.000	.792	.001
	Pelvis (AP)	.000	.000	.000	.925	.853

a significant relationship between the acquisition parameters (kV and mAs), effective dose, and DAP. In addition, the high mAs observed for certain examinations could be due to an imprecision in the manufacturer's programed reference exposure technique or to imprecise manual adjustment by the radiology technologist in response to variations in patient size that exceeded the exposure technique recommended by the manufacturers (Alshamrani *et al.*, 2021).

According to Table 5, DRLs in terms of DAP for the four X-ray examinations included in this study are lower than those reported in France (IRSN, 2020). However, DRL in terms of DAP calculated for the thorax (PA) was higher than those reported in Germany (Wright and Ramsdale, 1998), Austria (Wachabauer *et al.*, 2019), and Saudi Arabia (Alshamrani *et al.*, 2021). The DRLs for the lumbar spine (AP) and abdomen (AP) calculated in this study are higher than those reported in Germany and Austria. For the pelvis (AP), the DRL of this study was higher than that reported in Germany, Austria, and Saudi Arabia.

The marked increase in the 75th percentile and the mean DAP observed in certain X-ray examinations could be attributed to the selection of a high mAs technique and a wide field size. In addition, technologists' sub-optimal practices regarding the choice of radiographic technique (*i.e.*, mAs) or oversized collimation may also affect this increase in DAP (Alshamrani *et al.*, 2021).

The optimisation of radiation applications in radiology depends on the size of the patient. It is there for recommended to report parameters that characterise the patient's stature (*e.g.* BMI, body weight, body diameter, and size-specific dose estimate) (AAPM, 2011). However, the operators at the study site do not consider the patient's BMI when choosing the acquisition parameters, which has an impact on the dose delivered to the patient. Therefore, three of the examinations included in this study showed no significant relationship between BMI and DAP. These are the thorax ($p = 0.876$), lumbar Spine ($p = 0.159$) and pelvis ($p = 0.853$). Whereas the abdomen shows a significant relationship between patient BMI and DAP ($p = 0.001$).

The development and implementation of a radiation protection strategy in collaboration with healthcare professionals, radiologists, medical physicists, radiology technologists, and radiation safety officers is essential for the systematic optimisation of ionising radiation applications, including the use of DRLs and local reference values (El Fahssi *et al.*, 2023). Furthermore, the effectiveness of using local diagnostic reference levels and comparing doses between local hospitals to reduce radiation doses has been demonstrated. Overall, the adoption of local reference levels has been successful and highly relevant (Wright *et al.*, 1998). All radiologists need to know the typical local doses in their department in relation to national and international diagnostic reference levels (Vassileva and Rehani, 2015).

Over the last years, a culture of patient radiation protection has developed in Morocco following a several studies carried out in this field (Semghouli *et al.*, 2016; Talbi *et al.*, 2021; Aabid *et al.*, 2023; El Fahssi *et al.*, 2024b; Semghouli *et al.*, 2024b). With this in mind, the decree on the protection of workers, the public and the environment against ionizing radiation has just been adopted by the public authorities, and mentions for the first time the importance of establishing DRLs as the main tool for optimizing doses delivered to patients during radiological examinations. It also stresses the need to assign medical physicists to radiology departments, which has had a positive impact on dose optimization in these departments. In addition, the comparison between the dosimetric values of the four most frequently performed radiographic procedures that we established in this department in 2020, and those carried out as part of this study, showed a remarkable reduction (up to 50%) in ESD for certain conventional examinations such as chest X-rays (El Fahssi *et al.*, 2023). This marked improvement could be attributed to several factors, including the strengthening of the training program for radiology technicians, and the introduction of a radiation protection and radiobiology module in their training program (ICRP, 2017). In addition, the results of previous studies we have carried out on the estimation of doses delivered to patients have been communicated to department managers so that they can be made aware of them and make the necessary decisions. These optimization efforts have had a positive impact on protecting patients from unnecessary exposure during medical imaging examinations. However, to ensure the sustainability of optimized radiological procedures, we recommend the following measures: (1) assign a medical physicist to each department; (2) set up a quality assurance program; (3) develop a continuing education program for medical and paramedical staff; (4) plan public awareness campaigns on the harmful effects of ionizing radiation

5 Conclusion

The variation in doses delivered for the radiological examinations included in this study is significant. Consequently, it is possible to reduce the dose delivered to patients in the regional hospital of Agadir. This could be achieved through the continuous training of radiology workers, implementation of a quality assurance program for equipment, and institutionalization of DRL as an approach to reducing patient doses and health service costs.

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Conflicts of interest

The authors declare that they have no conflicts of interest in relation to this article.

Data availability statement

Data associated with this study will be available upon request.

Author contribution statement

S. Semghouli, M. El Fahssi, designed the study, performed the statistical analysis and wrote the first draft of the manuscript. A. Dahbi, B. Amaoui managed the reviewing and editing. All authors read and approved the final version of the manuscript.

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