Research Article

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Estimation of Entrance Surface Dose for Radiography Examinations in Arrazi Hospital from Mohammed VI University Hospital Center of Marrakech (Morocco).

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ABSTRACT

In order to minimize patient entrance surface dose (ESD), this study aims to determine the diagnostic reference levels (DRLs) for routine radiography in Arrazi Hospital (ARH) at the Mohammed VI University Hospital Centre (Med VI UHC) in Marrakech, Morocco. A total of 1170 radiography examinations (RE) were included. They underwent 13 separate projections in the adult radiology department of the Marrakech-Safi region teaching hospital.

The X-ray tube's dose area product (DAP) was used to figure out the patient's entrance skin dose (ESD) for the cervical spine anterior-posterior (AP), cervical spine lateral (LAT), lumbar spine AP, lumbar spine LAT, abdomen AP, pelvis AP, shoulder AP, knee AP, knee LAT, skull AP, skull LAT, and the chest AP. The 75th percentiles with respect to ESD for cervical spine AP, cervical spine LAT, lumbar spine AP, lumbar spine LAT, abdomen AP, pelvis AP, shoulder AP, knee AP, knee LAT, skull AP, skull LAT, and chest AP were 2.1 mGy, 1.8 mGy, 3.7 mGy, 5.9 mGy, 1.9 mGy, 2.35 mGy, 1.5 mGy, 0.7 mGy, 0.65 mGy, 2.9 mGy, 2.7 mGy, and 0.25 mGy, respectively. We compared our DRL results with those of other countries. Although the estimated DRLs are encouraging, significant efforts are needed to reduce them, particularly for shoulder, knee, and skull X-rays.

Keywords : Radiography, Entrance Skin Dose (ESD), Dose Area Product (DAP), DRL.

INTRODUCTION

According to research by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000), approximately 4 to 5 billion x-ray examinations are performed worldwide each year. No other imaging technique is used on the same scale.

The patient dose associated with an X-ray examination is a composite function of several factors, including tube current, beam voltage, exposure time, type of X-ray generator, and image receptors. In addition, the patient dose is significantly influenced by technician-specific factors and radiographic procedures. For a given X-ray projection, the results of several national and international surveys have shown that patient dose can vary significantly between patients and X-ray facilities. It is therefore essential to assess patient dose in any diagnostic X-ray facility (Ciraj et al., 2005; Hart et al., 2009; Roch P. et al., 2013).

With the objective of minimizing the risk associated with these exposures, it is necessary to reduce the dose received by the patient through several processes, such as quality control of facilities and radiological procedures and the establishment of Diagnostic Reference Levels (DRLs). This concept was introduced by the International Commission on Radiological Protection (ICRP) and the European Commission (EC) (ICRP, 1996; EC, 1999). The idea of DRLs was created to promote the optimization of radiation exposure to patients. Several organizations (ICRP, 2017; IAEA, 2007; EC, 2014) and countries (Germany 2010; Lithuania, 2010; UK, 2012; Greece; 2019; France, 2020; Iran, 2020; Saudi Arabia, 2022) have been involved in setting DRLs for diagnostic imaging.

In recent years, the concept of DRL has emerged as a topic of current interest and importance in Morocco. Therefore,

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several studies have been carried out to determine the DRL in computed tomography CT and in conventional and interventional radiology (Benmessaoud et al., 2021; El Mansouri et al., 2022; Talbi et al., 2022; Benamar et al., 2023; Khajmi et al., 2023). The aim of this study is to evaluate the entrance skin dose received by adult patients in the conventional radiology room of the Arrazi hospital of the Med VI UHC in Marrakech (Morocco) and to propose our local DRLs for general radiography examinations.

MATERIALS AND METHODS

Patient exams and dosimetric calculations

This investigation was carried out prospectively. Picture archiving and communication system PACS were used to collect data, store and categorized for each examination on a computer using a Microsoft Excel spreadsheet. This study includes 1170 radiography exams of adult patients (over the age of 18 years). Radiographs were sampled between March and July 2022. In this study, patients weighing an average of 70 kg were involved, and the typical dose for an average patient was evaluated. This simple audit of estimated entrance surface dose did not include any patients who weighed more than 80 kg or less than 60 kg. Patients with a weight of >80 kg or <60 kg were excluded from this survey. The number of examinations and exposure factors for conventional radiology exams performed are shown in Table 1. The conventional emergency radiology department of ARH of Med VI UHC is equipped with a Philips digital tube diagnostic model, which has been in service since 2016, with a flat sensor as an X-ray detector. A dose assessment was performed on patients undergoing the eight most common diagnostic radiographs, including twelve individual projections: the cervical spine AP, cervical spine LAT, lumbar spine AP, lumbar spine LAT, abdominal AP, pelvis AP, shoulder AP, knee AP, knee LAT, skull AP, skull LAT, and chest AP. Each radiograph was completed in the same X-ray department.

Dose calculations

As per the projection, patient dosimetry was carried out using the DAP and ESD. The radiation dose in the air multiplied by the area of the X-ray field yields the DAP, which is measured in mGy.cm2. It was computed automatically for every exposure. DAP has been used to determine the doses administered. Every examination routinely shows these measurements on the X-ray console. The following formula was used to estimate the ESD (Leclet H., 2016):

$$ESD = BSF \times (DAP/IF)$$

IF is the irradiation field in cm2, and BSF is the backscattered factor. As per the study of Leclet in 2016 (Leclet H., 2016), BSF is equivalent to 1.35 for voltages ranging from 60 to 80 kV and 1.5 for voltages over 80 kV.

Statistical assessment

In order to prepare the data for analysis, the Microsoft Excel 2007 program was used to rearrange and record the data. For every radiographic examination, the results were computed to determine the 75th percentile. Descriptive statistics and the 50th and 75th percentile values of the dosimetric variable of ESD were used to evaluate the statistics, as well as the minimum, maximum, and average values of voltage (kV) and intensity (mAs) were estimated. These information numbers were obtained to establish DRLs for radiography utilizing X-rays; the values' 75th percentiles were compared to DRLs from published studies conducted in French during 2013 (Roch P. et al., 2013), European Unions in 2014 (EU, 2014), the United Kingdom within 2016 (UK, 2016), Nigeria in 2017 (Joseph Zira et al., 2017), Iran during 2020 (Motlagh Hoseini et al., 2020), and Ghana in 2023 (Gyan et al., 2023).

RESULTS AND DISCUSSIONS

The total number of adult patients included in this investigation is 1170. 62% (n = 756) are man, and 38% (n = 414) are woman. From **Figure 1**, the most frequent radiographs are X-rays of the thorax, knee, and abdomen, successively with a percentage of 30%, 19%, and 10%, respectively. On the other hand, the examinations of the pelvis, lumbar spine, cervical spine, and skull do not exceed 7%. For each of the eight exams, the average tube potential (kV), tube current (mAs), and exposure time (ms) were obtained and reported in **Table 1**. The minimum and maximum age criteria for all exams were 19 and 84 years, respectively. For the kV, the range is 44 kV to 125 kV; for the mAs, the range is 1 mA to 113 mAs; and from 1 ms to 208 ms is the range for exposure time in milliseconds. The vast kV, mAs, and ms ranges were caused by the significant variances in patient size, weight, height, and radiography techniques utilized by radiology professionals.

For every projection and exam under study, **Table 2** displays the calculated mean, 50th and 75th percentiles of the entrance skin dose in mGy. The estimated mean ESD ranged from a minimum of 0.25 mGy to a maximum of 4.59 mGy for all examinations and projections. While the established diagnostic reference levels DRLs for the entrance skin doses ESD of the radiological examinations for AH of Med VI UHC were 2.1 mGy, 1.8 mGy, 3.7 mGy, 5.9 mGy, 1.9 mGy, 2.35 mGy, 1.5 mGy, 0.7 mGy, 0.65 mGy, 2.9 mGy, 2.7 mGy, and 0.25 mGy, cervical spine AP, cervical spine AP, cervical spine LAT, lumbar spine AP, lumbar spine LAT, abdominal x-ray AP, pelvis x-ray AP, Schoulder AP, knee AP, knee LAT, skull AP, skull LAT, and chest PA, respectively.

The DRLs in terms of ESD of 5.9 mGy for lumbar spine LAT radiography are higher than the other protocols. This is due to higher exposure parameters (i.e., kVp and mAs) than the other tests. Field size is another factor influencing the

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diagnostic reference level, which is larger for the abdomen than the other tests.

The chest X-ray AP projection was found to have the lowest DRLs of ESD at 0.25 mGy, indicating lower exposure compared to the other examinations. In this study, the DRL of the cervical spine AP and LAT, the knee AP and LAT, and the skull AP and LAT are approximately identical; the discrepancy does not exceed 14%. However, because the patient width is greater in the LAT position than in the AP position, the DRL of 5.9 mGy of the LAT lumbar spine is 160% higher than the AP lumbar spine of 3.7 mGy. In comparison to the examinations for shoulder X-ray AP projection and abdominal X-ray AP projection, the DRL in the pelvic X-ray AP projection is 36% and 19% higher, respectively.

These quantities depend on a number of factors that influence the patient's exposure. kVp has an effect on both the quantity and quality of the radiation beam. For all radiography devices, the output increased with increasing kVp, resulting in a higher dose to the patients. The exposure is directly proportional to the mAs parameter. The scattered radiation will increase with a larger field and impose more surface doses. The focal spot-to-surface distance (FSD) factor could also affect radiation exposure to patients. These mentioned parameters are selected by the operator. Therefore, the level of knowledge and commitment of the operator in applying the appropriate parameters is effective on the absorbed dose. Through regular training of personnel, it is possible to reduce the dose to the patient without compromising image quality.

Figure 1: Frequency distribution of radiographs examined.

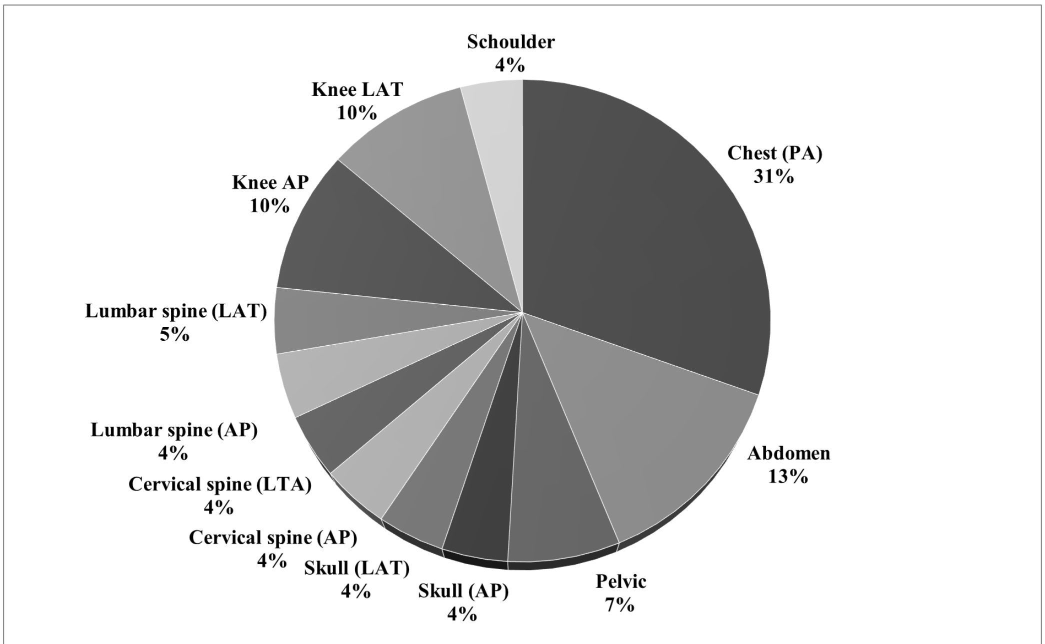

Table 1.

Examinations Projection	Number of radiographies	kV	mAs	Exposure time (ms)
		Min-Max-Mean	Min-Max-Mean	Min-Max-Mean
Cervical spine (AP)	52	55-70-64	3-12-9	7-38-25
Cervical spine (LAT)	51	57-77-68	1-50-13	2-126-31
Lumbar spine (AP)	52	57-77-70	10-33-22	13-39-24
Lumbar spine (LAT)	53	60-90-76	5-80-28	6-208-37
Abdominal (AP)	160	57-85-75	4-113-26	4-116-29
Pelvic (AP)	85	50-85-72	3-40-18	3-43-20
Shoulder (AP)	50	50-77-68	1-85-17	1-70-21
Knee (AP)	115	44-85-61	1-8-5	4-56-30
Knee (LAT)	115	48-85-64	1-6-5	1-10-9
Skull (AP)	50	60-77-73	8-16-15	9-19-16
Skull (LAT)	51	48-80-73	3-22-14	9-27-17
Chest (PA)	336	70-125-94	1-13-3	2-17-7

Table 1: Data obtained for the number of examinations projection, minimum, maximum, mean values of tube potential(kv), tube current (mAs), and exposure time (ms), of technical parameters for radiographic examinations studied.

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Table 2: The calculated entrance skin dose (ESD) for all projections and examinations.

Examinations Projection	ESD (mGy)		
	Mean	50th percentiles	75th percentiles
Cervical spine (AP)	1.35	1.04	2.1
Cervical spine (LAT)	1.69	0.83	1.8
Lumbar spine (AP)	3.09	3.15	3.7
Lumbar spine (LAT)	4.59	3.68	5.9
Abdominal (AP)	1.44	1.25	1.9
Pelvic (AP)	1.68	1.74	2.35
Schoulder (AP)	1.2	1.01	1.5
Knee AP	0.53	0.47	0.7
Knee LAT	0.57	0.5	0.65
Skull (AP)	1.77	1.29	2.9
Skull (LAT)	1.96	1.57	2.7
Chest (PA)	0.24	0.15	0.25

International comparison of DRLs

Table 3 shows the comparison of established diagnostic reference levels for radiographic examination with data of French into 2013 (Roch P. et al., 2013), the European Commission within 2014 (EC, 2014), the United Kingdom during 2016 (UK, 2016), Nigeria in 2017 (Joseph Zira et al., 2017), Iran into 2020 (Motlagh Hoseini et al., 2020), and Ghana within 2023 (Gyan et al., 2023). The DRLs for AP/LAT cervical spine of 2.1 mGy/1.8 mGy were higher when compared with those of Nigeria of 0.62 mGy/0.79 mGy, Iran of 1.6 mGy/1.7 mGy, and Ghana of 0.3 mGy/0.3 mGy but lower than those of the French of 4 mGy/4 mGy, and EC of 4 mGy/7 mGy. The 75th percentiles of ESD for AP/LAT Lumbar spine of 3.7 mGy/5.9 mGy in this analysis were less than those seen in French of 10 mGy/25 mGy, EC of 5 mGy/8 mGy, UK of 5.7 mGy/10 mGy, and Iran of 5.3 mGy/11.8 mGy but above than those registered in Nigeria of 1.22 mGy/1.59 mGy, and Ghana of 1.6 mGy/3.1 mGy. This may typically be related to the radiography procedures employed in these examinations.

Table 3: Comparison of the 75th percentiles results of each examination with the relevant ESD literature.

Examinations Projection	This study	French 2013	EC 2014	UK 2016	Nigeria 2017	Iran 2022	Ghana 2023
Cervical spine (AP)	2.1	4	4	-	0.62	1.6	0.3
Cervical spine (LAT)	1.8	4	7	-	0.79	1.7	0.3
Lumbar spine (AP)	3.7	10	5	5.7	1.22	5.3	1.6
Lumbar spine (LAT)	5.9	25	8	10	1.59	11.8	3.1
Abdomen (AP)	1.9	8	3	4	1.01	4.3	1.3
Pelvic (AP)	2.35	9	4	4	0.82	3.2	0.9
Schoulder (AP)	1.5	-	0.7	0.5	0.71	-	-
Knee (AP)	0.7	-	0.4	0.3	0.5	-	-
Knee (LAT)	0.65	-	0.7	0.3	0.91	-	-
Skull (AP)	2.9	3	0.7	1.8	1.02	2.2	0.7
Skull (LAT)	2.7	5	1	1.1	1.01	2.4	0.6
Chest (PA)	0.25	0.3	0.3	0.15	0.59	1.4	0.3

The established DRLs for abdominal and pelvic X-ray AP projection of 1.9 mGy-2.35 mGy were very lower than observed values in French of 8 mGy-9 mGy, EC of 3 mGy-4 mGy, UK of 4 mGy-4 mGy, and Iran of 4.3 mGy-3.2 mGy, but much higher when compared to Nigeria of 1.01 mGy-0.82 mGy, and Ghana of 1.3 mGy- 0.92 mGy. This could generally be linked to the technology used.

The third quartile dose at the entrance surface presented here for the shoulder AP projection of 1.5 mGy is well above the results of other studies. This demonstrates that higher exposure parameters are used for this radiography because of the more thickness in this part of the body.

The DRLs of this work based on ESD for Knee AP projection of 0.7 mGy are higher than those of the EC of 0.4 mGy, UK of 0.3 mGy, and Nigeria of 0.5 mGy. Whereas, expect DRL in the UK during 2016 for knee LAT projection; the third quartile of ESD is lower.

Regarding skull AP/LAT, the DRLs values of 2.9 mGy/2.7 mGy were greater than those published in the other countries, with the exception of the French's 2013 estimate of 3 mGy/5 mGy. For chest X-ray PA projection, the DRLs in this study were 0.25 mGy higher than that seen in the UK (0.15 mGy), but less than those registered in the French (0.3 mGy), EC (0.3 mGy), Nigeria (0.59 mGy), Iran (1.4 mGy), and Ghana (0.3 mGy).

Table 3 shows that there are differences between our study's DRLs and those of official organizations (EC) and the other reporting nations. The variations in dosage between the research centers are consistent with the results of (Shrimpton PC et al., 1991), who revealed that disparities between the centers might reach up to 10 to 40 in the UK and 8 to 20 in Norway. The radiography technology system may be responsible for these variances. Different dosages in such an intersurvey comparison will result from a range of causes, including statistical variances, measuring techniques, clinical approach, and equipment. For example, in Nigeria (Joseph Zira et al., 2017), the study was conducted in two university teaching hospitals, and 750 patients were considered for the study. While all 1170 examinations in our investigation were conducted in a single digital radiography room with a single X-ray machine, the French (Roch P. et al., 2013) and UK (UK, 2016) surveys during 2013 and 2016 selected patient dosage data from a large number of institutions of different sizes. A very large number of hospital radiological examination doses were also reviewed.

CONCLUSION

This project developed DRLs in terms of ESD for eight radiographic examinations at the Mohammed VI University Hospital Centre at the Arrazi hospital in Marrakech, Morocco. An evaluation of local practices, taking into account operational procedures or equipment performance.

The findings demonstrated that, with the exception of the DRLs of the shoulder, knee, and skull radiographs, which were greater than those published elsewhere, most of the DRLs were lower than the suggested international DRLs.

In order to minimize the risk of stochastic effects associated with radiography, the X-ray department of the Arrazi Hospital requires a process of homogenization of radiation exposure to patients undergoing radiographic examinations, regular quality control of equipment, and a dose optimization strategy.

To establish a baseline, the information gathered in this study could be compared to subsequent dose assessments. Authorities at the national and professional levels might also find this dose survey helpful to develop the national DRLs for conventional radiography in Morocco.

Conflict of interest

There is no conflict of interest for this paper

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