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Getting started with medical physics in Morocco via the introduction of local dose reference levels and international bench marking

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SUMMARY

Introduction and purpose: The present work is part of the 'Radiology As A Steward For Quality In Moroccan Healthcare' (RASQUAM) of the VLIRUOS (Flanders, Belgium). Patient dose measurement campaigns were considered the best first initiative to promote medical physics Quality Assurance activities and to prepare the roll-out of a patient dose management system. The study in 5 Moroccan hospitals focused on common diagnostic radiology examinations. Patient doses were expressed as Entrance Skin Dose (ESD) and the Effective Dose (ED). The aim of the study was to calculate the local Dose Reference Levels (DRL), to compare dose data results with international literature and to plan subsequent actions.

Material and methods: The work was carried out in six conventional radiology rooms of five hospitals, designated by A, B, C, D, E and F. The examinations included Chest, Cervical spine, Skull and Lumbar spine, for lateral and Postero Anterior (PA) or Antero Posterior (AP) projections. Technical parameters (kV, mAs, FFD) and patient data (age, sex, weight) were collected at the time of the examination. Patient dose estimates were obtained with the DoseCal software that provides ESD and E for adults.

Results and discussion: The radiological parameters vary depending on the examination, projection types and rooms. The Local Diagnostic Reference Levels (lDRL) in terms of ESD are 0.35mGy for Chest PA, 0.8 mGy for Chest AP, 2.79mGy for Skull AP, 2.07 mGy for cervical spine AP, 2.36 mGy for cervical spine LAT and 2.72 mGy for lumbar AP spine. The local DRLs comply with international recommendations and their comparison with previous studies was satisfactory.

The average effective doses were: 0,03 mSv for the Chest PA, 0,07 mSv for the cervical spine AP, 0.03 mSv for the cervical spine LAT, 0.45 mSv for Lumbar AP, 0.66 mSv for the lumbar LAT, 0.03 mSv for the Skull AP and 0.01 mSv for the scull LAT.

Conclusion: The local DRLs are promising preliminary results that should be worked out up to the level of national DRLs. Medical physicists can now start with quality optimization strategies.

Key words: dose, radiologic x ray, body organ dose

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INTRODUCTION

Ionizing radiation is widely used in medicine for diagnosis and treatment. The number of people exposed to low doses of radiation used in diagnostic radiology far exceeds the number of patients at higher doses used in radiotherapy [1]. This leads to actions in different contexts to prevent the risks of exposures involving many people. Indeed, low dose ionizing radiation for diagnostic use has great medical benefits; however, its widespread use has also raised concerns about the harmful the inducted effects. The biggest preoccupation with ionizing radiation is the increased risk of cancer, especially after childhood exposures [2].

The general principle of ALARA radiation protection [3] indicates that exposures should be kept as low as reasonably achievable by reducing doses to patients. This means that special attention must be paid to each medical exposure. Every exposure to radiation must be carried out with great vigilance. If the necessary measures are not considered, exposure to X-rays can cause damage to the body, thus inducing certain types of cancers [4]. In addition to the rules established to protect the population against ionizing radiation, the standardization of radiological practices remains a challenge to overcome. This implies that certain measures to optimize radiological parameters and practices are necessary.

The radiographic image quality is the main element to be taken with great regard. To obtain a good image, certain measures concerning the quality of the equipment as well as radiological practices, must be followed. The European guidelines [5] give an example of good radiographic techniques by which diagnostic requirements and dose criteria can be achieved. This is in line with the optimization of medical exposure, where quality criteria must go hand in hand with a low dose of radiation. These provisions will protect the patient and staff from unnecessary exposure to radiation. The establishment of Diagnostic Reference Levels (DRLs) can help to intervene if certain aberrations are noted. They are defined for typical examinations for standard size patient groups or standard phantoms for defined types of equipment. These levels should not be exceeded for standard procedures when good normal practice in diagnostic and technical performance is applied. This was adopted by The

Council of the European Union adopted the concept of DRL in the Medical Exposure Directive (MED) 97/43/EURATOM [6]. The International Atomic Energy Agency (IAEA) advice on the use of DRLs in radiology, in the International Basic Safety Standards [7]. This concept was introduced by ICRP publication 73 ICRP, which introduced the term "Diagnostic Reference Level", developed the recommendation from ICRP publication 60. The main objective is advisory to identify the examinations delivering doses systematically exceeded or below a dose of radiation insufficient to obtain an appropriate medical image. The diagnostic reference levels do not represent a dose constraint, and not linked to limits. The main goal is ensuring the adoption of the DRLs into national legislation and regulations concerning radiation protection [8]. The countries where DRLs are well established for radio diagnostic examinations and interventional radiology procedures require that these should be reviewed regularly and used for optimization purposes [5].

In our case, the national diagnostic reference levels are not yet adopted and even less used as a reference, to review radiological procedures and equipment when large dose differences are mentioned. The present work is part of the 'Radiology as a Steward for Quality in Moroccan HealthCare' (RASQUAM) of the VLIRUOS (Flanders, Belgium) to contribute to the establishment of national diagnostic reference levels. The study was performed in Moroccan hospitals and focused on some common diagnostic radiology examinations such as (Chest, Skull, cervical, Lumbar).

The aim of this work is to estimate the Skin Entrance Dose (ESD) and the Effective Dose (ED) for patient exposure to x-rays and to compare these results with other data published in previous studies.

MATERIALS AND METHODS

The data were collected in six conventional radiology rooms of five hospitals, in the cities of Rabat, Ouezzane and Tantan. For the sake of confidentiality, the rooms are randomly identified as A, B, C, D, E and F. The examinations included Chest, Cervical spine, Skull and Lumbar spine (Table 1).

The technical parameters used (x-ray tube voltage kV, milliamperage mAs and the focus Skin distance FSD) and patient data (age, sex, weight), were collected at the time of the examination. These values are used to calculate the dose using the DoseCal software that provides the Entrance Skin Dose (ESD) and the Effective Dose (ED) for adults.

Once the potential of the tube, the tube current, the exposure time and the focus-skin distance are known, the ESD value is given by the following expression used by Ofori, et al. [9].

$$ESD = BSF \times Output \times mAs \times \left(\frac{100}{FSD}\right)^2 \times \left(\frac{KV}{KV(Output)}\right)^2 \times 0.001$$

Tab. 1. X-ray machine characteristics

Hospital	A	B	C	D	E	F
Tube	Stefanix Evidence	SIEMENS LUMINOS RF CLASSIC 150/40/80HC	SIEMENS	-------	Comet DX81HS-28/70-150	SIEMENS R202 MLP/B
Manufacture date	-------	2012	2004	-------	Sep-01	2001-05
Inherente filtration (mmAl/ kV)	-------	1.5 /80	1.5/80	-------	0.9/70	Jan-75
Add. filtration (mmAl)	-------	1	1	-------	2	2.5

Tab. 2. Number of patients for all the hospitals

Exam	Projection	Hospital	Number of patients	Age (mean)
CHEST	PA	Room 1	10	36
		Room 2	16	63
		Room 3	42	52
		Room 4	19	51
		Room 5	32	48
		Room 6	20	47
	AP	Room 1	10	59
		Room 2	14	67
Skull	Face	Room 1	19	35
	LAT	Room 1	21	35
cervical	Face	Room 1	10	50
		Room 2	6	49
	LAT	Room 1	18	41
		Room 2	6	49
lumbar	Face	Room 1	7	37
		Room 2	12	50
	LAT	Room 1	7	37

Where

- BSF is backscattering factor
- Output (in mGy / mAs) is the output of the x-ray tube at 1 m normalized to 32 mAs; determined using PTW ion chamber
- mAs is the product of the tube current (in mA) and the exposure time (in seconds)
- FSD is the distance between the x-ray source and the skin (in cm)

The tube output (in mGy/mAs) of all x-ray machines was measured using a PTW ionization chamber. The doses were calculated first by the last relation considering the output of each X-ray tube, then by the software. The results were comparable with an average accuracy of 5%.

RESULTS AND DISCUSSION

Tables 2-4 summarize the number of patients by examination and the radiological parameters kv, mAs and FSD for the examinations carried out, for the 6 rooms of the 5 hospitals.

The kV varies, depending on the type of examination, from 100 to 110 kV for PA projection of Chest examination in hospital A and from 102 to 125 in hospital B and from 53 to 100 kV and 96 to 125 kV for the projection of AP, respectively in hospitals A and B. In Table 5 are presented skin entrance doses and the effective doses.

The skin entrance doses and the effective doses calculation (Tables 5 and 6) show that the values vary according to the examinations as well as the hospitals where the data were collected.

In hospital E, where examinations are carried out by analog (silver) radiology, a reduction in PA chest examination dose (Table 5) is observed. This is linked to good radiological practice due to the experience of the radiology technician of this department. In fact, the average value of mAs is significantly lower than that of hospitals A, B, C and D (Table 3).

For the PA chest examination, Table 5 shows that, A and B rooms presents higher ESD values than the recommended ones (300 μSv) [8].For the skull face examination, the mean values of the ESD (Table 6) correspond to the recommended one (5000 μSv) [8]. Some differences in radiological practices were noted across the rooms where the data were taken. For the chest examination projection PA; the lowest ESD median values (Table 5) were observed; except in rooms A and B; mainly due to the adequate radiological used. Indeed; the median charge were less than 3 mAs (equal to 2 mAs in room E) and the FSD is greater than 120 cm: The voltage varying between 100 and 120 kV (Table 3). In room A; a large fluctuation for the mAs values was noted with a maximum of 10 mAs and a median of 5 mAs. This remark is also valid for the AP projection (Table 4).

Tab. 3. Technical radiological parameters for chest PA for all the rooms

Exam	Chest PA																	
Rooms	A			B			C			D			E			F		
	kV	mAs	FSD	kV	mAs	FSD	kV	mAs	FSD	kV	mAs	FSD	kV	mAs	FSD	kV	mAs	FSD
mean	104	4,98	123,98	113,06	4,03	123,38	119,93	2,89	126,7	119,21	2,86	129,31	110,31	2,06	1320,3	99,05	4,55	123,77
max	110	10	127	125	5,06	127	120	4,01	143	120	3,2	137	117	3,2	147	111	2.5	127
min	100	2,5	122	102	3,24	120	117	2,2	111	114	2,42	113	104	1,6	109	78	3	122,99
median	103,5	5	122,1	113	3,63	123	120	3,2	127	120	3,1	132	110	2	132,5	101	3	123

Tab. 4. Technical parameters for chest, scull, cervical and lumbar examinations for rooms A and B

Rooms		A						B					
Position		AP			LAT			AP			LAT		
Exam		kV	mAs	FSD	kV	mAs	FSD	kV	mAs	FSD	kV	mAs	FSD
Chest	Mean	92,1	5,11	85,14	-------	-------	-------	112,43	4,19	92,66	-------	-------	-------
	Max	109	8	97	-------	-------	-------	125	8,07	97	-------	-------	-------
	Min	60	2,5	73	-------	-------	-------	96	3,23	88	-------	-------	-------
	Median	100	5	85,85	-------	-------	-------	113	3,82	93	-------	-------	-------
Skull	Mean	60,7	46,42	76	60,81	45,81	80,27	65	32,32	90,9	-------	-------	-------
	Max	65	63	78	65	63	80,6	70	75,08	91,6	-------	-------	-------
	Min	60	32	76	60	32	80	60	14,06	90,9	-------	-------	-------
	Median	60	50	77	60	50	80,5	65	20,06	91,6	-------	-------	-------
Cervical	Mean	60,15	30,3	78,83	58,92	35,67	83,25	66,83	29,36	93,67	66,83	29,36	99,2
	Max	61,5	50	91,9	70	56	84,4	75	36,05	94	75	36,04	99,4
	Min	60	16	76,9	50	16	81,3	60	22,05	92	60	22,05	99
	Median	60	30	76,9	59,5	36	83,1	66,5	28,53	94	66,5	28,52	99,2
Lumbair	Mean	80,64	64,14	74,91	80,64	70,57	69,31	79,21	51,25	116,05	-------	-------	-------
	Max	99	90	77	99	125	72,4	87,5	71	125	-------	-------	-------
	Min	52	36	74	52	36	68,7	70	22	89,6	-------	-------	-------
	Median	86	63	74,2	86	63	68,7	81	50	125	-------	-------	-------

Table 7 representing a comparison of the ESD values relatively to previous studies, reveals that the results comply with the international recommendation. The values are in accordance with those of international recommendations and, with the exception of those of UK and Canada, are in the range found by most previous studies and sometimes lower. This conclusion is also deducted from table 8 regarding the effective dose results. The dose to the organ has been detailed in Table 9. It is noted that rooms E and D have the lowest values, due to the appropriate choice of radiological parameters.

The values are in accordance with international standards

Tab. 5. ESD and ED for CHEST PA projection for all rooms

	ESD					ED				
Rooms	Min	Median	Mean	Max	75th Percentile	Min	Median	Mean	Max	75th Percentile
A	0,18	0,46	0,43	0,88	0,50	0,02	0,03	0,04	0,07	0,06
B	0,36	0,38	0,43	0,66	0,46	0,03	0,04	0,04	0,06	0,05
C	0,19	0,29	0,3	0,48	0,35	0,02	0,03	0,04	0,07	0,04
D	0,19	0,24	0,25	0,36	0,28	0,02	0,02	0,03	0,05	0,03
E	0,11	0,15	0,16	0,22	0,18	0.01	0,02	0.02	0,03	0,02
F	0,14	0,28	0,29	0,42	0,35	0,01	0,03	0,03	0,04	0,04

Tab. 6. ESD for the other examinations for rooms A and B

Examine		Room	ESD Min	Median	Mean	Max	75th Percentile
Chest	AP	A	0,35	0,55	0,67	1,11	0,83
		B	0,55	0,75	0,75	1,16	0,77
Skull	AP	A	1,96	3,06	2,95	3,92	3,23
		B	0,61	1,15	1,98	5,01	2,35
	LAT	A	4,65	7,28	6,91	9,28	7,37
Cervical	AP	A	1,00	1,75	1,71	2,38	2,07
		B	1,10	1,45	1,66	2,51	2,07
	LAT	A	0,99	1,77	2,07	4,03	2,75
		B	1,11	1,50	1,67	2,62	1,96
lumbar	AP	A	4,60	8,08	8,91	14,13	11,47
		B	1,30	3,45	3,33	5,61	3,96
	LAT	A	2,70	5,01	4,92	8,95	5,83

Tab. 7. Mean and DRL ESD (mGy)

Examine		ESD (mGy) Chest		Skull		Cervical		Lumbar	
Projection		PA	AP	FACE	LAT	FACE	LAT	FACE	LAT
Our Study	Mean	**0,31**	**0,68**	**2,47**	**6,91**	**1,69**	**1,87**	**6,12**	**4,92**
	DRL	**0,35**	**0,81**	**2,79**	**7,37**	**2,07**	**2,36**	**7,72**	**5,83**
EU RP 109 [9]	Mean	-------	-------	-------	-------	-------	-------	-------	-------
	DRL	0,3	-------	5	3	-------	-------	10	30
Canada 2013 [10]	Mean	0,14	------	1,67	0,76	0,62	0,44	3,72	6,28
	DRL	-------	------	-------	-------	-------	-------	-------	-------
Slovenia 2006 [11]	Mean	0,29	0,32	2,2	1,73	1,4	1,4	-------	-------
	DRL	0,35	0,35	2,54	2,02	1,73	1,83	-------	-------
India 2009 [12]	Mean	0,53	0,38	-------	4,11	-------	-------	7,3	14,19
	DRL	0,68	0,47	-------	5,16	-------	-------	8,39	15,66
UK 2005 [13]	Mean	0,1	0,13	1,54	1,07	-------	-------	3,86	8,03
	DRL	0,14	0,15	2,04	1,34	-------	-------	5,06	11,2
UK 2019 [13]	Mean	-------	-------	-------	-------	-------	-------	-------	-------
	DRL	0,15	0,2	1,8	1,1	-------	-------	5,7	10
France 2012 [14]	Mean	-------	-------	-------	-------	-------	-------	-------	-------
	DRL	0,4	-------	4,8	2,6	-------	-------	10	26
Iran 2016 [15]	Mean	0,49	-------	1,47	1,01	0,67	0,79	2,81	4,28
	DRL	0,7	-------	2,55	1,42	1,07	1,17	3,55	4,69
Brazil 2009 [16]	Mean	0,3	0,4	2,8	2,04	0,52	0,77	5,4	11,2
	DRL	0,35	0,5	3,28	2,14	0,72	1,2	6,6	16,2
Ghana 2014	Mean	0,27	-------	-------	-------	1,05	0,45	3,25	------
[17]	DRL	-------	-------	-------	------	-------	-------	-------	-------
JAPAN 2019 [18]	Mean	0,17	0,17	1,3	1	0,45		2,3	6,5
	DRL	0,2	0,2	1,6	1,4	0,6		2,9	8,9

Tab. 8. Mean effective dose ED

Studies	Chest PA	Chest AP	Skull AP	Cervical AP	Cervical LAT	Lumb AP
Our study	0,03	0,19	0,03	0,08	0,03	0,45
CANADA 2013 [10]	0,0204	-----	0,0202	0,023	0,0025	0,38
BANGLDESH 2018 [19]	0,011	0,022	-----	-----	-----	0,133
Serbia Montenego 2005 [20]	0,05	-----	0,03	0,09	0,02	0,8
GHANA 2014 [17]	0,02	-----	-----	0,05	0,03	0,41
Metaxas2018 Greece [21]	0,01	-----	0,02	0,03	0,03	0,26
UK2008 ICRP 60 [22]	0,014	-----	0,022	0,018	0,012	0,409
UK2008 ICRP 103 [23]	0,014	-----	0,033	0,018	0,012	0,389

Tab. 9. Body mean dose organ (mGy) for Exam Chest PA

Organs	Room A	Room B	Room C	Room D	Room E	Room F	Values reported in literatures (mGy)
							UK [24]
Adrenal Glands	0,12	0,13	0,10	0,13	0,05	0,06	0.052
Breast Glands	0,03	0,03	0,03	0,02	0,01	0,01	------
Lungs	0,12	0,13	0,11	0,14	0,05	0,08	0.046
Spleen	0,08	0,09	0,07	0,05	0,03	0,04	0,043
Thyroid	0,07	0,07	0,06	0,05	0,03	0,05	------

and comparable to those of most of the studies considered for examinations and projections used; except for skull LAT. The chest PA DRLs of the present study are of the same order as those of Slovenia and Brazil, whereas they are lower than those of India and Iran and that they are obviously higher than those the UK and Canada and Japan; while being within the range of values proposed by the European community. The DRLs of the other examinations are on the whole comparable to most of the previous studies (Table 7).

CONCLUSION

This preliminary study was carried out in five radiology departments to estimate the local diagnostic reference levels, considering the most used examinations. The overall DRLs values were in accordance with international recommendations, although some rooms had higher values mainly due to an increase in the X-ray tube load because of to the variability of radiological practices. These results may lead to awareness raising relating to the optimization of radiological practices and consequently of the doses received by patients. A broader investigation targeting more radiology departments across the country should be undertaken to determine the national DRLs.

In addition, training of radiology technicians is necessary and imminent for the following investigation to be beneficial and fruitful.

COMPLIANCE WITH ETHICAL STANDARDS

Conflicts of interest

Sanae Douama, Youssef Bouzekraoui, Imane Ou-Saada, Hilde Bosmans, Lesley Cockmartin, Rachid Errifai, Zaama Lahoucine, M Ouahman, and Farida Bentayeb declare that they have no conflict of interest. There is no source of funding.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent

The institutional review board of our institute approved this retrospective study, and the requirement to obtain informed consent was waived.

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