

ARTICLE

Evaluation of radiation dose and establishment of local DRLs for adult during abdominopelvic CT scan imaging for university hospital centers, Morocco

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Abstract – Objective: In this study, we have planned to establish the local Diagnostic Reference Levels (DRLs) for the five University Hospital Centers in Morocco and to propose a national DRL for abdominopelvic CT examinations for adult patients.

Materials and methods: Data were collected using a specially designed form, which included patient demographics, exposure parameters and dosimetric indicators such as dose-length product (DLP) and CT volume dose index (CTDI_{vol}). The establishment of local and national DRL in terms of CTDI_{vol} and DLP was carried out in accordance with the methodology described in Report 135 of the International Commission on Radiological Protection (ICRP). The effective dose was assessed using the DLP and the dose conversion factor appropriate for this location.

Results: A total of 300 patients undergoing abdominopelvic examinations at the five Moroccan university hospitals were collected for this study. Patients' mean age, weight and BMI were (50.97 ± 15.05) years (67.94 ± 11.41) Kg and (25.71 ± 3.03) Kg/m² respectively. The local DRL, in terms of DLP were 551.56, 2293.33, 709.02, 843.52 and 1059.62 mGy·cm and in terms of CTDI_{vol} were 11,05, 46,40, 13,14, 12,01, 9,88 mGy respectively for UHC-1, UHC-2, UHC-3, UHC-4 and UHC-5 hospitals. The proposed National DRL, defined as a single value for the 75th percentile on the aggregation of data from the five centers, for abdominopelvic scan CT was 773.20 mGy·cm and 12.05 mGy for DLP and CTDI_{vol}, respectively.

Conclusion: The Moroccan DRL was comparable to those of other countries, ranking 10th among 21 countries. However, we are still seeking to reduce and optimize radiation dose while maintaining good image quality for reliable diagnosis, and this can be achieved by enhancing radiographers' and radiologists' knowledge of radiation protection, protocol justification, and optimization through rigorous hospital radiation audits at national level.

Keywords: Abdominopelvic CT scan / DLP / CTDI_{vol} / NDRL / Moroccan university hospital centers

1 Introduction

Since the discovery of X-rays, medical imaging has continued to evolve and improve, offering increasingly precise, efficient and innovative technologies (McCullough and Leng, 2020). The process involves visualizing the various tissues and organs of the human body to monitor normal and abnormal anatomy and physiology (Eberhard and Alkadhi, 2020). Today, medical imaging techniques have become an

important tool for the therapy and diagnosis of almost all major types of disease and abnormality. Computed tomography (CT) is one of the imaging techniques used for this purpose. It remains on the rise, given its key role in the assessment, diagnosis, screening and management of a wide range of medical conditions. This rise may have contributed to an increase in patients' exposure to radiation, with a potential increased lifetime risk of cancer. To reduce the radiation dose, radiologists, medical physicists, manufacturers and researchers have implemented a series of improvements in the development of examination protocols, software and hardware, as well as artificial intelligence (Eberhard and Alkadhi, 2020; McCullough

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Table 1. Specifications of the machines used for data collection.

Hospital	Manufacturer	Type	Installation
UHC-1	Siemens Somatom	Spiral/ 16	2008
UHC-2	General Electric	Spiral/ 16	2007
UHC-3	Optima	Spiral/ 64	2011
UHC-4	Siemens Somatom	Spiral/ 64	2009
UHC-5	General Electric	Spiral/ 16	2014

and Leng, 2020; Wang *et al.*, 2020). However, the concept of Diagnostic Reference Level (DRL) was introduced in the early 1990s in Publication 60 (ICRP, 1991) of the International Commission on Radiological Protection (ICRP) to apply the principle of optimization to patient exposure in the field of medical imaging. The implementation of DRLs was recommended in Publication 73 "Radiological Protection and Safety in Medicine" (ICRP, 1977), and then made mandatory in 1997 in European Union member states by Directive 97/43/Euratom. This led some countries to publish its first decree on diagnostic reference levels in radiology and nuclear medicine. Diagnostic reference levels, which are a tool for optimization, should not be regarded as "dose limits" or "optimal doses". In practice, these levels are established for standardized examinations and typical patients. They should not be exceeded, on average for a given facility and examination, without justification during routine practical procedures. DRLs are dosimetric indicators of the quality of practice, designed to identify and monitor situations requiring corrective action, and to quantify the effectiveness of an optimization approach. In principle, managers of conventional radiology, CT and nuclear medicine facilities are required to carry out an annual assessment of the doses delivered to their patients during diagnostic procedures. Analysis of the data, by comparing their average value with the DRL, should enable professionals to situate their practices in relation to a national benchmark, and to take corrective action in the event of unjustified excesses. Indeed, exceeding the national benchmark could be considered as a potential sign of malfunction during one of the stages of the process of carrying out the imaging scan. The DRL is a warning indicator provides guidance for dose optimization, and ensures justification of appropriate doses for a given clinical indication. In this way, a facility with recent equipment offering considerable latitude in terms of optimization will be able to apply the principle of dose optimization as effectively as possible, by setting itself a more ambitious objective than the current DRL.

Many initiatives have been undertaken in Morocco focusing on radiation exposure during CT procedures. Monte Carlo methods were used to estimate patient radiation exposure and foetal dose during CT pelvimetry (Aabid *et al.*, 2023a, 2023b). Assessment of physicians' knowledge of patient radiation protection when prescribing CT scans (Amaoui *et al.*, 2023), and establishment of local diagnostic reference levels for several CT procedures, such as cerebral (Semghouli *et al.*, 2022a), pelvimetry (Semghouli *et al.*, 2020), chest and abdomen (Mansouri *et al.*, 2022), thoraco-abdominal and lumbar (Amaoui *et al.*, 2019; Semghouli *et al.*, 2022c). Other research has been conducted to assess the risks of

radiation exposure to patients following brain (Abid *et al.*, 2019a; Semghouli *et al.*, 2022b) CT scan examinations. The absence of a prior study on national practices for optimizing abdominopelvic tomography prompted us to undertake this study. This investigation aimed to evaluate radiation exposure doses for adult patients, then to establish the local diagnostic reference level (DRL) for the five university hospitals in Morocco as well as to propose a national DRL.

2 Materials and methods

2.1 Data collection

This study was based on data collected during abdominopelvic CT procedures in five Moroccan university health centers, namely UHC-1, UHC-2, UHC-3, UHC-4 and UHC-5. All are public hospitals serving and providing diagnostic services to a large population in and around the above-mentioned cities. Table 1 summarizes the data for the health centers included in this study, along with specifications relating to the CT scanners installed in these centers, such as manufacturer, type and date of installation.

Data were collected for 300 adult patients at a rate of 60 CT examinations per hospital between February 2023 until June 2023. For patients undergoing abdominopelvic CT examinations, patient data (age, sex and weight), exposure parameters (tube voltage (kV), tube current (mAs), rotation time (s), pitch value) and dosimetric parameters (dose-length product (DLP) and CT dose index volume (CTDI_{vol})) were collected.

2.2 Dose calculation

The methodology described in Report 135 (Vañó *et al.*, 2017) of the International Commission on Radiological Protection (ICRP) was followed to calculate the dosimetric parameters. The Computed Tomography Dose Index (CTDI (mGy)) is a standardized measure of the radiation dose resulting from a CT scanner and is essential for comparing the radiation power of different CT scanners. CTDI₁₀₀(mGy) (represents the linear dose distribution measured on a 100 mm long by a pencil-shaped ionization chamber) and CTDI_w (single slice dose weighted average) were used in the past. While for currently used helical scanners, the CTDI_{vol} parameter is the most commonly used index.

The dosimetry parameters' CTDI_w, CTDI_{vol}, DLP (mGy.cm) and effective dose ED(mSv) can be calculated using the following equations (ICRP, 2001, McNitt-Gray, 2002):

Table 2. Statistical variation within the sample.

Parameter	Mean	Max	Min	±SD
Age (year)	50.96	92.00	19.00	15.05
Weight (kg)	67.94	100.00	50.00	11.41
BMI (kg/m ²)	25.71	32.36	20.10	3.03

$$CTDI_w(\text{mGy}) = \frac{1}{3}CTDI_{100,c} + \frac{2}{3}CTDI_{100,p}, \quad (1)$$

where C is the average dose at the centre and p the average dose at the periphery.

$$CTDI_{vol}(\text{mGy}) = \frac{CTDI_w(\text{mGy})}{\text{Pitch}}, \quad (2)$$

$$DLP(\text{mGy.cm}) = CTDI_{vol}(\text{mGy}) * \text{Scanlength}, \quad (3)$$

$$ED = DLP \times k, \quad (4)$$

where k is the dose conversion coefficient of the abdominopelvic organ.

The national third quartile DLP for CT examinations of the abdomen-pelvis was calculated as the aggregation of data coming from the five university hospital centers then compared with international levels in 21 different countries.

2.3 Statistical analysis

All data were analyzed using Microsoft Excel (MS 2010). CT scan data were analyzed using descriptive statistics. The mean DLP for CT scans of the abdomen and pelvis was calculated, and quantitative variables were expressed as mean and standard deviation.

3 Results

This study focused on the five university hospital centers (UHCs) in Morocco. The mission of UHC is to provide tertiary-level care, clinical teaching at university and post-graduate level in medicine and pharmacy, practical training of nursing staff and medical research and nursing care. Three different brands of CT were used in these hospitals (Siemens Somatom, General Electric and Optima), and all were multi-slices (16-64) (Tab. 1).

3.1 Patients data

The study included 300 adult patients aged 19 to 92, with weights ranging from 67.94 to 100 kg and a mean BMI of 25.71 kg/m². Table 2 provides a statistical presentation of patient data on age, weight and body mass index (BMI).

3.2 Exposure and imaging parameters

Table 3 summarizes the descriptive statistics for exposure and imaging parameters. Exposure parameters for all abdominopelvic CT examinations in the five UHCs were set at an average of 120 kV for voltage (with the exception of UHC-1, where voltage ranged from 120 kV to 130 kV). For the tube current, the highest was used at CHU-2 (218 mAs), while the lowest was used at UHC-1 (127 mAs). In terms of pitch, the lowest average was recorded at UHC-3 (0.64) and the highest at UHC-2 (1.5). In addition, the highest average slice thickness was recorded at UHC-1 (13.84) and the lowest at UHC-3 (6.59).

3.3 Dose assessment

Table 4 shows the descriptive statistics for DLP, CTDI_{vol}, and effective dose of abdominopelvic examination per university hospital center in Morocco. The average value of DLP (1443.04 mGy.cm) in UHC-2 hospital was larger than those of the other four hospitals, which could be due to the higher average pitch used as well as the mAs encountered in this hospital. Furthermore, a significant difference was demonstrated by comparing the mean DLP of abdominopelvic CT between different Moroccan UHC ($p < 0.05$). The effective doses (ED), for UHC-1, UHC-2, UHC-3, UHC-4 and UHC-5 hospitals were estimated to be 8.27, 34.40, 10.64, 12.65 and 15.89 mSv respectively. The estimated value for ED for UHC-2 hospital is two times higher than those of UHC-4, UHC-5, and three times higher than that of UHC-3 and four times higher than that of UHC-1 hospital.

A UHC in Morocco is the main health structure in the region. It serves patients from the region where it is located or from others in terms of diagnostic and therapeutic care. It is essential to keep in mind that in the total optimization procedure DRLs represent only a small part. For appropriate diagnostic or therapeutic radiological procedures performed in the local area, region or country where they are used, DRLs should be developed. The distributions' third quartile value defined on the aggregation of data coming from all regions is commonly utilized as National Diagnostic Reference Level (NDRL). Consequently, potentially unusual practices can be identified using NDRL while they aren't ideal doses. DRLs can as well be set for a particular locality or region within a country or, in special circumstances, for multiple countries. For this study, the proposed national DRL for the abdominopelvic was defined as a single value for the 75th percentile on the aggregation of DLP and CTDI_{vol} data from the five University hospital centers studied. The proposed National DRL for

Table 3. Summary of descriptive statistics for exposure and imaging parameters per Hospital.

Hospital	Exposure and imaging parameters				
	Exam Parameter	kV	mAs	ST*(mm)	Pitch
UHC-1	Mean	120.33	127.07	13.84	1.26
	Median	120.00	110.00	15.00	1.20
	Range	120–130	35–341	5.00–15.00	0.5–1.75
UHC-2	Exam Parameter	kV	mAs	ST*(mm)	Pitch
	Mean	120	218.58	10.25	1.5
	Median	120	239.6	12.5	1.6
UHC-3	Exam Parameter	kV	mAs	ST*(mm)	Pitch
	Mean	120.00	210.68	6.59	0.64
	Median	120.00	220.00	5.00	0.75
UHC-4	Exam Parameter	kV	mAs	ST*(mm)	Pitch
	Mean	120.00	157.53	9.54	0.82
	Median	120.00	155.00	10.00	0.60
UHC-5	Exam Parameter	kV	mAs	ST*(mm)	Pitch
	Mean	120.00	167.86	11.31	1.20
	Median	120.00	225.00	12.50	1.75
	Range	120–120	105–225	10.00–12.5	0.60–1.75

Table 4. National and local dosimetric parameters in terms of DLP, CTDI_{vol} and ED.

	DLP (mGy.cm)		CTDI _{vol} (mGy)		ED (mSv)
	Mean	75°	Mean	75°	Mean
UHC-1	568.60	551.56	10.55	11.05	8.27
UHC-2	1443.04	2293.33	28.99	46.40	34.40
UHC-3	622.06	709.02	11.69	13.14	10.64
UHC-4	677.40	843.52	9.87	12.01	12.65
UHC-5	710.63	1059.62	8.14	9.88	15.89
Moroccan DRLs	658.86	773.20	11.40	12.05	9.88

abdominopelvic scan CT was 773.20 mGy-cm and 12.05 mGy for DLP and CTDI_{vol}, respectively.

4 Discussion

In the present study, a survey was carried out on radiation exposure during adult abdominopelvic CT examination in the five main university hospitals in Morocco, with the aim of establishing NDRL of this procedure. The survey allowed characterizing the radiation exposure of adult patients after abdominopelvic CT procedures, such as the mean and 75th percentile for DLP and effective dose. This information is an accurate representation of the state of abdominopelvic CT practices in Morocco. Dosimetric parameters were analyzed. Then benchmarked against the norm for 21 countries, the values established in this study ranked Morocco 10th among countries with the highest 75th percentile DLP value. These slightly high doses should draw the attention of CT

practitioners and organizations such as the Moroccan Nuclear and Radiological Safety and Security Agency to investigate the causes and establish methods for optimizing protection to reduce unnecessary exposure.

This dose variability could be explained by differences in CT machine technology in terms of beam collimation and detector arrays. Another reason for this variability could be the use of different protocols by clinicians, and radiographers' adherence to CT parameters (Potential Tube Current and Scan Time) set by manufacturers for abdominopelvic CT scans without optimization according to clinical indications. In addition, some radiographers are unfamiliar with AC modulation functions, while others have not used them during scanning. Dose optimization, *i.e.* reducing the delivered dose while maintaining adequate image quality, can be achieved with AC modulation (Livingstone *et al.*, 2010). Dose optimization is therefore always essential. Significant variability was observed in the DRL of abdomino-pelvic CT scans

Table 5. Benchmarking of the established Moroccan DRL in terms of DLP(mGy.cm) with international values.

Study	Year	DRL	Δ Morocco-Country
Saudi Arabia(Al-Othman <i>et al.</i> , 2022)	2022	886	−112.8
Lebanon Switzerland (Karout <i>et al.</i> , 2022)	2022	967	−193.8
Australia (Lee <i>et al.</i> , 2020)	2020	600	173.2
UK (Shrimpton <i>et al.</i> , 2003.)	2003	745	28.2
Greece (Simantirakis <i>et al.</i> , 2015)	2015	758	15.2
Japan (Kanda <i>et al.</i> , 2021)	2020	1000	−226.8
Germany (Appel <i>et al.</i> , 2018)	2018	700	73.2
USA (Kanal <i>et al.</i> , 2017)	2017	775	−1.8
France (Roch <i>et al.</i> , 2018)	2018	650	123.2
Syria (Kharita and Khazzam, 2010)	2009	721	52.2
Turkey (Atac <i>et al.</i> , 2015)	2015	204	569.2
Italy(Compagnone <i>et al.</i> , 2021)	2021	555	218.2
Ireland (Foley <i>et al.</i> , 2012)	2012	600	173.2
Canada (Wardlaw, 2018)	2017	806	−32.8
Nigeria (Ekpo <i>et al.</i> , 2018)	2017	1486	−712.8
Kenya (Korir <i>et al.</i> , 2016)	2016	1842	−1068.8
India (Saravanakumar <i>et al.</i> , 2014)	2014	482	291.2
Portugal (Santos <i>et al.</i> , 2014)	2014	800	−26.8
Egypt (Salama <i>et al.</i> , 2017)	2016	1325	−551.8

in the five Moroccan university hospitals. The 75th percentile for abdomino-pelvic CT was lowest at UHC-1 and highest at UHC-2. Interestingly, the university hospital had a significant impact on the 75th percentile of DLP. Differences in CT technology, scanning protocols and professionals' knowledge and practice of patient radiation protection contribute greatly to these variations (Amaoui *et al.*, 2023; Ekpo *et al.*, 2018). On the other hand, tube current has a direct linear effect on radiation dose (*i.e.* 50% reduction in tube current results in 50% reduction in associated dose) and this may be the reason for the highest dose noted at UHC-2 among the five centers mentioned in this study (Lira *et al.*, 2015). In addition, exposure parameters in terms of slice thickness and pitch differ considerably from one hospital to another, which may also explain the different results of CTDI, DLP and ED.

This study provides these DRLs are proposed as NDRLs for abdominopelvic CT examination in Morocco. All data included in this analysis were obtained using a multi-slice spiral CT scanner with an average tube potential of 120 kVp. The CT systems included in the current study differ in terms of technology and model, with the number of slices per rotation ranging from 16 to 64. The DRL results for the centers studied were comparable, with the exception of the DRL noted at UHC-2, which was very high. The results show large dose variations between UHC-2 and the other centers (Tab. 4). Variations in CTDI_{vol} and DLP for CT examinations between centers may be influenced by population characteristics, practice, technology, as well as examination protocol.

The proposed local DRLs for the five university hospitals in terms of DLP were between 551.56 mGy-cm (UHC-1) and 2293.33 mGy-cm (UHC-2) and 9.88 mGy (UHC-5) and 46.40 mGy (UHC-2) for CTDI_{vol} (Tab. 4). By comparing these results with those obtained in similar studies by El Fahssi *et al.*,

(in press) who reported 444.51 mGy for DLP and 8.14 mGy for CTDI_{vol} and by Benamar *et al.*, (2023) who found 517.1 mGy.cm for DLP and 11.3 mGy for CTDI_{vol}, our findings showed a higher value for DLP and CTDI_{vol}.

Table 5 summarizes a benchmarking between the DRL results obtained by this study and other DRLs established by various studies around the world. Comparing the NDRL≈773mGy established for the abdomino-pelvic procedure with that of other countries, Morocco demonstrated a dose significantly almost four times higher than that of Turkey (204 mGy) and almost two and a half times smaller than that of Kenya (1842 mGy). Lebanon, Japan, Kenya, Nigeria and Egypt showed an abdomen-pelvis CT dose 25%, 29%, 138%, 92% and 71% higher than Morocco respectively (Ekpo *et al.*, 2018). Whereas Italy, India and Turkey recorded an abdomen-pelvis CT dose 55%, 61% and 279% lower respectively than Morocco. However, this value remains comparable to those reported by the rest of the countries. A graphic illustration in Figure 1 clearly highlights this comparative approach. This further confirms the need to develop protocols and procedures as well as optimize CT examination practices in Morocco. The significant variations in dose within the same university hospital and between university hospitals in Morocco could be due to differences in CT machines technical platforms, the protocols and procedures used, the training levels of radiology technicians in terms of optimizing procedures and, above all, the non-assignment of medical physicists in radiology departments to date in Morocco.

During this investigation, we have analyzed data relating to abdominopelvic CT scan procedures from all UHCs in Morocco. Indeed, the Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR) is responsible for the regulation and control of activities involving sources of

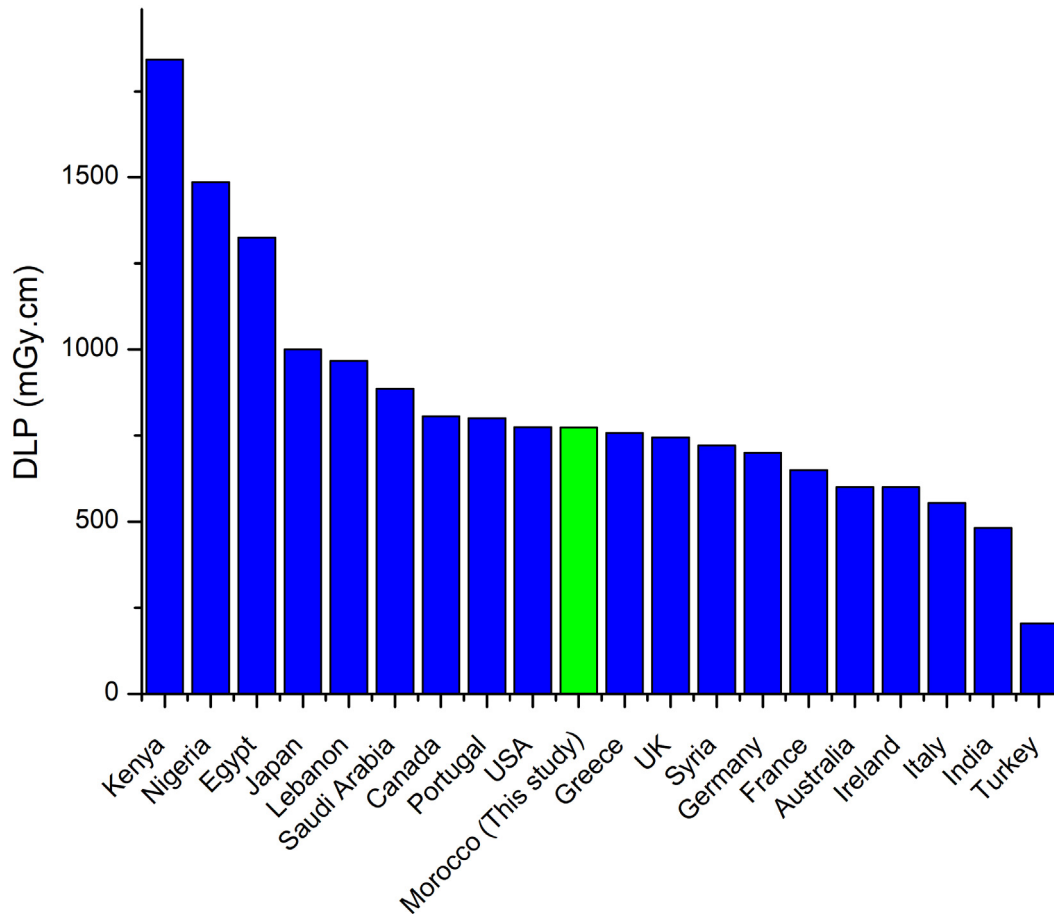


Fig. 1. Comparison of Moroccan DRL established at the 75th percentile of DLP with international values.

ionizing radiation. One of its missions is to establish national surveys on the doses administered to patients during the most common radiological examinations. However, AMSSNuR has not yet published data regarding NDRLs of radiological examinations in Morocco. Our dose survey proposal provides recommendations to radiation protection authorities and associated agencies that can be used to conduct national dose surveys for abdominopelvic CT scans in Moroccan hospitals. In view of rapid advancements in CT imaging technology, we recommend that AMSSNuR and hospitals update DRLs for CT procedures on a periodic basis to monitor radiation exposure during CT examinations in patients in Morocco.

5 Conclusion

The aim of this study was to evaluate radiation doses in adult patients undergoing abdominopelvic CT examination. The DRLs are proposed as NDRLs for this procedure and have been compared with those of other countries. This comparison identified an acceptable average DLP dose compared to other countries, since the Moroccan DLP was 10th among the 21 countries with the highest DLP values. The current study has some limitations: in particular, the data collected do not include a wide range of scanners available in Morocco, from 4 to 128 slices of CT technology, nor do they include all the country's geographical regions. As such, data will be collected

prospectively in future work to mitigate these limitations. However, the strength of this work is the availability of patient weight data (BMI) which ensures dose accuracy. Consequently, the results provide a national reference for CT doses for abdominopelvic CT examination. However, there is still a need to reduce and optimize radiation dose while maintaining good image quality for reliable diagnosis, and this can be achieved by enhancing radiographers' and radiologists' knowledge of radiation protection, protocol justification, as well as optimization through rigorous hospital radiation audits at national level.

Conflict of interest

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

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Ethical approval

This study did not carry out activities that would require approval by a research ethics committee.

Informed consent

This article does not contain any studies involving human subjects.

Authors contributions

S. Semghouli contributed as the main contributor of this paper. All authors read and approved the final version of the paper.

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