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ARTICLE

Patient radiation doses from adult CT examinations at the Souss Massa Regional Hospital

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Abstract – Objective: This study aimed to assess patient radiation doses, and to establish diagnostic reference levels for Adult CT examinations at the Souss Massa Regional Hospital, Morocco.
Method: Data from 6 CT examinations were collected between January and June 2023 at the Souss Massa Regional Hospital, including patient age, sex, weight, and height, as well as scanner acquisition parameters such as the number of series, use of contrast media, rotation time plus slice thickness, the displayed Computed Tomography Dose Index ($CTDI_{vol}$), and the Dose Length Product (DLP). Diagnostic reference levels (DRLs) were calculated for each type of CT examination by estimating the 75% percentile of $CTDI_{vol}$ and DLP. The effective dose is calculated using the following formula: E(mSv) = EDLP × DLP (mGy.cm). The data were statistically analyzed using SPSS version 21.0 software.
Results: DRLs in terms of CTDIvol, and DLP for the brain without contrast media are 64,45 mGy, and 1405,77 mGy.cm respectively. For chest CT without contrast media, they are 11,13 mGy, and 417,73 mGy.cm respectively. The data from the abdominal CT show that the CTDIvol (9,74 mGy) and DLP (529,31 mGy.cm) values with contrast media are higher than those without contrast media, which are (9,35 mGy) and (515,21 mGy.cm) respectively. DRls in terms of CTDIvol and DLP for abdomen and pelvis (AP) CT with contrast media are 8,14 mGy and 444,51 mGy.cm respectively. For chest abdomen and pelvis (CAP) with contrast media they are 8,51 mGy, and 571,30 mGy.cm respectively. The effective doses were 2,37, 6,50, 6,24, 6,76, 5,07, 7,13 mSv for the brain without contrast media, chest without contrast media, abdomen without contrast media, abdomen with contrast media, AP with contrast media, and CAP respectively.
Conclusion: Adapting CT protocols according to the morphology of patients and the conditions under which each examination is performed can help maintain the doses received by patients at an optimum level.

Keywords: Computed tomography / CTDIvol / DLP / effective dose

1 Introduction

Computed tomography (CT) has become an indispensable imaging method in routine clinical practice. It is a non-invasive technique capable of providing images of the inside of the human body that are not biased by the superposition of distinct anatomical structures (Thorsten M. B, 2008). However, CT procedures deliver approximately 50% of the collective effective dose from medical and dental exposures in many countries, because of the relatively high doses delivered in CT scanning compared with other diagnostic imaging modalities (NCRP, 2009).

Many epidemiological studies have shown a small yet significant increase in cancer risk at typical CT doses (Lin, 2010). According to the INWORKS study, the estimated mortality rate from solid cancer increased with cumulative dose by 52% per Gy, with a time lag of 10 years. (Richardson *et al.*, 2023).

This implies rigorous application of the two principles of radiation protection: justification and optimization (AIEA, 2018). In this context, there are many optimization procedures, including the establishment of diagnostic reference levels (DRLs). The DRL has been proven to be an effective tool that aids in optimization of protection in the

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medical exposure of patients for diagnostic and interventional procedures (ICRP, 2017).

The use of DRLs reduces the overall dose and the range of doses observed in clinical practice. In the United Kingdom, the 2005 DRLs for radiography, fluoroscopy, and dental *x*-rays were approximately 16% lower than those in 2000 and approximately half of those in the mid-1980s (Kanal *et al.*, 2017).

In Morocco, medicine accounts for more than 80% of the installations and activities that use ionizing radiation sources. The field of health records includes over 300 scanners, 40 electron accelerators used for treatment and 24 nuclear medicine centers. These figures are expected to increase in the future with the construction of new regional centers and the expansion of mandatory health insurance (Mrabit, 2022).

Several previous studies have examined diagnostic reference levels in Moroccan hospitals. In this context, El Mansouri *et al.* found that the established DRLs in Morocco in terms of CTDIvol were 57.4, 12.3 and 10.9 for CT examinations of the head, chest, and abdomen, respectively (El Mansouri *et al.*, 2021). For DLP, they were 1020, 632 and 714, respectively. For their part, Benamar *et al.* found that the DRLs in terms of CTDIvol for head, chest, abdomen-pelvis, chest-abdomen-pelvis, and lumbar examinations were 57.7, 11.1, 11.3, 11.6 and 20 mGy respectively. In terms of DLP, they were 1250.4, 392.2, 517.1, 833.27 and 707.37 mGy.cm, for the mentioned types of examinations respectively (Benamar *et al.*, 2022).

This study, which aims to estimate the doses received by adult patients during CT examinations, completes the study carried out by EL Fahssi *et al.*, 2023 which calculated the doses delivered to patients in conventional radiology in the Souss Massa region. This study covers 6 routine CT examinations: Brain without contrast media, chest without contrast media, abdomen without contrast media, abdomen with contrast media, abdomen and pelvis (AP) with contrast media, and chest abdomen and pelvis (CAP) with contrast media.

2 Method

Data of this study were collected between January and June 2023 at the Souss Massa Regional Hospital. A total of 360 patients' data were collected from the Optima General Electric 16-slice scanner, covering 6 routine CT examinations: Brain without contrast media, chest without contrast media, abdomen without contrast media, abdomen with contrast media, abdomen and pelvis (AP) with contrast media, and chest abdomen and pelvis (CAP) with contrast media.

Patient data were specified for each type of CT scan, including age, sex, weight, and height, as well as scanner acquisition parameters including number of series, use of contrast media, rotation time plus slice thickness, the displayed Computed Tomography Dose Index ($CTDI_{vol}$), and the Dose Length Product (DLP).

DRLs were calculated for each type of CT examination by estimating the 75% percentile of $CTDI_{vol}$ and DLP. The effective dose is calculated using the following formula:

$E(\mathrm{mSv}) = \mathrm{EDLP} \times \mathrm{DLP}$ (mGy.cm) (Delchambre, 2012).
Where EDLP is the millisievert per second conversion factor.

Table 1. Conversion factors for the anatomical regions scanned (Delchambre, 2012).

Epdl ($mSv.mGy^{-1}.cm^{-1}$)	
Anatomical regions	Adult patients over 17 years of age
Head	0,0021
Neck	0,0058
Head + neck	0,0031
Chest	0,0148
Abdomen +/− pelvis	0,0154
Chest abdomen and pelvis	0,015

Table 2. The Summary of acquisition parameters per type of CT scan.

Parameters	CT examinations					
	Brain C−	Chest C−	Abdomen C+	Abdomen C−	AP C+	CAP C+
kV	120	120	120	120	120	120
mAs	120	125	120	120	120	120
Pitch	1	1,75	1,75	1,75	1,75	1,75
Slice thickness (mm)	1,25	1,25	1,25	1,25	1,25	1,25

The mean tube voltage (Kv), electric charge (mAs), pitch, and slice thickness are indicated for each CT examination.
C+: with contrast media.
C−: without contrast media.

Table 1 presents the conversion factor according to the type of CT-scan.

Student's *t*-test was used to examine the association between patient gender and effective dose. To study the association between age and body mass index (BMI), Pearson's parametric test was used after confirmation of the normal distribution of all variables. A linear regression test was then performed to understand and model the relationship between these variables.

2.1 Data analysis

The data were statistically analyzed by SPSS software version 21.0. The third quartile (75th percentiles) is considered according to ICRP publication 135 as the reference value for setting diagnostic reference levels in terms of $CTDI_{vol}$ and DLP.

3 Results

360 patients who underwent a CT scan of one of the anatomical regions already mentioned took part in this study. All patients were adults aged over 18 years and weighing between 50 and 90 kg.

Table 2 shows that the voltage is invariable for all examinations (120 kV). The charge is fixed on 125 mAs for chest CT, and 120 mAs for the rest of examinations. The pitch is equal to 1 for the Brain CT and equal to 1,75 for the rest of

Table 3. The mean of CTDIvol, DLP, and effective dose for Brain C−, Chest C− and CAP C+.

	Brain C−			Chest C−			CAP C+		
Parameters	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
$CTDI_{vol}$	53,80	20,73–78,04	14,43	9,64	5,48–15,83	3.29	7,17	4,55–10,33	1.80
DLP	1131,44	607,07–1669,28	339,60	367,15	205,35–643,10	137.6	465,73	219,09–666,49	128.94
Effective dose	2,37	1,27–3,50	0,71	6,50	3,63–11,38	2.43	7,13	3,29–10,00	1.93

Table 4. The mean of CTDIvol, DLP, and effective dose for Abdomen C−, Abdomen C+, and AP C+.

	Abdomen C−			Abdomen C+			AP C+		
Parameters	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
$CTDI_{vol}$	7,25	2,26–12,81	2.68	7,99	4,06–10,63	2.68	6,31	2,26–9,96	1.98
DLP	405,11	99,04–748,14	171.18	438,95	215,37–614,68	171.18	314,45	75,6–627,2	132.95
Effective dose	6,24	1,53–11,52	2.64	6,76	3,32–9,47	2.57	5,07	1,16–9,66	2.05

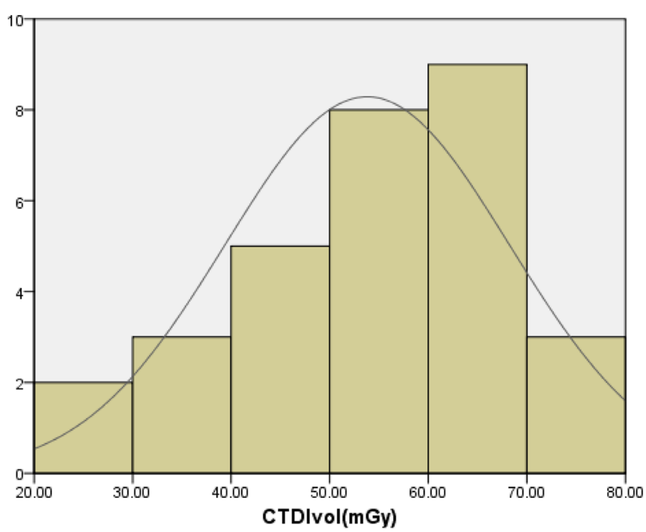

Fig. 1. Distribution of CTDvol values during brain CT examinations.

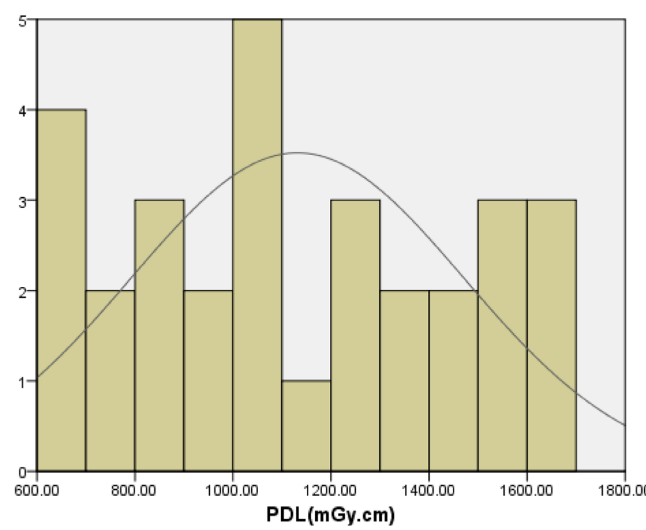

Fig. 2. Distribution of DLP values during brain CT examinations.

CT-exams. The slice thickness is equal to 1,25 for all CT-exams.

Tables 3 and 4 show that the mean $CTDI_{vol}$ varies from 6,31 mGy for AP with contrast media to 53,80 mGy for brain without contrast media. The mean DLP varies from 314,45 mGy.cm for AP with contrast media to 1131,44 mGy.cm for the brain without contrast media. The mean effective dose varied from 2,37 mSv for the brain without contrast media to 7,13 mSv for CAP with contrast media.

According to Figures 1 and 2 the CTDIvol values for brain CT vary from 20.73 to 78.04 mGy with a mean value of 53.80 mGy. DLP values vary from 607.07 to 1669.28 mGy.cm with a mean value of 1131.44 mGy.cm.

Table 5 shows that the DRL in terms of $CTDI_{vol}$ varies from 8,14 mGy for AP with contrast media to 64,45 mGy for the brain without contrast media. The DRL in terms of DLP varies from 417 mGy.cm for the chest without contrast media to 1405,77 for the brain without contrast media.

Table 6 shows that there was no association between patient gender and effective dose for all CT examinations. However, there is an association between patient age and the effective dose for brain CT without contrast media and chest CT without contrast media. In addition, there was an association between BMI and the effective dose of AP CT with contrast media and CAP CT with contrast media.

4 Discussion

The results show that, in terms of exposure parameters, the tube voltage is invariable for all examinations with a fixed value of 120 kV. In addition, the voltage does not change according to whether or not a contrast media is administered.

Table 5. Comparison of DRLs assessed in terms of $CTDI_{vol}$ and DLP with those of previous studies.

	This study		Morocco 2021		Saudi Arabia 2022		IRSN 2023	
	3^{rd} $CTDI_{vol}$	3^{rd} DLP	3^{rd} $CTDI_{vol}$	3^{rd} DLP	3^{rd} $CTDI_{vol}$	3^{rd} DLP	3^{rd} $CTDI_{vol}$	3^{rd} DLP
Brain C−	64,45	1405,77	57.4	1020	48	962	46	850
Chest C−	11,13	417,73	12.3	632	7	250	9,5	350
Abdomen C−	9,35	515,21	10.9	714				
Abdomen C+	9,74	529,31						
Abdomen and Pelvis (AP) C+	8,14	444,51			11	957	13	625
Chest Abdomen and Pelvis (CAP) C+	8,51	571,30					11	750

Calculated DRLs in terms of CTDIvol and DLP are indicated for each CT-exam.
C+: with contrast media.
C−: without contrast media.

Table 6. *p*-value distribution according to the relationship between sex, age, body mass index and effective dose for each examination.

		Effective dose (*p*-value)					
		Brain C−	Chest C−	Abdomen C+	Abdomen C−	AP C+	CAP C+
Sexe	Student's *t*-test	0.514	0.242	0.080	0.199	0.063	0.12
Age	Pearson Correlation	0.023**	0.001**	0.109	0.604	0.301	0.330
Body mass index (BMI)	Pearson Correlation	0.80	0.398	0.061	0.06	0.000**	0.003**

**Correlation is significant if *p*-value <0.05.

The charge is also fixed at 120 mAs for all CT-exams except Chest CT without contrast media. This situation is due to the use of standard protocols, and the lack of adjustment of these protocols to the patient's morphology. In fact, lowering the tube voltage to achieve dose reduction has been proposed. However, it should be accompanied by an image quality measurement to verify that no diagnostic information will be lost (Christos P *et al.*, 2022). For the iodine contrast, there is a strong dependence on tube potential, which is much in favour of lower kV settings. Therefore, 80 instead of 120 kV would allow the patient dose to be reduced by almost a factor of two without sacrifying image quality (Nagel, 2007). Usually, the average voltage and charge used for the head region are higher than those used for the AP and CAP regions. This leads to lower DRLs in terms of CTDIvol, and consequently, DLP for the AP and CAP regions (Hasan *et al.*, 2022). Consequently, the fixed value of these technical parameters (kV and mAs) used in this study will have an effect on the comparison of the dosimetric data collected with those from similar studies.

In terms of effective dose, the results show that the average effective dose calculated for CT scans of the brain without contrast media (2.37 mSv) is higher than that indicated by the International Commission on Radiological Protection Publication No. 103 (1,7 mSv) (ICRP, 2007). The effective doses calculated by this study for the chest without contrast media, AP with contrast media and CAP with contrast media were 6,50, 5,07, and 7,13 mSv respectively. These values are all lower than those indicated by ICRP Publication 103 which are 6,8, 15,5, and 18,3 mSv respectively.

DRLs in terms of $CTDI_{vol}$, and DLP for brain without contrast media are 64,45 mGy, and 1405,77 mGy.cm respectively. These values are higher than those reported by two Moroccan surveys (Semghouli et al., 2022a ($CTDI_{vol}$: 40,94 mGy; DLP: 969,90 mGy.cm) ; El Mansouri *et al.*, 2022 ($CTDI_{vol}$: 57.4 mGy; DLP: 1020 mGy.cm)), and higher than those fixed by the Institute for Radiological Protection and Nuclear Safety (IRSN) ($CTDI_{vol}$: 46 mGy; DLP: 1020 mGy.cm) (IRSN, 2023), and higher than those reported in Saudi Arabia ($CTDI_{vol}$: 48 mGy; DLP: 962 mGy.cm) (Albahiti *et al.*, 2022). Brain CT protocols for this study did not consider patient's gender or the size and shape of the skull, which could influence the dose distribution in CT examinations. In addition, the contribution of overranging to the total CT dose is thus considerably higher for CT examinations with shorter scan ranges such as head CT (Kayun *et al.*, 2021). These high dosimetric values could also be due to the use of mAs and kVp higher than the international recommended value, the lack of sufficient manpower, and the lack of evidence of quality control checks on the CT machines (Abdulhamid, 2022). In addition, there was no significant relationship between patient gender and effective dose for brain CT examinations ($p = 0.514$). However, there was a significant relationship between patient age and effective dose ($p = 0.023$). Age was significantly and negatively associated with the effective dose. In this context, Khursheed *et al.* found that an inverse trend is observed between normalized effective dose and phantom age for scans of four regions of the trunk and head (Khursheed *et al.*, 2002). The results show also no association between BMI and the effective dose for brain CT. In fact, for CT imaging of the skull or brain, BMI does not show good accuracy because the effective diameter of the head does not very much in adults (Steiniger *et al.*, 2022). The higher dosimetric values recorded for brain CT scans require a review of the procedures and protocols for this type of examination at our hospital. In addition, the authors of this study have planned a study including several hospitals in the Souss Massa region to further study brain CT examinations.

For chest CT without contrast media, the calculated DRLs in terms of CTDIvol and DLP are 11,13 mGy, and 417,73 mGy.cm respectively. These values are lower than those reported by El Mansouri *et al.*, 2022 ($CTDI_{vol}$: 12,3 mGy; DLP: 632 mGy.cm), but they are higher than those reported in Saudi Arabia ($CTDI_{vol}$: 7 mGy; DLP: 250 mGy.cm), and the IRSN ($CTDI_{vol}$: 9,5 mGy; DLP: 350 mGy.cm). Variations in dosimetric values across different studies for chest CT-scans, may be accounted for differences in scan lengths, institutional preferred protocols, availability of dose reduction algorithms and age of scanners (Arlany *et al.*, 2023).

The data from the abdominal CT show that the $CTDI_{vol}$ (9,74 mGy) and DLP (529,31 mGy.cm) values for abdomen CT with contrast media are higher than those without contrast media, which are (9,35 mGy) and (515,21 mGy.cm) respectively. Indeed, one of the objectives of using iodinated contrast media is to better adapt the higher voltage ranges of the *X*-ray tube, which would allow greater flexibility in scanning protocols and thus lead to techniques that can provide equivalent diagnostic value at lower radiation doses (Schöckel *et al.*, 2020). However, the operators of the CT examinations in the site concerned in this study do not consider using contrast products to reduce kv and mAs and consequently, the dose delivered to patients.

DRls in terms of $CTDI_{vol}$ and DLP for AP with contrast media were 8,14 mGy and 444,51 mGy.cm respectively. These values are lower than those fixed by the IRSN (CTDIvol: 13 mGy; DLP: 625 mGy.cm), and also lower than those reported in Saudi Arabia (CTDIvol: 11 mGy; DLP: 957 mGy.cm). For CAP with contrast media, DRLs in terms of CTDIvol and DLP are 8,51 mGy, and 571,30 mGy.cm respectively. These values are lower than those fixed by the IRSN (CTDIvol: 11 mGy; DLP: 750 mGy.cm).

The results of this study show a significant relationship between BMI and the effective dose for AP CT ($p = 0.000$) and CAP CT ($p = 0.003$), and the effective dose increases with BMI. For the same CT examinations, Chan *et al.* found that for every kilogram of weight, there is a 0.13 mSv increase in the effective dose, which is equal to 6.5 chest radiographs per CT examination (Chan *et al.*, 2012).

In addition, the mean $CTDI_{vol}$ and DLP values for the chest, AP, and CAP were lower than those reported by Amaoui *et al.* and Semghouli *et al.* (Amaoui *et al.*, 2019; Semghouli *et al.*, 2022b). The last two studies were conducted at the same site as this study.

Reductions in CTDIvol and DLP will reduce the total collective dose to the population (Dimitroukas *et al.*, 2022). In addition, it is possible to maintain the radiation dose at an optimum level by using a combination of CT protocol homogenization and optimization of radiation doses with an iterative process that maintains the image quality (Rajiah, 2020), standardizing acquisition protocols, properly using dose reduction tools, examining and adjusting the acquisition parameters and image quality indices when abnormally high NRD values are observed (Sebelego *et al.*, 2023), and improving education of practitioners in medical radiation protection (Paulo *et al.*, 2020).

5 Conclusion

The results of this study showed that the dosimetric values for brain CT and chest CT were significantly higher than those reported in several previous studies. Therefore, it is necessary to review the protocols for performing this CT examination. Our results also show that the dosimetric values for the other CT examinations covered in this study are lower than those reported in similar studies.

Conflicts of Interest

The authors declare no conflict of interest.

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Ethical approval

This study received ethical approval from ethics committee for biomedical research, Mohammed V University of Rabat, under the protocol number 28/22.

Informed consent

This article does not contain any studies involving human subjects.

Authors contributions

M. EL FAHSSI, S. SEMGHOULI, M. CAOUI: Conceptualization, Methodology, M. EL FAHSSI, S. SEMGHOULI, B. AMAOUI: Writing original draft. M. EL FAHSSI, S. SEMGHOULI, M. CAOUI: Visualization, Investigation. S. SEMGHOULI, M. CAOUI, L. JROUNDI: Supervision. M. EL FAHSSI, S. SEMGHOULI, M. CAOUI, L. JROUNDI, B. AMAOUI: Reviewing and Editing.

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