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Research Article

Establishment of Typical Dose Reference Level (DRL) Values for Adult Patients Undergoing Computed Tomography in Three Hospitals in Brazzaville, Congo Republic

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Abstract
The present study aimed at to establish typical dose reference level (DRL) values for adult patients undergoing computed tomography (CT) examinations in three hospitals in Brazzaville, Congo Republic. The examinations considered were head, chest, abdomen-pelvis, chest-abdomen-pelvis and lumbar spine CT scans. For each examination, the median of the distribution for the volume CT dose index *($CTDI_{vol}$)* and dose-length product *(DLP)* were determined. The median values were considered as the typical *DRL* values. Hypothesis testing was also carried out to statistically compare the mean values obtained for each participating CT facility. In the case of head scan, the typical values proposed in the present study in terms of $CTDI_{vol}$ and DLP were 15–48% and 28–60% lower than the DRL values reported in the literature, respectively. In the case of lumbar spine, the typical value determined in this study in terms of DLP was 48–70% greater than the DRL values provided in the literature. The typical values proposed for chest, abdomen-pelvis and chest-abdomen-pelvis were within the DRL values reported in the literature. It is possible that the adoption of the typical values proposed in the present study will help in reducing the dose received by adult patients undergoing CT examination in Congo Republic.

Keywords: Computed tomography, diagnostic reference level, adult patient

1. INTRODUCTION

A diagnostic reference level (DRL) is a form of investigation level used for the optimization of protection in the medical exposure of patients [1]. This concept is used in conjunction with other measures of protection optimization to restrict individual doses. The initial intention would be to not exceed, or to remain at this level, and the purpose is to reduce all doses to levels that are as low as reasonably achievable, economic and societal factors being taken into account. DRLs are used in medical diagnosis to indicate whether, in routine conditions, the levels of patient dose from a specified imaging procedure are unusually high or low for that procedure. If so, a local review should be initiated to determine whether protection has been adequately optimized or whether corrective action is required [2]. For CT, DRLs are determined in terms of either the volume CT dose index ($CTDI_{vol}$, in mGy) or the dose-length product (DLP, in mGy.cm). CTD_{Ivol} quantifies the amount of radiation given in one tube rotation to a standard phantom. This can be related to the dose received by the patient for that slice. The standard phantom is either 16 cm in diameter for the head or 32 cm in diameter for the body [3]. The DLP quantity relates to the total amount of radiation received during a given scan sequence or full examination [4].

Several studies dealing with DRLs are found in the literature. Korir et al have estimated national DRLs associated with CT examinations in clinical practice in Kenya [5]. They determined national DRLs for 20 types of CT examinations. Dimitroukas et al [6] proposed institutional (local) DRLs for 573 adult patients who underwent eleven common CT examinations. These local DRLs were compared to corresponding Greece national DRLs and international values. Zira et al [7] determined DRLs for 113 paediatric head CT examinations in Kano metropolis, Nigeria. The values provided were intended for future use and comparisons and as a potential dose optimization tool. Vassileva et al [8] reported the results from an international dose survey in paediatric CT in 32 countries. They

Table 1. CT machines involved in the study.

Computed tomography facility						Method of Data Collection
Code	**Brand**	**Model**	**Serial Number**	**Year of Manufacture**	**Year of Installation**	
A	Toshiba	Activion 16	1CA0882216	2008	2008	Manually
B	Toshiba	Activion 16	1CA0882217	2008	2008	Manually
C	Neusoft	NeuViz 16	N16E150005	2015	2018	Manually

proposed international DRLs established at rounded 75th percentile values of the distribution of median values from all CT facilities involved. Until now, no such studies have been conducted in the Republic of Congo, particularly in CT. The goal of the present study is to establish typical values using the DRL quantities $CTDI_{vol}$ and DLP for adult patients undergoing CT examination in selected hospitals in Brazzaville, Republic of Congo, chosen because they cover most of CT scan examinations performed in this region of the country. This study, the first in the country on this matter, is important as it establishes the first typical values in CT practice that will serve in establishing national DRL in the Republic of Congo.

2. MATERIALS AND METHODS

2.1. Materials

Table 1 presents the main features of the CT machines considered in this study.

2.2. Methods

2.2.1. Collection of Data

The present work is a retrospective study dealing with adult patients. The data were directly collected from the CT machines (Figures 1 and 2), from June 2018 to July 2019.

All patient data were anonymized before their evaluation. The information collected was the examination type, number of acquisitions, age, sex of the patient, $CTDI_{vol}$, and *DLP* associated with the examination.

2.2.2. Statistical Analysis

Microsoft Office Excel Professional Plus 2013 (Microsoft corporation, USA) and Matlab (The MathWorks, Inc, USA) version R2013a were used to analyze the data collected. As only three CT facilities were involved in the present study, the median values of the distribution of DLP and $CTDI_{vol}$ of five of the examinations considered were defined as typical DRL values in agreement with the International Commission of Radiological Protection (ICRP) publication 135 [1].

It is important to mention that the technicians performing CT examinations did not record patient size in most of the cases. Therefore, this parameter (the size) was not taken into account in the evaluation of typical values. Furthermore, the three facilities involved in the study declared that they use manufacturer-installed scanning protocols without any optimization efforts. This means that, in general, examinations are performed giving the same $CTDI_{vol}$ value for all adult patients, indicating that a single mAs value is used and no automatic

Figure1. Scanner machine (brand Neusoft Neuviz) in l'hospital C.

exposure control is used or no mAs is adjusted with patient size. Finally, for examinations with contrast, which are in fact double-phase examinations, with the first phase performed without a contrast product, the technicians did not record $CTDI_{vol}$ and DLP values for each phase. They only recorded values corresponding to the overall examination. For this reason, examinations with contrast were not taken into account for the evaluation.

Hypothesis testing was also carried out to statistically compare the mean values obtained for each participating CT facility [9]-[11]. The null hypothesis was that two compared data sets were drawn from the same population with the same mean (H_0: $\mu_x - \mu_y = 0$), while the alternative hypothesis was that two compared data sets were drawn from different populations with different means (H_1: $\mu_x \neq \mu_y$). The test statistic used is shown in Eq. 1;

$$t_{v,\alpha} = (\bar{X} - \bar{Y})/(\sqrt{\frac{s_x^2}{n_1} + \frac{s_y^2}{n_2}}) \text{ (}t\text{-distribution)} \quad \textbf{(1)}$$

where X and Y are the $CTDI_{vol}$ or DLP collected for each of the two facilities to be compared, respectively; n_1 and n_2 are the respective sample sizes; $t_{v,a}$ is the t-value with degrees of freedom v, is the quantity that cuts off an area of size α to the right under the t-distribution; and v is derived from the Satterthwaite's approximation. The statistical significance level considered was $\alpha = 0.05$. The population of the means of samples taken from each of the three CT facilities was considered. The samples were considered independent from each other and identically distributed so that the central limit theorem (CLT) could be applied. As the sample sizes were greater than 30, it was reasonable to consider the distribution of the sample means approximately normal [12]. The CLT was applied to the only sample collected in each CT facility.

3. RESULTS AND DISCUSSIONS

3.1. Results

The patient demographics are provided in reference [13]. Table 2 shows, for each hospital, the number of patients per examination type. Table 3 presents the main parameters of the standard protocols used. Figure 3 shows the overall DLP distribution for each examination considered. From the distribution of DLP values for head scan (Figure 4), it was observed that the lowest values were essentially those collected in Hospital C. Furthermore, Table 4 presents selected distribution parameters per examination type, hospital, and CT system. It shows that the $CTDI_{vol}$ values collected in hospital C for head scan were, on average, ≈ 50% lower than those collected in the other two hospitals. For these reasons, only the data distribution for hospital C were considered for establishing typical values for head scan. For chest, abdomen-pelvis (AP), chest-abdomen-pelvis (CAP), and lumbar spine scans (Figure 5), the variation in the DLP values between hospitals was less pronounced as for head scan. Thus, all the data were considered for typical values establishment.

Hypothesis testing showed that $CTDI_{vol}$ values

Figure 2. Scanner machine (brand Toshiba Activion) in hospital A and B.

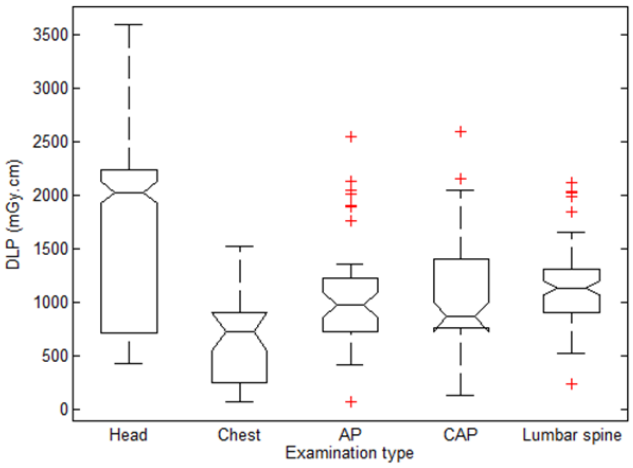

Figure 3. Distribution of *DLP* per examination type.

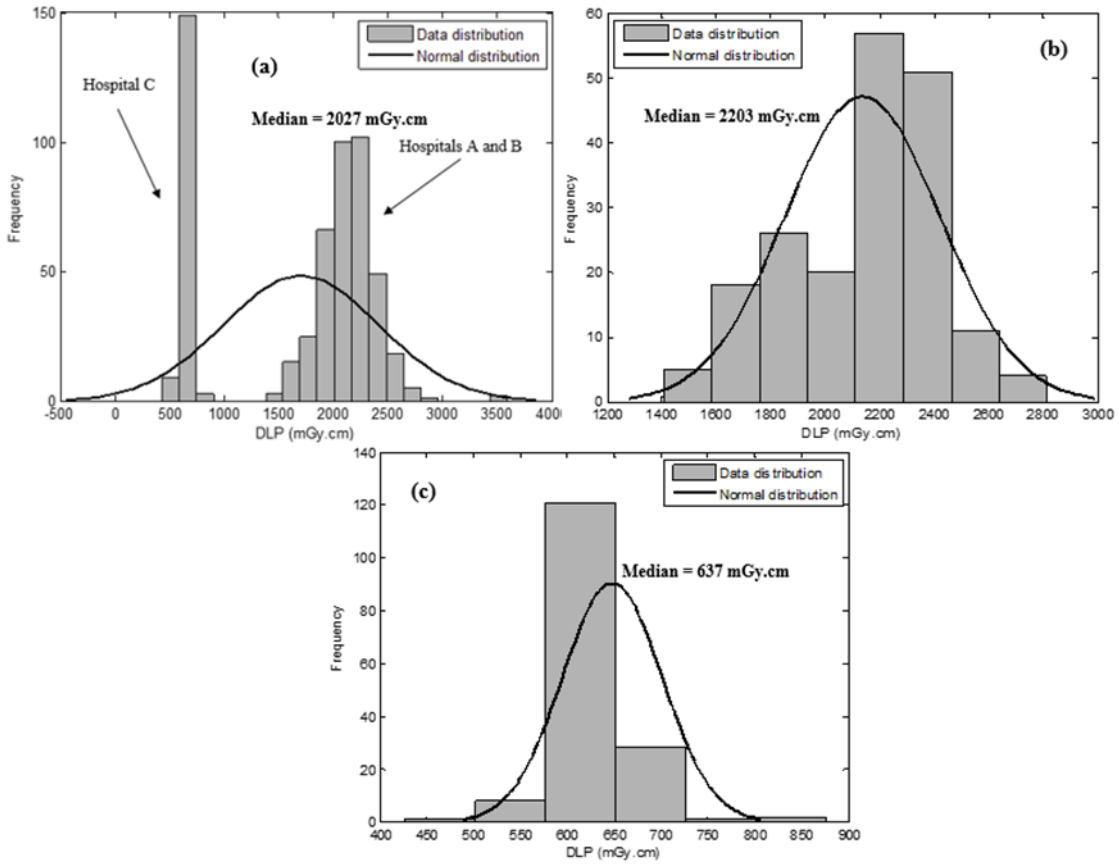

Figure 4. Distribution of *DLP* for head scan. Overall distribution (a), distribution for hospitals A and B (b), and distribution for hospital C (c).

from hospital A were significantly different from those from the other two hospitals, except for the case of lumbar spine scan (*p-value* = 0.71, comparison with hospital B). The $CTDI_{vol}$ values from hospitals B and C were not significantly different (*p-values* = 0.15, 0.95, and 0.24 for chest, AP, and CAP scans, respectively), except for the cases of head and lumbar spine scans (*p-value* = 0.00). Contrariwise, DLP values from hospitals A and B were not significantly different for head scan (*p-value* = 0.64), AP scan (*p-value* = 0.15) and lumbar spine scan (*p-value* = 0.11). However, the *DLP* values from hospital C were significantly different from those of the other two hospitals, except for the cases of lumbar spine scan (*p-value* = 0.09, comparison with hospital A) and AP scan (*p-*

value = 0.54, comparison with hospital B).

Table 5 shows selected statistical parameters of the overall $CTDI_{vol}$ and *DLP* distributions per examination type. This table also compares the median values determined in this study as typical values with the DRLs established in other studies. In the case of $CTDI_{vol}$, the typical value determined in this study (44.3 mGy) for head scan was lower (15–48%) than the *DRL* values reported in references [5][6][14][15]. The typical value determined for chest scan (22.0 mGy) was similar to that reported in Moifo et al. [15] and greater (16–120%) than the other values reported in [5][6][16]-[19]. Typical values determined in the present study for AP, CAP and lumbar spine scans were in between the values (1–15% lower and 10–80% upper) given in references [5][6]. In the case of *DLP*, the typical value determined (637.3 mGy cm) for head scan was 28–60% lower than the *DRL* values reported in references [5][6][15]-[18]. For chest scan, the typical value (708.4 mGy cm) was 1 to 21 % lower than the values reported in references [5][15], while it was 16–63% greater than *RDL* values determined in references [15]-[17]. For AP scan, the value provided in this study (740.1 mGy cm) was greater (3–23%) than those given in [15][18], whereas it was lower (7–60%) than the values determined in references [5][16][17]. In the case of CAP, the typical value (866.3 mGy cm) provided in the present study was 8 to 33% lower than the values given in references [6][16]-[18]. Finally, the typical values proposed for lumbar spine (1137.0 mGy cm) were 48–70% greater than the *DRL* values reported in the literature [5][6][15]-[18].

3.2. Discussion

The choice of considering only the data distribution for hospital C, in the case of head scan, is in agreement with the principle of optimization of radiation protection which recommends keeping the exposure of patients to the minimum necessary to achieve the required diagnostic objective [14]. Hypothesis testing has shown that, although hospitals A and B use the same type of CT machine and the manufacturer-installed scanning protocols, it seems that technicians do not always use imaging protocols systematically as presented in Table 3. The patient size and the choice by technicians of some parameters such as pitch factor, scan length, beam width, slice thickness, etc., may explain the statistically significant difference observed in $CTDI_{vol}$ and DLP values between the two hospitals. Although ICRP recommends $CTDI_{vol}$ and DLP as DRL quantities [1], the authors share the opinion that the latter quantity is a better choice to establish local DRLs as it incorporates both $CTDI_{vol}$ and scan length and quantifies the total amount of radiation patients receive during a given scan, so that it can be considered to be related more closely to risk [4][20]. The median values determined in this study as typical values were proposed for both examinations with and without the use of a contrast product. This means that in the particular case of double-phase examinations, the proposed typical values should be considered in each phase. The comparison with other studies has shown that, except for the case of

Table 2. Distribution of patients per hospital and examination type.

Examination Type	Hospital		
	A	B	C
	Type of CT machine		
	Toshiba Activion 16	Toshiba Activion 16	Neusoft Neuviz 16
	Number of patients		
Head	228	246	209
Chest	53	35	36
AP	78	57	43
CAP	64	40	100
Lumbar spine	25	30	31
Total	448	410	419

Table 3. CT examination protocols used in the hospitals considered in this study.

Type of CT machine										
	Toshiba Activion 16					Neusoft Neuviz 16				
CT scan	***kVp***	***mAs***	**Pitch**	**Collimation (mm)**	**FOV*(mm)**	***kVp***	***mAs***	**Pitch**	**Collimation (mm)**	**FOV* (mm)**
Head	120	250	0.688	16 (8–16)	240 (S)	120	280	(0.2–1.5)	(12–24)	(50–500)
Chest	120	150	1.438		204 (L)	120	250			
AP†	120	187	0.938		204 (S)	120	250			
CAP‡	120	150	0.938		204 (S)	120	250			

The range of some parameters are provided in parenthesis; †Abdomen-Pelvis; ‡ Chest-Abdomen-Pelvis; * FOV: Field of view.

Table 4. Selected distribution parameters per examination type, hospital, and CT system.

Hospital A						
CT machine	Toshiba Activion 16					
	$CTDI_{vol}$ (mGy)			*DLP* (mGy cm)		
Examination	Range	Mean±1σ	Med.	Range	Mean±1σ	Med.
Head	88.1–99.7	89.6 ± 1.5	90.7	1410.0–2812.2	2136.5 ± 284.8	2203.1
Chest	26.7–49.0	26.7 ± 8.0	26.2	484.9–1393.1	869.4 ± 267.4	963.0
AP	14.7–34.3	16.0 ± 5.1	14.7	416.4–843.1	708.1 ± 96.0	725.4
CAP	26.4–30.0	28.8 ± 1.9	30.0	1533.3–1996.2	1826.2 ± 185.5	1828.4
Lumbar spine	14.7–33.0	28.3 ± 5.5	29.8	578.3–1656.2	1076.3 ± 294.0	1098.9

Table 4. *Cont.*

Hospital B						
CT machine			**Toshiba Activion 16**			
		***CTDI*$_{vol}$ (mGy)**			***DLP* (mGy cm)**	
Examination	Range	Mean±1σ	Med.	Range	Mean±1σ	Med.
Head	96.5–99.3	99.1 ± 0.8	99.3	1807.3–3594.8	2148.5 ± 222.1	2125.0
Chest	20.5–21.2	20.5 ± 1.0	21.1	519.6–827.6	667.8 ± 110.6	667.2
AP	26.5–53.0	28.9 ± 8.0	26.5	769.3–1089.0	862.3 ± 151.7	795.4
CAP	21.2–21.2	21.2 ± 0.0	21.2	1336.9–1400.6	1379.4 ± 36.8	1400.6
Lumbar spine	12.5–53.1	29.2 ± 12.0	24.0	654.3–1400.6	964.6 ± 172.4	913.9
Hospital C						
CT machine			**Neusoft Neuviz 16**			
		***CTDI*$_{vol}$ (mGy)**			***DLP* (mGy cm)**	
Examination	Range	Mean±1σ	Med.	Range	Mean±1σ	Med.
Head	35.5–44.3	43.8 ± 1.9	44.3	427.0–876.4	648.0 ± 53.1	637.3
Chest	19.8–19.8	19.8 ± 0.0	19.8	77.6–911.9	408.8 ± 368.5	162.0
AP	19.8–36.7	28.7 ± 8.7	36.6	652.5–1075.4	924.4 ± 153.6	980.4
CAP	19.8–36.7	22.4 ± 6.2	19.8	680.1–1890.3	1007.4 ± 332.6	866.1
Lumbar spine	19.8–42.7	39.8 ± 5.4	41.2	527.9–1522.7	1195.8 ± 187.9	1190.6

Note : Med.: Median

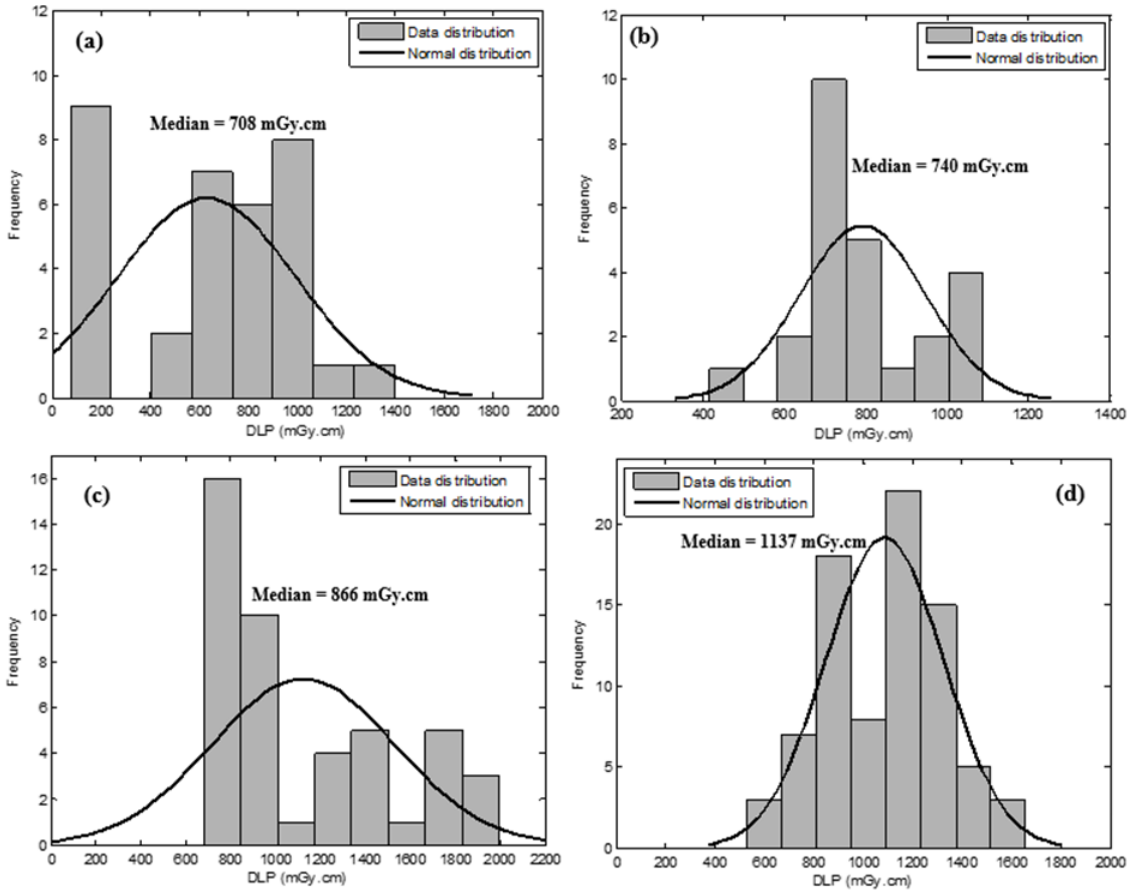

Figure 5. Overall distribution of *DLP* for chest scan (a), AP scan (b), CAP scan (c), and lumbar spine scan (d).

lumbar spine scan, typical values determined in this study compare well with the DRLs established in the literature. Finally, the adoption of the proposed typical values will certainly help in reducing the dose received by adult patients undergoing CT examination in the three hospitals involved in the study.

4. CONCLUSIONS

The present study aimed to establish typical values for adult patients undergoing CT examinations in three hospitals in Brazzaville, Congo Republic. The typical values determined for head scan were lower than the values reported in the literature, while for chest, AP, CAP and lumbar spine scans, the DRL values provided were globally within the range of values reported in the literature. It is the opinion of the authors that the adoption of the typical values proposed in this study will certainly help in reducing the dose received by adult patients undergoing CT examination in the Congo Republic.

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Table 5. Selected statistical parameters of the overall distribution of $CTDI_{vol}$ and *DLPs* collected in the study and comparison with other studies.

Examination	*DLP* (*mGy.cm*)								
	This study			Other Studies (DRL**)					
	Range	Mean ± 1σ	Median	Cameroon [15]	Kenya [5]	Greece [6]	Japan [16]	France [19]	Australia [18]
Head	427.0–876.4	648.0 ± 53.1	637.3	1151	1612	1055	1350	1050	880
Chest	77.6–1393.1	630.6 ± 361.3	708.4	715	895	480	550	475	390
AP	416.4–1089.0	793.3 ± 154.3	740.1	716	1842*	--	1000	800	600
CAP	680.1–1996.2	1123.1 ± 406.9	866.3	---	---	1020†	1300	1000	940
Lumbar spine	527.9–1656.2	1086.2 ± 238.5	1137.0	769	712	725	---	700	670
Examination	***CTDI*$_{vol}$ (*mGy*)**								
	This study			**Other Studies (DRL**)**					
	Range	**Mean ± 1σ**	**Median**	**Cameroon [15]**	**Kenya [5]**	**Greece [6]**	**Japan [16]**	**France [19]**	**Australia [18]**
Head	35.5–44.3	43.8 ± 1.9	44.3	52	61	67	85	65	52
Chest	14.4–49.0	23.7 ± 6.7	22.0	22	19	14	15	15	10
AP	14.7–53.0	24.3 ± 9.5	19.8	15	20*	--	20	17	13
CAP	19.8–36.7	23.1 ± 6.0	19.8	---	---	17†	18	20	11
Lumbar spine	12.5–53.1	32.9 ± 10.0	29.8	25	20	35	---	--	26

Note: * This DRL value is for the abdomen scan; ** 75th percentile values; † This DRL value is for the chest & abdomen scan.

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Conflicts of Interest

The authors declare no conflict of interest.

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DATA AVAILABILITY STATEMENT

The authors will make available the data supporting the findings of the present study upon reasonable request.

ETHICAL APPROVAL

As a retrospective study, the institutional review board approval was obtained without patients' informed consent.

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