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THE ASSESSMENT OF LOCAL DIAGNOSTIC REFERENCE LEVELS (DRLS) FOR COMMON ADULT CT EXAMINATIONS IN ZAYED MILITARY HOSPITAL USING SIZE-SPECIFIC DOSE ESTIMATES

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ABSTRACT
Computed tomography (CT) significantly contributes to the radiation exposure that the population receives, primarily due to its delivery of relatively high radiation doses. Diagnostic Reference Levels (DRLs) are utilized to optimize clinical practice and prevent unnecessary radiation doses. However, Traditional DRL values do not account for patient size. This study aimed to assess the effect of patient size on Local Diagnostic Reference Levels (LDRLs) for adult CT exams frequently performed at Zayed Military Hospital using Size-Specific Dose Estimates (SSDE). The study collected retrospective data from two branches of Zayed Hospital between March and December 2023, totaling 156 patient records. The study focused on three standard CT exams: Chest, Abdominal Pelvis (AP), and Kidney Urinary Bladder (KUB). A prospective analysis was conducted for the Dose Length Product (DLP) and the volume CT dose index ($CTDI_{vol}$), both with and without the SSDE factor. LDRLs were defined as the 75th percentile of $CTDI_{vol}$ and DLP. The results were compared with both international and national DRL values. For $CTDI_{vol}$ (mGy), the proposed LDRLs that follow the conventional DRL are as follows: 5.8, 8.9, and 4.8, and for the chest, AP, and KUB examinations, respectively. In contrast, the LDRL values with the SSDE factor (mGy) are 7.6, 11.8, and 5.2 for the chest, AP, and KUB exams. The $CTDI_{vol}$ and DLP values were found to be aligned with international standards and the initial NDRL report. Based on the difference between the $CTDI_{vol}$ and LDRLs values, this study shows that the SSDE can provide reliable data for radiation safety protocols by considering patient specificity and size.

Index Terms – Computed Tomography (CT), CT dose index-volume, Diagnostic Reference Levels (DRLs), Dose Length Product, Size-specific dose estimates.

INTRODUCTION
Ionizing radiation is used in computed tomography (CT) scans to provide detailed cross-sectional images of the body. Diagnostic images allow for earlier and more accurate disease diagnosis; thus, the usage of CT scans has increased rapidly during the last two decades. However, concerns about the overuse of CT scans and the potential for patient harm have been expressed [1, 2]. Computed tomography (CT) is known for its potential for high radiation doses during patient diagnosis and treatment. When utilizing CT as a diagnostic modality, it is critical that you strictly stick to radiation protection guidelines, including justification, optimization, and limitation [3]. The optimization principle has been an essential aspect of radiological protection (ICRP, 1991), and the optimization concept has played a significant part in protecting against radiation, particularly in diagnostic imaging. Efficient and effective utilization of medical imaging techniques is essential. Optimization aims to provide clinical images of the required quality, enabling accurate and reliable diagnoses for individual patients [3–5].

According to the ALARA concept, patient dose optimization is mandatory to minimize radiation dose during medical procedures while achieving the intended diagnostic or therapeutic result. Regulations mandate the direct measurement of patient dosage and the formation of diagnostic reference levels (DRLs) to achieve optimization

[6]. The ICRP established diagnostic reference levels (DRLs) in 1996 and supported their use in ionizing radiation-based medical imaging, including CT exams. DRLs have been identified as a significant tool for radiation dose optimization and a type of investigation level used to aid in optimizing the medical exposure of patients in diagnostic and interventional procedures. DRLs are used to find out if the median value of a dose quantity recorded from a particular operation for a group of patients with average weights is unusually high or low for that procedure under normal circumstances. Establishing DRLs can help with dose audits and improve patient radiation protection by encouraging dose reductions without compromising image quality or patient care [1,6].

Determining DRLs for CT exams relies on amounts derived from two CT dose quantities. The first is the volume Computed Tomography radiation Index ($CTDI_{vol}$), which quantifies the mean absorbed radiation within the scanned volume and the radiation dose administered by a single gantry rotation, measured in milligray (mGy) [7]. The second is the dose length product (DLP), which considers the scan length to estimate the radiation dose absorbed by a patient, measured in milligray centimeters (mGy.cm). Although these factors are widely used, none consider the patient's size [7, 9]. Therefore, the size-specific dose estimate (SSDE) should be proposed to determine diagnostic reference levels (DRLs) for CT scans to solve this problem. The American Association of Physicists in Medicine (AAPM) task groups 204 and 220 introduced the size-specific dose estimate (SSDE) concept [8, 9]. The AAPM released studies in 2011 and 2014 regarding the calibration of $CTDI_{vol}$ for SSDE using the effective diameter (ED) and water-equivalent diameter (D_w) for patients planned for CT scans [10]. The American College of Radiology (ACR) updated the diagnostic reference values of CT exams for various patient-size groups in 2017 using SSDE [10]. It considers the effects of scanning parameters and differences in patient size. SSDE has been increasingly popular as a substitute for $CTDI_{vol}$. SSDEs are increasingly being used to determine DRLs for CT examinations. This change aims to increase dosage delivery accuracy and reduce the risk of employing X-rays [11].

However, there has been no reported utilization of DRLs for SSDE-based CT scans in the United Arab Emirates. This study assesses local Diagnostic Reference Level (LDRL) values based on SSDEs from the most often performed CT examinations at Zayed Military Hospital.

METHODS

After obtaining approval from the ethics and research committee, this study conducted a retrospective analysis of CT examinations at two branches of Zayed Hospital (H1 and H2) between March and December 2023, using data from that period. Data from 20-30 adult patients were gathered for each exam of various anatomical regions: Chest, Abdomen, Pelvis (AP), and Kidney Ureter Bladder (KUB). The study comprised individuals over 17 years old who underwent CT scans without administering contrast media on two CT scanners. Table 1 shows the specifications of the CT scanners involved in this study. The CT imaging parameters collected included the patient's age, gender, peak kilovoltage (kVp), milliampere (mA), scan time (T), scan length, rotation time, pitch factor, field of view, $CTDI_{vol}$, and DLP, and calculated the SSDE parameter.

Table 1. Ct Scanner Characteristics Per Hospital

Hospital	Scanner model	Slice
H 1	Optima 660	128
H 2	Revolution Apex	512

A. Statistical Distribution of LDRL without SSDE Parameter

In the data collection process, the median (50%) is an achievable dose, and the third quartile (75%) of the CTDIvol and DLP is set as an LDRL for the Zayed Military Hospital.

B. Calculation of LDRL with SSDE

Patient scans of each examination were collected from the picture archiving and communication system (PACS), and the slice with the greatest anteroposterior.

AP) and lateral diameter (LAT) in the axial scan were measured. The effective diameter was estimated as shown in the figure 1 below. The SSDE was calculated based on the patients' effective diameter (D_{eff}). Each CT image required the measurement of the anteroposterior (AP) thickness and lateral (LAT) width for all patients [2, 11, 12].

$$D_{eff} = \sqrt{AP \times LAT} \quad (1)$$

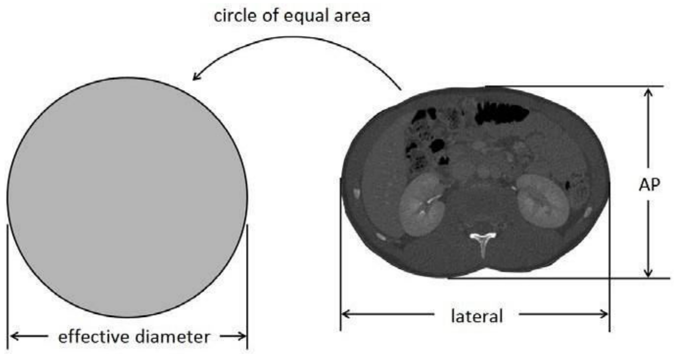

Fig. 1 the Anterior-Posterior (Ap) and Lateral Dimensions and the Effective Diameter. Ap Ct Radiograph Can Identify the Lateral Dimension, While a Lateral Ct Radiograph Can Determine The Ap Dimension. the Effective Diameter Is Shown by a Circle with the Same Area As the Patient's Cross-Section on A Ct Image [8].

Using standard calipers to measure the patient's thickness, the radiological technologist can determine the patient's lateral or anteroposterior dimensions to find an effective diameter (D_{eff}). The lateral (LAT) and anterior-posterior (AP) diameters were measured using a single transverse CT image [7, 12].

After finding the D_{eff} for each patient, the conversion factors (f size) were collected from The American Association of Physicists in Medicine (AAPM) Report 204 and normalized to patient size in water or tissue-equivalent materials. SSDE is calculated by multiplying the $CTDI_{vol}$ by the conversion factor [11, 12].

$$SSDE = f_{size} \times CTDI_{vol} \quad (2)$$

The quantitative variables derived from the examinations' doses (SSDE and $CTDI_{vol}$) were assessed, and their numerical values, median, and third quartile were determined. Furthermore, the results were compared with the data from other nations, specifically Morocco, Saudi Arabia, and Iran.

STATISTICAL ANALYSIS

Microsoft Excel software was used for statistical analysis. For every DRL quantity, descriptive statistics were provided, including the median, minimum, maximum, standard deviation, 50th percentile, and 75th percentile.

RESULTS

A total of 156 examination records were collected and analyzed. The data included information obtained from the Chest, Abdominal Pelvis (AP), and Kidney Urinary Bladder (KUB), both with and without the SSDE factor.

Table 2. Acquisition Parameters Applied In the Chest, Ap, And Kub Exams (F: Female, M: Male)

Exposure parameters	Chest	Abdomen	KUB
No of patients	52	44	60
Sex	43 M, 9 F	33 M, 11 F	53M,7F
Age (year)	17–85	17-83	18-85
Weight (kg)	65–85	65–85	65-85
Height (cm)	146–186	148–185	143-183
Tube voltage (KVp)	120	120	120
Product mAs (mAs)	120–191	62–217	50-133
Slice thickness (mm)	5	1.25	5
Rotation time (s)	0.5	0.5–0.6	0.5–0.6
Pitch	0.9-1	0.9	0.9-1.4

*M: Male, F: Female

Table 2 briefly describes the imaging parameters employed for acquiring CT images, while Table 3 shows patients' demographics mean and standard deviation for three examinations. The Proposed LDRLs are shown in Table 4. $CTDI_{vol}$ (Computer Tomography Dose Index Volume) values for chest, abdomen, pelvic, and KUB (Kidneys, Ureters, and Bladder) examinations in mGy were 5.8, 8.5, and 4.8, respectively. In addition, Table 5 displays the LDRL for DLP values in mGy.cm were 197.4, 426.8, and 218.9.

Table 3. Descriptive Statistics of Patient Characteristics for Each Examination with the Scan Parameters.

	Patient Characteristics								
	chest			Abdomen Pelvic			KUB		
	Age	H	W	Age	H	W	Age	H	W
Mean	42.69	166	75.38	35.32	169.59	75.5	37.88	169.88	74.69
Std	15.96	23.26	8.15	17.15	9.13	6.76	13.34	7.42	6.73

*Std: Standard deviation, H: Hight (cm), W: Wight (kg)

Table 4. The Local Diagnostic Reference Level (Ldrl) Based on the Volume Computed Tomography Dose Index Ctdivol (mgy) Obtained for the Three Computed Tomography (Ct) Exams in Zayed Military Hospital

LDR Without SSDE ($CTDI_{vol}$ mGy)			
Protocol			
	Chest	Abdomen	KUB
Average	4.9	8.9	4.35
Standard deviation	1.7	6.6	1.32
Minimum	3.1	4.3	3.42
Maximum	10.3	37	8.28
Median	4.4	7.4	3.58
Third quartile	5.8	8.5	4.83

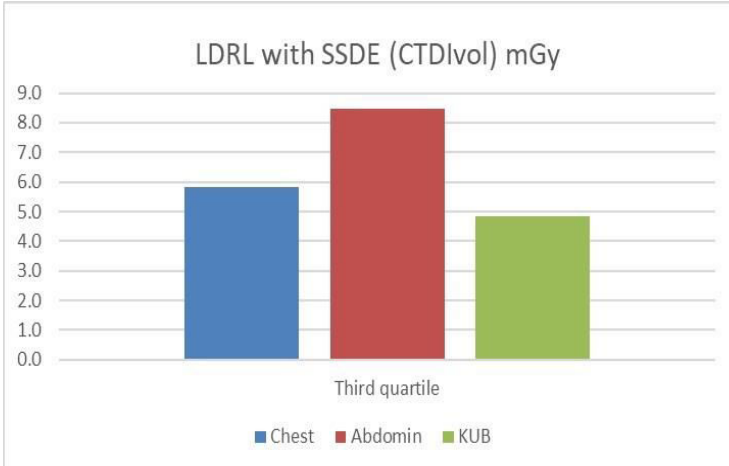

Fig. 2 LDRL without SSDE (Ctdivol) Mgy for the Three CT Exams in Zayed Military Hospital

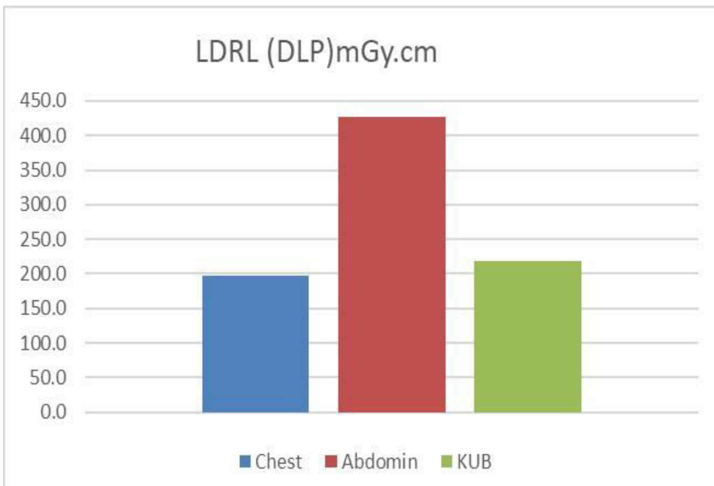

Fig. 3 the local diagnostic reference level (LDRL) based on dose length product (DLP) obtained for the three computed tomography (CT) exams in Zayed Military Hospital

Table 5. the Local Diagnostic Reference Level (Ldrl) Based On Dose Length Product (Dlp) Obtained For The Three Computed Tomography (Ct) Exams In Zayed Military Hospital

LDRL (DLP) mGy.cm			
Protocol			
	Chest	**Abdomen**	**KUB**
Average	175.2	373	206.2
Standard deviation	51.9	100.5	61.9
Minimum	97.7	203.4	144.3
Maximum	337.9	686	385.5
Median	158.9	382.2	175.6
Third quartile	197.4	426.8	218.9

Table 6. Displays the Suggested Ldrls for the Chest, Abdominal Pelvis (Ap), And Kub (Kidneys, Ureters, and Bladder), Determined By Ssde Values and Ldrls for the Chest, Abdominal Pelvis (Ap), and Kub (Kidneys, Ureters, and Bladder) Without Ssde Values.

LDR Without SSDE ($CTDI_{vol}$)mGy			
Protocol			
	Chest	**Abdomen**	**KUB**
Second quartile (50%)	4.4	7.4	3.58
Third quartile (75%)	5.8	8.5	4.83

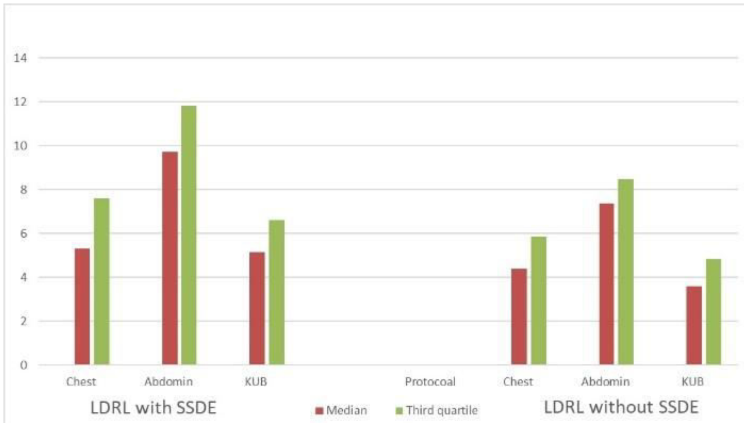

Fig.4 The graph compares LDRL with and without SSDE

Table 7. Displays the Suggested Ldrls for the Chest, Abdominal Pelvis (Ap), and Kub (Kidneys, Ureters, and Bladder), Determined by Ssde Values and Ldrls for the Chest, Abdominal Pelvis (Ap), And Kub (Kidneys, Ureters, And Bladder) with Ssde Values.

LDRL With SSDE (CTDIvol)mGy			
Protocol			
	Chest	Abdomen	KUB
Second quartile (50%)	5.3	9.7	5.13
Third quartile (75%)	7.6	11.8	6.6

Table 6 displays LDRL values without SSDE factor (mGy) as follows: 5.8, 8.5, and 4.3 for the chest, AP, and KUB, respectively. It can be noticed that the LDRL values with SSDE are higher than without SSDE, as shown in Table 7.

DISCUSSION

$CTDI_{vol}$ is a valuable measure for comparing output dosages among different scanners as the acquisition parameters directly influence it. Still, it does not consider the physical attributes of the patient. This is significant because the patient's size and the scanner's radiation output determine how much they will receive. The SSDE is calculated based on the CTDI vol. by utilizing a conversion factor dependent upon the patient's effective diameter.

This study evaluated the LDRLs for the CT examinations conducted at Zayed Military Hospital. As the authors know, no previously published studies have estimated LDRLs based on size-specific dose estimates (SSDEs) in the United Arab Emirates utilizing effective diameter. Contrary to the traditional approach, which relies on $CTDI_{vol}$ values and only considers examination parameters, SSDE considers patient size by integrating patients' D_{eff}. SSDE is essential because of its capacity to provide a more precise evaluation of radiation exposure. SSDE allows a more accurate assessment of a patient's personalized radiation dosage during a CT scan by considering their body size. This information is essential for optimizing the management of radiation doses, establishing DLRs, and minimizing the potential impact on patients.

In the evaluation of the values obtained in this study, a comparison of the third quartile for the conventional DRL was made with international and national values. This study shows lower CTDIvol and DLP values for the conventional DRL for the chest, AP, and KUB exams than for the UK 2019 DRLs [13]. The CTDIvol (mGy) values were as follows: 5.8, 8.5, and 4.83 in this study, while for the UK, they were 8, 10, and 6.3. In addition, a similar observation was for the DLP (mGy.cm) values; this study values were 197.4, 426.8, and 218.9, while for the UK 2019 survey values were, 300, 530, and 290 for chest, AP, and KUB, respectively, the reason for this difference may be owed to the different CT parameters settings from different scanner manufactures and the large sample size involved in the UK survey. Moreover, in this study, DLP values for chest and AP exams were lower than those for the UAE 2015 Initial CT Adult DRLs, which were 443 and 671 mGy.cm, respectively [14]. The LDRLs suggested using SSDEs, which were shown to be in line with the other reported DRLs studies, where the values in SSDE are higher than the CTDIvol for chest and AP examinations. The ratio of SSDE to CTDIvol in this study is 1.31 and 1.38, respectively. A similar ratio was observed in the reported 2021 Moroccan study [12]; the ratio is 1.5 and 1.35 in Moroccan, 1.4 and 1.35 in India, and 1.45 and 1.6 in KSA for chest and AP examinations, respectively.

From Table 8, the reader can notice that this study's SSDE median values are lower than the other reported studies, where the values are 5.3 and 9.7 for chest and AP examination in the current study and 12.15 and 12.16 in Moroccan [12], respectively. In KSA [15], the values were 8 and 10 for chest and AP exams, respectively, and in the USA [16], the values were 8 and 11 for chest and AP exams, respectively. On the other hand, Iran's study also shows a significant increase in both studies for chest and abdomen 13 and 15 mGy, respectively [2]. The higher DRLs found in the Iran study may be attributed to the bigger body sizes of the patients, leading to a more significant amount of radiation being administered during the tests, as the radiation dosage is directly related to patient size. A significant correlation occurred between the $CTDI_{vol}$ and SSDE values, with the SSDE values consistently exceeding the $CTDI_{vol}$ values in all examinations. The correlation between patient size and radiation exposure emphasizes the significance of considering specific patient attributes while establishing diagnostic reference levels (DRLs).

Table 8. Displays Comparison of the SSDE Median Values From This Study with Other Studies

	This Study	Saudi Arabia	Morocco	Iran
Chest	5.3	8	12.16	13
Abdomen	9.7	10	12.15	15

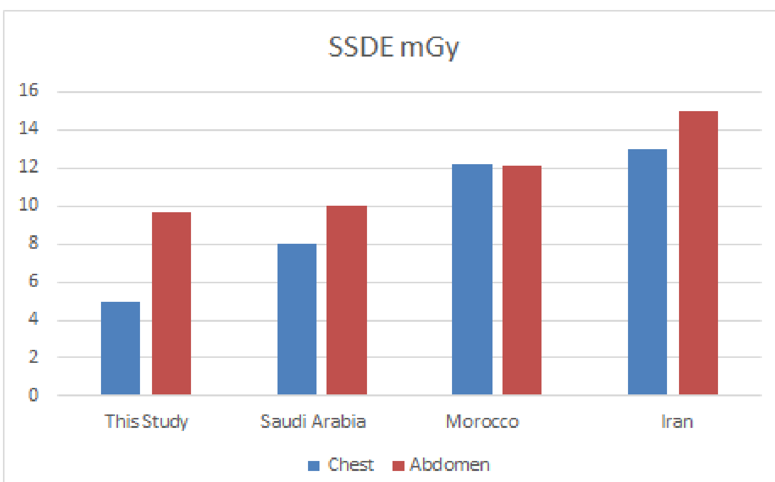

Fig.5 Comparison of median SSDE values obtained from this study with other studies.

This study has limitations. For example, the measurements were only taken at two hospitals; future studies could include additional hospitals and larger patient samples. Furthermore, manual collection was a time-consuming technique for obtaining examination parameters per patient, and human mistakes could occur, which can be reduced by employing computer software.

CONCLUSION

In conclusion, our study utilized manual data collection to determine local DRLs in adult CT exams of the chest, abdomen, pelvis, kidney, and urinary bladder based on the SSDE values. Given that the computation considered the patient's specific size, it is unsurprising that the SSDE values were greater than those of the conventional $CTDI_{vol}$. Due to the tube current's automated adjustment, the SSDE increases during these three exams as the patient's size increases. Our study's values were lower than those of other studies and were consistent with others. As a result of these factors, the SSDE is a helpful tool that may instruct CT users how to reduce radiation exposure, mainly when they utilize it in place of $CTDI_{vol}$ as a diagnostic reference value.

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