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Diagnostic Reference Levels for Computed Tomography Examinations in Iran: A Nationwide Radiation Dose Survey

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ABSTRACT

Introduction: International Commission on Radiological Protection introduced three basic principles of radiation protection, namely justification, optimization, and dose limit. Medical exposure has no dose limits, and generally, diagnostic reference levels are used as a tool for optimization of patient protection.

Material and Methods: Dosimetry was performed on 20 CT scanners located in 14 cities in 12 provinces of Iran. A calibrated pencil-shaped ionization chamber, standard head and body CT dosimetry phantoms and a radiation monitor were used to determine and calculate Computed Tomography Dose Index (CTDI) and Dose Length Product (DLP). The DLP-based estimates of effective dose were derived using effective dose conversion coefficients.

Results: The $_{n}CTDI_{w}$ values for head phantoms fell within the range of 22.05-168.38 and 43.77-426.69 µGy/mAs for 5 and 10mm slice thicknesses, respectively. These values for body phantom were 4.65-146.39 and 9.43-308.92 µGy/mAs for 5 and 10mm slice thicknesses, respectively. The third quartile of $CTDI_{vol}$ and DLP values for head CT examinations were 49.85 mGy and 1161.00 mGy-cm, respectively. The body CT examinations had the values of 8.89 mGy and 370.97 mGy-cm, respectively. The findings of this study revealed that the above-mentioned values can be considered as national diagnostic reference levels for head and body CT examinations in Iran.

Conclusion: The results of the current study suggested that there is a need to re-assess DRLs for CT examinations at regular time intervals by the appropriate regulatory authority which can improve the continuous performance of CT scanners in Iran.

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Introduction

Computed tomography (CT) scan is an advanced imaging modality that uses X-rays and computations to provide cross-sectional images of the body. This method was introduced in 1972, and so far, there have been great advancements in its both technical and clinical aspects. CT scan rebuilds anatomical cross-sectional images based on X-ray attenuation. Today, radiographic examinations play an important role in diagnosing and treating illnesses, making CT scan imaging a modality heavily requested by physicians. CT scan imaging reduces scanning time, and provides three-dimensional, high-quality, and high-resolution anatomical images, especially in low-contrast soft tissues.

Despite all the benefits, CT scans cause higher patient radiation dose compared to other imaging modalities. The received dose depends on a number of factors, including the type of CT scan, device filter, duration of scan acquisition, patient's body thickness, radiation factors, and CT scan protocol. Radiation exposure from CT scan is greater than the exposure from most common imaging modalities, such as conventional radiography. These doses are often close to or greater than the standard levels, which can increase the risk of cancer. Therefore, organizations such as National Council on Radiation Protection and Measurements and Food and Drug Administration (FDA) are concerned about the risks associated with radiation exposure and strive to reduce the unnecessary radiation exposure from medical imaging devices [1]. CT scan exposure can be affected by a number of factors, including the number of scans, tube current, scanning time, patient size, axial scan range, scan pitch, tube voltage, and specific design of the scanner being used [2]. Radiology operators are able to alter tube current, which has a significant effect on determining patient radiation dose [3]. In 2009, a study conducted in the US and England showed a 20% increase in the use of CT scan over the past two decades, suggesting the increased dose received by patients and staff in imaging departments [4]. As a

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result, this issue can cause various adverse effects, such as cancer and cataract in the long-term [5].

International Commission on Radiological Protection introduced three basic principles of radiation protection, namely justification, optimization, and dose limit [6]. Justification refers to the fact that any decision that alters the radiation exposure situation should do more good than harm. Optimization means that the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors. Dose limit implies that the total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits recommended by the Commission.

Dose limits are not applicable since ionizing radiation used for the medical purpose is a justified essential tool that will do better than harm. Additionally, medical exposure of patients has unique considerations which put the suitability of dose limits under question. Therefore, medical exposure does not use dose limits, instead diagnostic reference level (DRL) is used as a reference value for optimizing the protection of patient consistent with good image quality [7]. Various CT dose quantities are adopted using suitable instruments to determine DRLs for CT scan examinations. The quantities are CT dose index (CTDI); volume dose index ($CTDI_{vol}$); weighted dose index ($CTDI_w$); normalized weighted dose index, $CTDI_w$/mAs ($_nCTDI_w$); dose length product (DLP) and effective dose (E).

The CTDI can be calculated through phantoms and using thermoluminescent dosimeter (TLD) or ionizing chamber [8]. It can be measured under certain conditions in cylindrical phantoms, which can image the head and body of the patient. In this state, the rays scattered in phantom develop long sequences in axial dose profile, and the length in which the dose profile should be integrated will be several times as large as slice thickness. FDA has recommended that dose profile should be integrated in a thickness 14 times as large as the thickness of the slice of interest and expressed as dose absorbed in polymethylmethacrilate (PMMA) (known as Perspex in Iran and Leucite in the US) [9]. The utilized cylindrical phantoms should have a diameter of 16 cm for head and 32 cm for the body. Integrating dose in a constant length by an ionization chamber with a sensitive volume length of 100 mm to measure CTDI is called $CTDI_{100}$, and it is defined as follows:

$$CTDI_{100} = \frac{1}{nT}\int_{-50}^{+50} D(z)dz \quad (1)$$

Where, n is the number of slices with the nominal thickness of *T*.

Weighted CTDI or $CTDI_w$ is a type of $CTDI_{100}$, which is calculated in standard phantoms, one for the head and one for the body, in the center of the phantom, as well as its four peripheral holes. It is calculated by the following formula:

$$CTDI_w = \frac{1}{3}CTDI_c + \frac{2}{3}CTDI_p \quad (2)$$

The $CTDI_c$ is a result of measuring dose in the central hole of a phantom, while $CTDI_p$ is the mean value of the dose measured in the peripheral holes of a phantom, each of which is 10 mm away from the external surface of the phantom. If the result of the above formula is divided by mAs (C), the obtained quantity is called normalized $CTDI_w$ or $_nCTDI_w$:

$$_nCTDI_w = \frac{1}{C}\left(\frac{1}{3}CTDI_c + \frac{2}{3}CTDI_p\right) \quad (3)$$

The $_n CTDI_w$ can be used to compare different CT scanners in the same protocol. The CTDI can be calculated in open air ($_nCTDI_{air}$) to calculate an organ and the effective dose of patients. Today, some new methods for calculating CTDI have been proposed [10].

Volume computed tomography dose index ($CTDI_{vol}$) is equal to $CTDI_w$ divided by pitch and it is independent of the patient size and scan length. Therefore, the $CTDI_{vol}$ does not quantify how much radiation any specific patient receives but simply indicates the intensity of the radiation being directed at that patient. The DLP or dose length product is the product of the $CTDI_{vol}$ and the scan length for a group of scans. This number can be summed over the entire exam to give an estimate of the total dose.

Considering the increased number of imaging requests over the past few years [4, 11], some cross-sectional studies have been performed to examine the level of received dose from CT scans. However, a gap in total dosimetry is notable all around Iran. To the best of our knowledge, there is only one study which addressed patient doses in CT scan examinations in Iran [12]. Accordingly, we aimed to determine CT dose levels, propose DRL for CT examinations in Iran and compare the results with the standard levels and the values in other countries.

Materials and Methods

The percentage frequency of each type of CT examinations in Iran has been estimated based on the data obtained from questionnaires distributed to all Iranian universities of medical sciences that were responsible for gathering basic statistical information on the healthcare network. In addition, some useful statistical information was obtained from 'social security organization' [13]. More detailed information was collected on sites where dosimetry was performed. Needless to say, we did not have access to the CT examinations frequency of a large number of departments affiliated to non-governmental and non-social security organization centers data. However, the collected data was not sufficient to estimate the annual number of examinations.

Dosimetry was performed on 20 CT scanners located in 14 cities in 12 provinces of Iran. Five CT scanners were in Tehran, two in Mashhad, Two in Tabriz, and one in each city of Rasht, Qazvin, Arak, Isfahan, Shiraz, Bushehr, Karaj, Ahwaz, Zahedan, Sari, and Amol. Occupationally exposed workers in the 20 studied CT scan centers used different imaging protocols for the same body organs. The reason is that radiographers use different methods to select the number of slices and mA values or the CT scanner facilities, such as the selection of kVp. Dosimetry in open air, as well as head and body phantoms, were conducted for 5 and 10mm slices.

1. CT scan dosimetry phantom

Many factors can influence CTDI, namely kVp, scan mode, and phantom size. Therefore, to measure the dose level, standard head and body CT dosimetry phantoms were used. Head and body phantoms were made of Perspex with a diameter of 16 cm and the 32 cm in cylinders, respectively. Both phantoms had holes along the cylinder axis, which were 1 cm in diameter (Figure 1). The central hole serves to determine $CTDI_c$, while the lateral holes whose distance between their center and the external edge of the phantom is 1 cm were employed to determine $CTDI_p$. When the ionization chamber was placed in each of these holes, other holes were filled with rods made of Perspex. Furthermore, a rod with three transverse holes with a diameter of 1.6 mm was used to adjust the phantom on the CT scan bed. The distance between the center of each hole and its adjacent hole was 2.5 mm, with the holes at 120 degrees in relation to each other at the cross-section of the rod (Figure 2). When adjusting the phantom for measurement, the mentioned inside the central hole of the phantom, and then the phantom was adjusted in the center of a CT rod was placed scanner gantry, such that in the obtained image from a single 10-mm transverse slice, the image of all the three holes was observable. In addition, when adjusting the phantom on the CT scan bed, the absence of lateral, angular, and rotational deviations should be ensured (Figure 3). This is performed using optical rays of the CT scanner and according to the standard protocol [14, 15]. A calibrated 6 cc pencil-shaped ionization chamber with an active length of 10 cm (10X6-3CT Ion Chamber) and a radiation monitor (9015) both made by Radcal Corporation, the USA were used as a dosimeter. The $_nCTDI_{air}$ values have been measured in air by using the ionization chamber as recommended by European Commission (EC) guidelines [14]. To calculate $CTDI_w$ and $_nCTDI_w$, the equations number 2 and 3 were used. The $CTDI_{vol}$ values were calculated by dividing $CTDI_w$ to pitch factors of any examination. Equation 4 was used to calculate DLP values:

$$DLP = CTDI_{vol} \times \text{Scan length} \qquad (4)$$

Finally, the effective dose values were estimated using DLP to effective dose conversion coefficients published by NRPB-W67 [16]

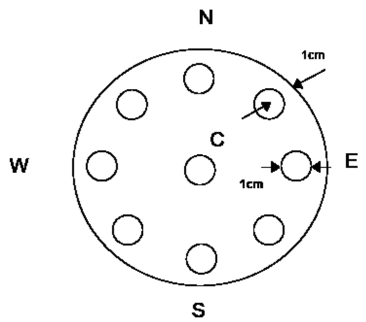

Figure 1. Cross-section of the standard cylindrical head and body phantoms for CT scan dosimetry

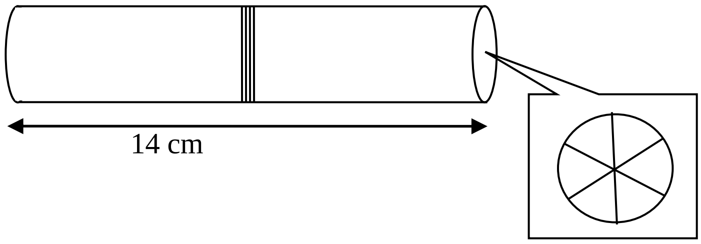

Figure 2. Representation of a rod for adjusting phantom in CT scanner and its lateral holes

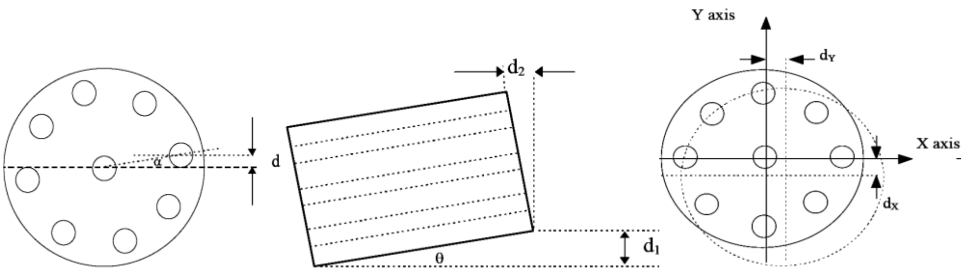

Figure 3. From right to left: lateral, angular, and rotational deviations of the phantom in CT scanner

Results

As Table 1 shows, the percentage frequency of CT examinations in Iran reveals the fact that more examinations are performed on men (63.92%) than women (36.08%). In addition, the findings of the current study showed that examinations with contrast media were 7.23% of all examinations. However, the estimation of the annual number of CT examinations in Iran was not possible due to the lack of information and some doubtful data.

Table 1. Annual percentage frequency of different CT examinations in Iran

CT Examination	Percentage Frequency		
	male	female	Total
Brain	65.22	34.78	77.03
Neck	57.93	42.07	0.79
Chest	50.14	49.86	3.99
Abdomen	59.37	40.63	6.58
Pelvis	57.14	42.86	4.60
Extremity	65.58	34.42	2.02
Cervical Spine	61.73	38.27	1.33
Thoracic Spine	71.61	28.39	1.29
Lumbar Spine	70.48	29.52	1.73
Other	61.74	38.26	0.63
Average	63.92	36.08	100

Table 2. Values related to kVp, mAs, $CTDI_w$, $_nCTDI_w$, and $_nCTDI_{air}$ in the head and body phantoms

CT Scanner No	Slice Thickness (mm)	Head				Body				$_nCTDI_{air}$ (mGy/mAs)
		kVp	mAs	$CTDI_w$ (mGy)	$_nCTDI_w$ (µGy/mAs)	kVp	mAs	$CTDI_w$ (mGy)	$_nCTDI_w$ (µGy/mAs)	
1	5	110	150	18.53	123.54	110	80	11.71	146.39	0.49
	10	110	150	36.26	241.73	110	80	24.71	308.92	
2	5	120	224	20.63	92.11	120	280	7.82	27.92	0.15
	10	120	144	26.23	182.13	120	180	10.07	55.93	
3	5	120	675	27.31	40.46	120	675	6.52	9.65	0.06
	10	120	675	54.40	80.59	120	675	12.99	19.25	
4	5	120	140	12.52	89.42	120	196	7.98	25.40	0.24
	10	120	140	26.34	188.16	120	196	12.76	65.09	
5	5	120	225	30.90	137.32	120	270	5.39	19.95	0.18
	10	120	225	60.74	269.94	120	270	13.62	50.44	
6	5	120	900	20.32	22.57	120	900	4.22	4.69	0.03
	10	120	900	39.39	43.77	120	900	8.55	9.50	
7	5	120	576	18.70	32.47	120	576	3.94	6.83	0.06
	10	120	576	37.79	65.61	120	576	7.46	12.96	
8	5	120	264	29.99	113.62	120	800	17.98	22.47	0.48
	10	120	264	59.60	225.74	120	800	34.87	43.58	
9	5	120	264	39.88	151.06	120	480	13.37	27.85	0.34
	10	120	264	58.20	220.45	120	480	26.68	55.58	
10	5	120	150	22.63	150.87	120	110	3.36	30.52	0.16
	10	120	150	44.42	296.16	120	110	7.15	65.01	
11	5	120	450	12.77	28.37	120	750	3.86	5.15	0.06
	10	120	450	25.29	56.19	120	750	7.53	10.04	
12	5	120	224	23.48	104.82	120	140	4.41	31.48	0.13
	10	120	140	48.33	345.24	120	140	9.28	66.26	
13	5	120	450	15.77	35.04	120	450	3.32	7.38	0.05
	10	120	450	31.63	70.30	120	450	6.68	14.85	
14	5	130	113	14.97	132.49	130	113	4.62	40.87	0.28
	10	130	113	29.02	256.78	130	113	9.45	83.66	
15	5	120	360	43.79	121.65	120	300	7.65	25.51	0.08
	10	120	360	76.11	211.43	120	300	14.16	47.19	
16	5	120	210	17.23	82.07	120	210	3.89	18.54	0.13
	10	120	210	34.10	162.37	120	210	7.68	36.55	
17	5	120	195	20.06	102.85	120	160	3.86	24.14	0.14
	10	120	195	47.77	244.96	120	160	9.82	61.35	
18	5	120	340	57.25	168.38	120	360	17.20	47.78	0.29
	10	120	340	45.07	426.69	120	360	38.61	107.24	
19	5	133	240	29.06	121.08	133	350	11.48	32.79	0.22
	10	133	240	57.70	240.42	133	350	23.25	66.44	
20	5	80	480	10.59	22.05	80	560	2.61	4.65	0.05
	10	80	480	21.04	43.82	80	560	5.28	9.43	

Table3. Statistical values of $CTDI_{vol}$ across all the studied CT scan centers

Type of study	$CTDI_{vol}$ (mGy)					
	Min	1st. quartile	Middle	Mean (±SD)	3rd. quartile	Max
Head	10.59	20.93	30.33	35.88 (17.73)	49.85	76.11
Body	2.64	4.01	5.12	8.25(6.73)	8.89	24.71

Table 4. Statistical values of DLP across all the studied CT scan centers and estimated effective dose

Type of study	DLP (mGy-cm)						Effective Dose (mSv)
	Min	1st. quartile	Middle	Mean (±SD)	3rd. quartile	Max	
Head	179.97	432.19	593.21	748.25(426.91)	1161.00	1603.00	1.57±0.90
Body	126.68	163.27	256.58	324.41(220.66)	370.97	871.63	4.87±3.31

Table 2 shows kVp, mAs, $CTDI_w$ and $_nCTDI_w$ values in head and body phantoms in the selected CT scanners in Iran. The $CTDI_w$ values represent the status of patient dose during different tests with the protocol specified for each CT scanner. Analysis of variance (ANOVA) test indicated that $CTDI_w$ values at both 5 and 10mm slice thicknesses in both head and body phantoms were significantly different among CT scanners ($P<0.05$).

With regard to the performance of different CT scanners, $_nCTDI_w$ values need to be compared. The $_nCTDI_w$ values for head phantoms were within the range of 22.05-168.38 and 43.77-426.69 µGy/mAs for 5 and 10mm slice thicknesses, respectively. These values for body phantom were 4.65-146.39 and 9.43-308.92 µGy/mAs for 5 and 10mm slice thicknesses, respectively. The values demonstrate very wide variation among different CT scanners in performing same examinations.

Table 2 shows the values of $_nCTDI_{air}$ which can be used to obtain effective organ doses with the application of suitable conversion factors or software programs, such as ImPACT CT Patient Dosimetry Calculator. The values are in the range of 0.03-0.49 mGy/mAs.

Finally, as the third quartile of $CTDI_{vol}$ and DLP values are determined as the national reference dose of CT scan imaging, their statistical values in the studied centers are mentioned in Table 3 and 4, and their third quartile is proposed to be the national reference dose of this test in Iran.

Discussion

The obtained results from the percentage frequency of CT examinations in Iran shows that brain examinations are the most frequent exam similar to almost all countries around the world [17]. Abdomen and pelvis examinations are the next frequent ones. More than 88% of all CT examinations in Iran are associated with the brain, abdomen, and pelvis. The significant benefits of CT to healthcare have ensured its continuous steady growth in use and clinical applications of this imaging devise. Consequently, the collective effective dose from CT examinations is gradually increasing. Therefore, to protect patients from the radiobiological effects of unjustified exposure to ionizing radiation, assessing patient dose and establishing DRLs are essential. The examination of DRL values can help us to determine standard doses for patients who are subject to use CT examinations.

Table 2 shows kVp and mAs values used in the dosimetry of head and body phantoms at both 5 and 10mm slice thicknesses. The obtained results showed some variation in kVp and mAs in different CT scanners. The kVp value was almost constant in all scanners; however, mAs values were within the range of 80-900. The CT scanner number 20 had the minimum value of kVp and $nCTDI_w$ in comparison with other CT scanners; therefore, it can be concluded that kVp value is one of the important factors that can affect CTDI.

As Table 2 indicates, the maximum values of $nCTDI_w$ were observed in CT scanner numbers 18 and 1 in head and body examinations, respectively. With the change in the amount of $CTDI_w$, it can be concluded that radiographic techniques, such as kVp and mAs have limited effects on $CTDI_w$. However, there are no explanations for these wide variations in CTDI values in the current study. The major goal of this study was not to find the reason; However, these changes may be due to differences in scanner type, tube filtration, beam shaping filters, scanner age, and work loadings. Future studies can be conducted to delve into the probable reasons for such variations. The results also show the importance of regular quality control of CT scanners.

Table 2 also shows the CTDI values in the head phantom compared to body phantoms. The $CTDI_w$ parameters had higher values in head tests compared to the body. This can be due to the lower diameter of the head compared to the body. In addition, in most of the studied scanners, mAs values used in head scans were higher than those used in the body. It was also observed that increasing slice thickness led to the increase in $CTDI_w$.

Descriptive statistics of $CTDI_{vol}$ and DLP values are presented in Tables 3 and 4. The range of $CTDI_{vol}$ was 10.59-76.11 mGy for head and 2.64-24.71 mGy for body examinations. The DLP values extend from 179.97 to 1603 mGy-cm for head and from 126.68 to 871.63 mGy-cm for body examinations. The coefficient of variation for $CTDI_{vol}$ was large for head (49.9%), $CTDI_{vol}$, body (81.6%) and DLP, head (57.0%); DLP, body (68.0%). Wide variations in the values suggested that significant reductions in the patient dose would be possible without adversely affecting image quality which was reported in studies related to other countries, as well [17].

Table 4 presented the statistical values of DLP across all the studied CT scan centers and estimated effective dose also shows effective doses. In a similar project performed in Iran using RANDO phantom and TLD-100 (developed by Harshaw), researchers found the absorbed dose for the head within the range of 0.5 - 11.45 mGy and for the stomach between 0.15 and 23.23 mGy [18]. In another study conducted in Japan, the effective dose for the head and body were 2.9 and 7.7-10 mSv, respectively [19].

Table 5 shows some of the studies conducted to obtain $CTDI_w$. Table 5 indicated significant differences between the values in this study and those in other investigations. The obtained data revealed that the more the number of CT scanners, the wider the range of changes in $CTDI_w$. Our data showed a maximum range of $CTDI_w$ in both head and body regions. Additionally, it was found that conducting the same test across various CT scanners can cause considerable differences in patient doses. This highlights the necessity of further investigations before purchasing a new CT scanner.

Table 6 reveals the third quartile values of $CTDI_{vol}$ and DLP values (or the DRL values) obtained from different studies. As can be observed, the values obtained in the current research were different from studies in other countries. Factors, such as mAs, kVp, and the number of slices can affect patient dose [20]. In some studies, a questionnaire method was employed for recording the scanning parameters and then estimating CTDI from the data [16, 21-23]. It should be noted that the number of CT scanners studied in Greece, Brazil, Iraq, and this study were 4, 2, 2, and 20, respectively. However, studies in UK, Kenya, and Taiwan included 182, 21 and 285 scanners.

Due to the widespread use of diagnostic protocols, a large number of people are exposed to X-rays, which has been using artificial sources of radiation. Therefore, determining the DRL level is effective in reducing side effects in the received dose and maintaining patient radiation protection. There has been an interest in estimating CT diagnostic reference levels because of the dramatic increase in the use of CT scan examination worldwide [24]. In Ireland, the obtained results from 3305 patients and 34 scanners showed the $CTDI_{vol}$ values for the head and body were 66.58 and 10.12 mGy, respectively [25]. In a comprehensive study of 633 patients, CTDI for the head was 9.3 mGy and 10.4 for the body mGy [26].

Some studies were performed in Iran to propose a reference level; however, they were carried out in a limited number of cities or provinces. Toori et al. Conducted a study in Mazandaran Province, Iran, with seven scanners and estimated $CTDI_w$ value as 42.16 mGy for the head and 10-7.94 mGy for the body (the abdomen and the chest) [20]. In that study, the data was collected using PMMA phantom in an ionizing chamber [20]. In a study by Afzalipour in Tehran, the estimated $CTDI_w$ value for the brain was 50.78 mGy and 9.11 mGy for the body (the abdomen) [27]. Although their findings regarding the head were in agreement with our results, Toori data was different from our results [20]. This discrepancy could be due to the fact that in that article radiation doses were tailored to specific organs, such as the chest and abdomen. In the current study, the total body phantom was studied and also scanner factors were different between these two studies, which might have affected the obtained doses. In 2017, a new method (i.e., quality- control-based dose survey method) to estimate DRL was introduced by researchers who conducted a study on 157 CT scanners in Tehran. Their study indicated that the $CTDI_{vol}$ values were 59 and 10-13 mGy for head and body, respectively. Moreover, the DLP values for head and body were 750, 300-650 mGy-cm, respectively. Their data were the best reference for Tehran CTDI and DLP [28, 29].

It should be noted that examination protocols, such as age can have an effect on $CTDI_{vol}$ and DRL. A study performed in Switzerland showed $CTDI_{vol}$ values were 20 mGy for the brain and 30-60 for the chest and abdomen among children [30]. In Japan, the estimated $CTDI_{vol}$ values were 16 and 11.1-67.7 mGy for head and body, respectively and DLP values for head and body were 16 and 394-847.9 mGy-cm among children [31]. As can be seen, children were exposed to much lower doses than adults. However, there are some countries where children are exposed to adult conditions [32, 33].

Table 5. Comparing the range of $CTDI_w$ (mGy) values obtained from 10-mm slices across different Studies

CT Scan Type	This Study	IAEA [34]	Greece [35]	Egypt [36]	Brazil [8]	Iraq [37]	Tanzania [38]	Taiwan [21]	Kenya [23]	Iran (Mazandaran) [20]
head	21.04-76.11	60	27-50	36-69	39.9-42.5	45.6	63.9	55	51	42.16
body	5.28-38.61	35	13.9-26.9	11-30	-	12-22.1	12.2-35.6	20-22	21-24	7.94-10

Table 6. Third Quartile Values of $CTDI_{vol}$ and DLP values in Some Studies

CT Scan Type	CTDIvol (mGy)							DLP (mGy-cm)						
	this Study	Iran [12]	UK [39]	Australia [40]	India [41]	Nigerian [42]	Ireland [25]	this Study	Iran [12]	UK [39]	Australia [40]	India [41]	Nigeria [42]	Ireland [25]
head	50	43	58	60	32	61	66.58	1161	700	890	1000	925	1310	10.12
body	9	10	8.5-11	15	12-16	17-20	10.12	371	550	110-900	700	456-482	735-1486	850

Conclusion

In this study, national DRLs were calculated for most frequent CT examinations in Iran. The values obtained in this study were in line with the values reported in the literature. To ensure that the CT scanners in Iran are improving their performance continuously, it will be necessary to re-assess DRLs for CT examinations at regular time intervals by the appropriate regulatory authority. The results also show the importance of regular quality control of CT scanners.

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