ORIGINAL ARTICLE

Determination of Effective Dose and Local Diagnostic Reference Level for Abdomen and Pelvis Computed Tomography with and without Contrast Agent

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Abstract

Purpose: The International Commission on Radiological Protection (ICRP) recommends that each community produces its own Diagnostic Reference Levels (DRL), taking into account the diversity of ethnicities, imaging protocols, and equipment types in individual communities. The goal of this examination is to research the DRL for the abdominal-pelvis Computed Tomography (CT) examinations accomplished at our clinical institution.

Materials and Methods: The information on 600 patients, recorded by the radiology center from May 1, 2022, to May 1, 2023, has been collected. All scans were performed using a GE Healthcare 16-slice scanner. Four imaging protocols were used for imaging the abdomen and pelvis of patients, including without contrast agent, with oral contrast agent, with contrast agent injection, and triple-phase. The median and seventy-fifth percentile values for the distribution of the CT dose index ($CTDI_{vol}$ in mGy) and dose length product (DLP) parameters have been computed.

Results: Effective dose values in the triple-phase ranged from 33.30 to 38.12 ± 0.1 mSv for patients with different DLP values. For scans without and with oral contrast agents, the effective dose ranged from 8.68 to 9.45 ± 0.2 mSv. Scans with contrast agent injection had an effective dose ranging from 10.83 to 11.45 ± 0.1 mSv, based on the total value of DLP. The determined DRLs were as follows: for abdomen and pelvis CT without contrast agent and oral contrast agent, the DRLs were 12 mGy and 605 mGy.cm, respectively. For the abdomen and pelvis CT procedures in the triple-phase, the DRLs were 11 mGy and 2382 mGy.cm, respectively. Finally, for the abdomen and pelvis CT with contrast agent injection protocols, the DRLs were 16 mGy and 1484 mGy.cm, respectively. The maximum Size-Specific Dose Estimate (SSDE) precontrast in the triple-phase protocol was 23.10±0.2 mGy.

Conclusion: The proposed DRL values for all imaging protocols, especially the triple-phase, exceed the international guidelines for DRL values in DLP and $CTDI_{vol}$ (mGy). Therefore, methods such as reducing the scan length should be considered to minimize the radiation dose to patients while preserving image quality.

Keywords: Abdominal Computed Tomography Scan; Contrast Agent; Radiation Dosimetry.

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1. Introduction

High-resolution images of the body's internal organs can be created using the imaging technique known as CT. As one of the quickest imaging techniques available, CT scans play a crucial role in the diagnosis of many diseases [1]. Despite its advantages, which make CT a gold standard for specific diagnostic purposes, the measurements of X-ray radiation remain an important source of public health concerns [2]. Up to 50% of ionizing radiation exposure to humans today is attributed to radiology techniques, with CT playing the most significant role among them [3]. Compared to traditional radiography, a CT scan has a higher radiation dose [4]. One abdominal CT scan, for instance, has a radiation dose comparable to between 100 and 250 chest X-rays [5]. The Effective Dose (ED) from a CT scan is between two and twenty mSv for the brain and abdomen-pelvis, respectively. This is comparable to one to seven years of background dose from the natural environment [6].

In the United States, around 80 million CT scans are conducted every year, with a yearly growth rate of roughly 10% [6]. This statistic showed a marked increase in CT usage compared to 3 million scans carried out in 1980 [7]. The population's exposure to radiation may increase as a result of increased CT use [8]. One of the most significant side effects of ionizing radiation is the development of cancer. There is compelling evidence that even brief exposure to radiation can increase cancer risk [9]. According to the US Food and Drug Administration, an effective dose of 10 millisieverts during a CT scan will raise the risk of cancer by about 1 in 2000 [10]. As a result, performing 80 million CT scans will lead to 40,000 cases of cancer [11]. These explanations show that CT scans have both beneficial and harmful aspects.

Abdominal and pelvic computed tomograms are among the most commonly performed radiologic procedures in the world, including in the U.S., which is why they are frequently sought for diagnostic purposes [12].

In practice, the concept of a diagnostic reference level has been suggested multiple times by the International Commission on Radiological Protection (ICRP) and serves as an effective tool for Nuclear Doctors and Diagnostic and Interventional Radiology practitioners to enhance their methods [13]. For determining an effective dose, DRLs need to be utilized at an investigative level. In cases where DRLs are consistently exceeded, a local assessment is usually conducted [14].

To achieve a balance between image quality and patient dosage, the use of DRLs can be applied. DRLs are also utilized to identify instances of high radiation doses (3rd quartile) and ensure that patients receive the lowest possible radiation dose. Regularly implementing DRLs is a valuable technique for optimizing CT practices over time [14].

It is recommended that each community develops its own set of DRLs, considering the diversity of ethnicities, imaging protocols, and equipment types present within each community [12].

Creating local DRLs offers several benefits, including the ability to assess the performance of a medical center against international standards and document the patient safety program. These aspects are crucial and necessary for accrediting medical institutions in today's healthcare landscape [12].

For the calculation of DRLs, two parameters, CTDIvol and DLP, are measured in 32 or 16-inch diameter acrylic phantoms at the conclusion of each scan. These measurements are displayed on the CT scanner console [13].

This study was conducted to establish the local DRLs for CT scans with and without contrast agent procedures in the abdominal and pelvic regions. These DRLs can also be determined at the hospital level.

2. Materials and Methods

2.1. Study Population

The study was conducted at the Radiology Department of Chamran Hospital in Kermanshah, Iran. 600 patients were included in the evaluation, consisting of 391 males (65%) and 209 females (35%). These patients underwent CT scans of the abdomen and pelvis, either with or without contrast. Out of the total patients, 450 underwent CT scans without the use of a contrast agent, 100 patients received contrast agent injections for their CT scans, and 50 patients underwent oral CT scans. The age range of the patients

was between 30 and 85 years, with an average age of 57.5 years.

2.2. Data Collection

Data for this study was collected from the CT scanner and the Picture Archiving and Communication System (PACS). Various types of information were included in the data, such as patient demographics (gender and age), frequency of referrals, insurance details, reports of CT scans, acquisition and exposure data (exposure parameters), and dosimetry data ($CTDI_{vol}$ and DLP).

The data collection period spanned from May 1, 2022, to May 1, 2023.

2.3. CT Model and Protocol

All scans in the study were performed using the GE Healthcare 16 Slices CT scanner. For the injection protocols, a Medtron injector was utilized.

Table 1 shows the protocols employed for triple-phase abdomen and pelvis imaging. Table 2 shows the protocols utilized for abdomen and pelvis imaging without the use of a contrast agent and with an oral contrast agent. Table 3 exhibits the protocols employed for abdomen and pelvis imaging with the injection of a contrast agent.

All CT scans of the abdomen and pelvis were conducted in accordance with a requisition form that outlined the relevant clinical indications. These indications encompassed various conditions such as

Table 1. Parameters of protocols used for triple-phase abdomen and pelvis imaging

Imaging protocol Imaging parameters	Precontrast	Arterial	Portal	Delay
kV	120	120	120	120
mAs	80	170	200	200
Tilt	0	0	0	0
sFOV	Large	Large	Large	Large
Interval (mm)	5	5	5	5
Thick Speed	5	5	5	5
Scan Type	Helical Full 1 s	Helical Full 0.8 s	Helical Full 0.8 s	Helical Full 0.8 s
Total Exposure Time	8.4	14.04	14.04	5.16

Table 2. Parameters of protocols used for abdomen and pelvis without contrast and oral contrast agent imaging

Imaging parameters	
kV	120
mAs	80
Tilt	0
sFOV	Large
Interval (mm)	5
Thick Speed	5
Scan Type	Helical Full 1 s
Total Exposure Time	8.4

Table 3. Parameters of protocols used for abdomen and pelvis with contrast agent injection

Imaging protocol Imaging parameters	Precontrast	With Contrast
kV	120	120
mAs	80	170
Tilt	0	0
sFOV	Large	Large
Interval (mm)	5	5
Thick Speed	5	5
Scan Type	Helical Full 1 s	Helical Full 0.8 s
Total Exposure Time	8.4	14.04

tumors, abdominal pain, mesenteric ischemia, injuries, infections, and other disorders affecting the abdominal organs.

To ensure consistency, each patient was positioned in a prone position with a pillow under his or her abdomen and their arms extended above their head. This positioning adhered to a standardized protocol developed in accordance with the guidelines set forth by the American College of Radiology for CT abdominal scans [15].

In the abdominal CT scan oral protocol, the patient begins consuming 20 ml of meglumine dissolved in 1.5 liters of water, starting 2 hours prior to the imaging procedure.

In the triple-phase abdomen and pelvis imaging, 85±3 ml of Visipaque was administered, with a contrast injection rate of 3-5 mL/s.

For each patient group, a CT scan was conducted, and different image processing techniques, such as Multiplanar Reformation (MPR), coronal, or sagittal views, were utilized based on the treatment requirements.

2.4. ED Calculation

ED is commonly utilized as a parameter in estimating stochastic effects, such as cancer and hereditary effects, in medical imaging. To determine ED, DLP, and conversion factors (referred to as "k-factors") from DLP to ED need to be employed. CT scanners generate DLP values, while Monte Carlo simulations generate k-factors. These simulations involve exposing computational human phantoms to simulated CT X-ray beams. K-factors are influenced by factors such as age, scan area, and tube voltage (kV). In this study, both adult and pediatric patients' k-factors from ICRP publication 103 were utilized [14]. We assumed that k-factors were 0.015 for 120 kV and the abdomen and pelvis region. DLP (mGy.cm) and k-factor ($mSv.mGy^{-1}.cm^{-1}$) are multiplied to determine ED (mSv) for the abdomen. As depicted in Equation 1:

$$ED = DLP \times k - factor \quad (1)$$

In this equation, DLP will be obtained by the output of the device and the k-factor is the conversion factor.

2.5. Calculation of DRL

The DRL was calculated from each radiological examination using the third quartile of the median, based on the recommendations of the ICRP [13].

2.6. Calculation of Size-Specific Dose Estimation (SSDE)

The American Association of Physicists in Medicine (AAPM) has released 204 SSDE concepts. These concepts are determined by multiplying a size-dependent conversion coefficient and $CTDI_{vol}$. This approach allows for a straightforward estimation of the average patient dose at the center of the scan area, taking into account the patient's size. The calculation of SSDE can be easily done by measuring the scanner output, specifically $CTDI_{vol}$. The value of SSDE can be determined using the Equations 2 and 3 [16].

$$f_{size}^{32X}=3.7043\times e^{-0.0367\,Deff} \quad (2)$$

$$\text{size specific dose estimate} = SSDE = f_{size}^{32X} \times CTDI_{vol}^{32} \quad (3)$$

Where the D_{eff} is the effective diameter of the body in the selected slice.

The CT scan image depicted in Figure 1 is used to measure the AP and lateral diameters necessary for the calculation of SSDE.

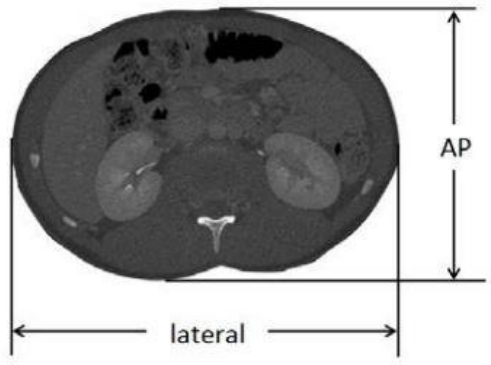

Figure 1. Method of measuring AP and lateral diameters on the CT scan image

2.7. Statistical Analysis

As far as descriptive statistics are concerned, continuous data were shown as mean and Standard

Deviation (SD), while categorical variables were shown as percentage numbers. A statistical analysis was conducted with IBM SPSS version 21(IBM Corporation, Armonk, New York, USA).

3. Results

The effective dose values in the precontrast phase ranged from 13.01 to 14.26 ± 0.1 mSv for patients with different DLP values. In the arterial phase, the range was from 6.05 to 7.65 ± 0.2 mSv, in the portal phase it ranged from 7.11 to 8.10 ± 0.1 mSv, and in the delay phase, it ranged from 7.11 to 8.10 ± 0.1 mSv. It is noteworthy that the maximum value is twice as low as the minimum value, indicating that patient doses were optimized based on this variation.

The effective dose value for the entire test ranged from 33.30 to 38.12 ± 0.3 mSv, as determined by the total value of DLP.

Table 4 contains the ranges of the different parameters in the triple-phase abdomen and pelvis protocols.

Although the dose per slice is similar across all CT machines, the dose per procedure may differ slightly depending on how long the scan takes. The length of the scan (in millimeters) directly affects the overall dose. Therefore, choosing the right scan length is essential for reducing variation. Patient height variations are one factor that may influence scan length. In CT scan imaging of the abdomen and pelvis, the pelvis may not be included in the image, although the imaging protocol starts from the diaphragm and continues to the patient's pubis.

Effective dose values in the abdomen and pelvis without contrast agent and oral contrast agent protocols ranged from 8.68 to 9.45 ± 0.1 mSv for patients with different DLP values. The maximum value shall be twice as low as the minimum value. These variations indicated that the doses of patients have been optimized.

Table 5 contains the ranges of the different parameters in the abdomen and pelvis without contrast and oral contrast agent protocols.

Effective dose values in the abdomen and pelvis with contrast agent injection protocols ranged from 10.83 to 11.41 ± 0.1 mSv for patients with different DLP values. The maximum value shall be twice as low as the minimum value. These variations indicated that the doses of patients have been optimized.

Table 6 contains the ranges of the different parameters in the abdomen and pelvis with contrast agent injection protocols.

Table 7 shows the values of SSDE for the Precontrast in the triple-phase protocol. The largest value refers to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

Table 8 shows the values of SSDE for the arterial in the triple-phase protocol. The largest value refers to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

Table 9 shows the values of SSDE for the portal in the triple-phase protocol. The largest value refers to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

Table 10 shows the values of SSDE for the delay in the triple-phase protocol. The largest value refers to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

Table 11 shows the values of SSDE for the abdomen and pelvis CT without contrast agent and oral contrast agent protocols. The largest value refers

Table 4. Values effective dose, $CTDI_{vol}$ and DLP in CT abdomen and Pelvis procedure (triple-phase)

Steps	$CTDI_{vol}$ (mGy)	DLP (mGy-cm)	Phantom (cm)	ED (mSv)
Precontrast	17.05 (15-19.10)	909.35 (867.51-951.20)	Body 32	13.63 (13.01-14.26)
Arterial	7.05 (5-9.10)	456.86 (403.42-510.30)	Body 32	6.85 (6.05- 7.65)
Portal	8.62 (6.12-11.12)	507.41 (474.61-540.21)	Body 32	7.60 (7.11- 8.10)
Delay	8.62 (6.12-11.12)	507.41 (474.61-540.21)	Body 32	7.60 (7.11- 8.10)
Total	10.33 (8.06-12.61)	2381.03 (2220.15-2541.92)	-	35.71 (33.30- 38.12)

Table 5. Values effective dose, $CTDI_{vol}$ and DLP in abdomen and pelvis CT without contrast agent and oral contrast agent protocols

Protocols	$CTDI_{vol}$ (mGy)	DLP (mGy-cm)	Phantom (cm)	ED (mSv)
abdomen and pelvis CT without contrast and oral contrast agent	11.76 (9.42-14.11)	604.64 (579.12-630.16)	Body 32	9.06 (8.68-9.45)

Table 6. Values effective dose, $CTDI_{vol}$ and DLP in abdominal and pelvis CT with contrast agent injection protocols

Steps	$CTDI_{vol}$ (mGy)	DLP (mGy-cm)	Phantom (cm)	ED (mSv)
Precontrast	14.98 (14.01-15.95)	701.22 (682.12-720.32)	Body 32	10.51 (10.23-10.80)
With Contrast	15.40 (14.60-16.20)	782.22 (762.12-802.32)	Body 32	11.73 (11.43- 12.03)
Total	15.19 (14.30-16.07)	741.77 (722.22-761.32)	-	11.12 (10.83- 11.41)

Table 7. SSDE values in mGy for different effective diameters and the precontrast in triple-phase protocol

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	15.00	23.10±0.2
26	1.43	15.20	21.73±0.1
28	1.32	15.60	20.59±0.1
30	1.23	15.90	19.55±0.2
32	1.16	16.30	18.90±0.3
34	1.09	16.50	17.98±0.1
36	1.03	16.70	17.20±0.3
38	0.98	16.90	16.56±0.1
40	0.92	17.10	15.73±0.2
42	0.88	17.40	15.31±0.2
44	0.84	17.60	14.78±0.1
46	0.81	17.90	14.49±0.2
48	0.77	18.00	13.86±0.3
50	0.74	18.20	13.46±0.1
52	0.71	18.60	13.20±0.3
54	0.68	18.70	12.71±0.4
56	0.66	18.90	12.47±0.1
58	0.64	19.00	12.16±0.3
60	0.62	19.10	11.84±0.1

to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

Table 12 shows the values of SSDE for the Precontrast in abdominal and pelvis CT with contrast agent injection protocols. The largest value refers to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

Table 13 shows the values of SSDE for the "with contrast" in abdominal and pelvis CT with contrast agent injection protocols. The largest value refers to a patient with an effective diameter of 24 cm, and the smallest refers to one with 60 cm.

The values of DLP (mGy. cm) and $CTDI_{vol}$ (mGy) obtained from the research with the results of other researchers are shown in Figures 2 and 3, respectively.

4. Discussion

The amount of radiation absorbed and the sensitivity of the organ for those exposed to ionizing radiation determine the potential risk of cancer in a direct proportion. As a result, it is critical to restrict radiation exposure in order to reduce the possibility of getting cancer or experiencing deterministic side effects. To prevent unneeded radiation exposure, the

Table 8. SSDE values in mGy for different effective diameters and the arterial in triple-phase protocol

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	5.00	7.70±0.2
26	1.43	5.12	7.32±0.2
28	1.32	5.25	6.93±0.4
30	1.23	5.35	6.58±0.1
32	1.16	5.56	6.44±0.2
34	1.09	5.72	6.23±0.3
36	1.03	5.90	6.07±0.5
38	0.98	6.01	5.88±0.3
40	0.92	6.21	5.71±0.2
42	0.88	6.35	5.58±0.2
44	0.84	6.55	5.50±0.4
46	0.81	6.74	5.45±0.1
48	0.77	6.92	5.32±0.4
50	0.74	7.25	5.36±0.5
52	0.71	7.55	5.36±0.1
54	0.68	7.86	5.34±0.1
56	0.66	8.35	5.51±0.2
58	0.64	9.08	5.81±0.1
60	0.62	9.10	5.64±0.2

Table 9. SSDE values in mGy for different effective diameters and the portal in triple-phase protocol

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	6.12	9.42±0.1
26	1.43	6.23	8.90±0.2
28	1.32	6.42	8.47±0.6
30	1.23	6.62	8.14±0.2
32	1.16	6.85	7.94±0.1
34	1.09	7.08	7.71±0.2
36	1.03	7.30	7.51±0.5
38	0.98	7.55	7.39±0.3
40	0.92	7.80	7.17±0.1
42	0.88	8.04	7.07±0.2
44	0.84	8.32	6.98±0.3
46	0.81	8.55	6.92±0.1
48	0.77	8.85	6.81±0.2
50	0.74	9.26	6.85±0.5
52	0.71	9.55	6.77±0.3
54	0.68	9.85	6.69±0.1
56	0.66	10.25	6.76±0.3
58	0.64	10.55	6.70±0.1
60	0.62	11.12	6.85±0.1

IAEA implores member nations to implement DRLs. This study examines the development of a regional DRL for CT pelvis and abdominal procedures.

Based on Tables 4 and 5, the effective dose in the triple-phase protocol is significantly higher compared to the abdomen and pelvis CT protocols without contrast agents and oral contrast agents. This is because the triple-phase protocol involves four stages of imaging, namely precontrast, arterial, portal, and delay, whereas the abdomen and pelvis CT protocols without contrast agents and oral contrast agents only require imaging in a single step.

Based on Tables 5 and 6, the effective dose in the abdominal and pelvis CT protocols with contrast agent injection is significantly higher compared to the abdomen and pelvis CT protocols without contrast agent

Table 10. SSDE values in mGy for different effective diameters and the delay in triple-phase protocol

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	6.12	9.42±0.1
26	1.43	6.23	8.90±0.2
28	1.32	6.42	8.47±0.6
30	1.23	6.62	8.14±0.2
32	1.16	6.85	7.94±0.1
34	1.09	7.08	7.71±0.2
36	1.03	7.30	7.51±0.5
38	0.98	7.55	7.39±0.3
40	0.92	7.80	7.17±0.1
42	0.88	8.04	7.07±0.2
44	0.84	8.32	6.98±0.3
46	0.81	8.55	6.92±0.1
48	0.77	8.85	6.81±0.2
50	0.74	9.26	6.85±0.5
52	0.71	9.55	6.77±0.3
54	0.68	9.85	6.69±0.1
56	0.66	10.25	6.76±0.3
58	0.64	10.55	6.70±0.1
60	0.62	11.12	6.85±0.1

Table 11. SSDE values in mGy for different effective diameters and the abdomen and pelvis CT without contrast agent and oral contrast agent protocols

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	9.42	14.50±0.1
26	1.43	9.75	13.94±0.2
28	1.32	9.95	13.13±0.6
30	1.23	10.25	12.60±0.2
32	1.16	10.45	12.12±0.1
34	1.09	10.75	11.71±0.2
36	1.03	10.95	11.27±0.5
38	0.98	11.10	10.87±0.3
40	0.92	11.35	10.44±0.1
42	0.88	11.55	10.16±0.2
44	0.84	11.95	10.03±0.3
46	0.81	12.32	9.97±0.1
48	0.77	12.75	9.81±0.2
50	0.74	13.01	9.62±0.5
52	0.71	13.23	9.39±0.3
54	0.68	13.45	9.14±0.1
56	0.66	13.69	9.03±0.3
58	0.64	13.97	8.94±0.1
60	0.62	14.11	8.74±0.1

and oral contrast agent. This is because the CT protocols with contrast agent injection involve two stages of imaging, namely precontrast and with contrast, whereas the CT protocols without contrast agent and oral contrast agent only require imaging in a single step.

In comparison to European countries, in Table 4 and Figures 2 and 3, the DRL value for a full range of DLP and $CTDI_{vol}$ values from triple phase protocol is more than double [17].

In comparison to European countries, Table 4 and Figures 2 and 3 show the DRLs for a full DLP and $CTDI_{vol}$ level of precontrast in triple phase protocols are more than double [17].

As shown in Table 4 and Figures 2 and 3 above, compared with European countries the value of DRL for total DLP and $CTDI_{vol}$ on arterial triple phase protocols is lower [17].

Table 12. SSDE values in mGy for different effective diameters and the precontrast in abdominal and pelvis CT with contrast agent injection protocols

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	14.01	21.57
26	1.43	14.12	20.19±0.2
28	1.32	14.25	18.81±0.6
30	1.23	14.32	17.61±0.2
32	1.16	14.45	16.76±0.1
34	1.09	14.56	15.87±0.2
36	1.03	14.75	15.19±0.5
38	0.98	14.92	14.62±0.3
40	0.92	15.01	13.80±0.1
42	0.88	15.10	13.28±0.2
44	0.84	15.19	12.75±0.3
46	0.81	15.25	12.35±0.1
48	0.77	15.37	11.83±0.2
50	0.74	15.46	11.44±0.5
52	0.71	15.55	11.04±0.3
54	0.68	15.67	10.65±0.1
56	0.66	15.79	10.42±0.3
58	0.64	15.92	10.18±0.1
60	0.62	15.95	9.88±0.1

Table 13. SSDE values in mGy for different effective diameters and the "with contrast" in abdominal and pelvis CT with contrast agent injection protocols

Lat+AP (Dim (cm))-Effective Dim	Conversion Factor	$CTDI_{vol}$ (mGy)	Size specific dose estimate (mGy)
24	1.54	14.60	22.48±0.1
26	1.43	14.75	21.09±0.2
28	1.32	14.82	19.56±0.2
30	1.23	14.95	18.38±0.2
32	1.16	15.01	17.41±0.1
34	1.09	15.12	16.48±0.2
36	1.03	15.22	15.67±0.5
38	0.98	15.35	15.04±0.3
40	0.92	15.47	14.23±0.1
42	0.88	15.59	13.71±0.2
44	0.84	15.75	13.23±0.3
46	0.81	15.79	12.78±0.1
48	0.77	15.85	12.20±0.2
50	0.74	15.95	11.80±0.5
52	0.71	16.00	11.36±0.3
54	0.68	16.06	10.92±0.1
56	0.66	16.13	10.64±0.3
58	0.64	16.15	10.33±0.1
60	0.62	16.20	10.04±0.1

The DRLs are lower than the countries in Europe, according to Table 4 and Figures 2 and 3, which show that DLP and $CTDI_{vol}$ values on portal within triple-phase Protocols have been reduced [17].

The DRL of the $CTDI_{vol}$ is lower compared to European countries as shown in Table 4 and Figure 3 below, with respect to delay phase values under triple-phase protocols [17].

Table 5 and Figure 2 show that compared to European countries, a higher DRL is observed for DLP in the absence of contrast agent and oral contrast agent protocols [17].

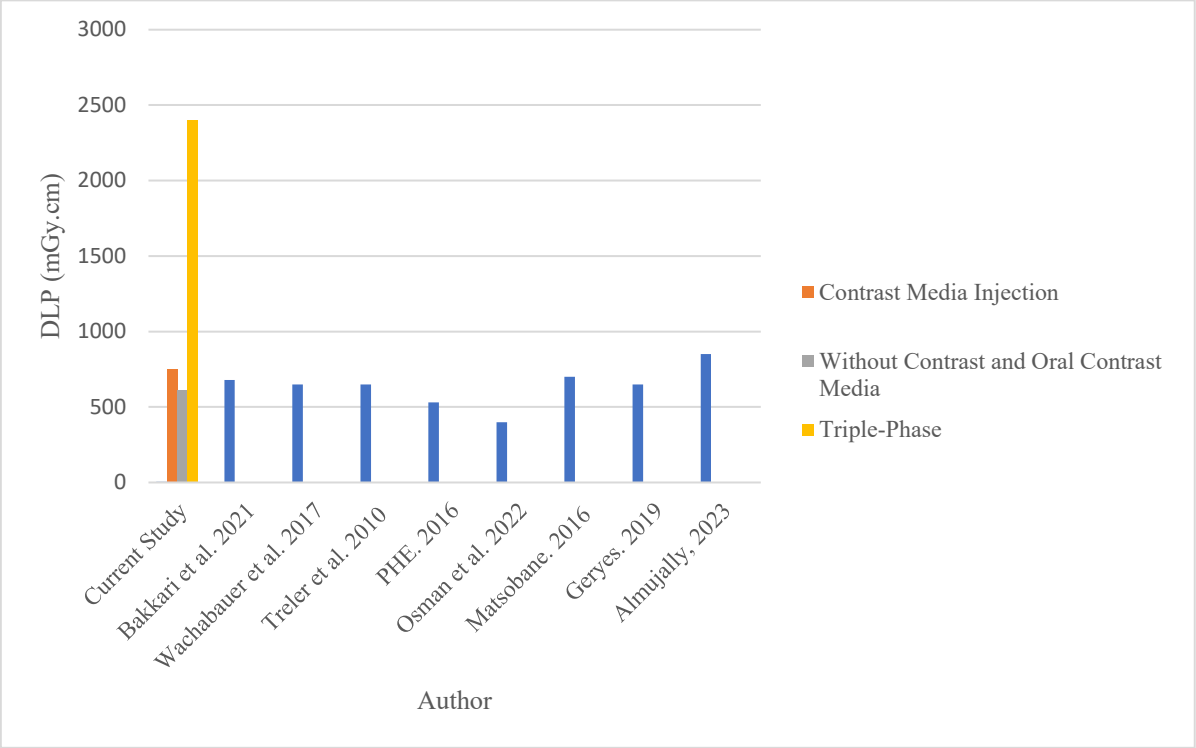

Figure 2. Comparing the DLP's third quartile value (mGy. cm) to other studies that have been published

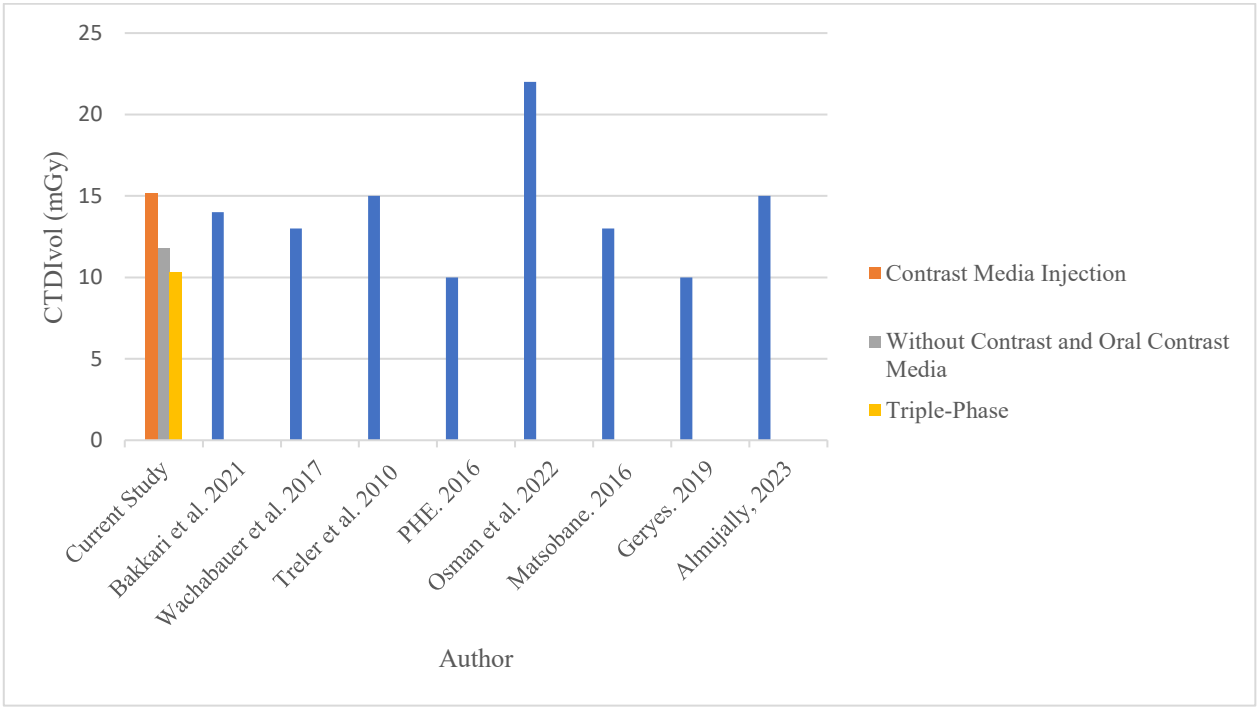

Figure 3. Comparing the $CTDI_{vol}$'s third quartile value (mGy) to other studies that have been published in the past

Compared to European countries, according to Table 5 and Figure 3, the DRL values for $CTDI_{vol}$ in the absence of contrast agent and oral contrast agent protocols are more than double [17].

Compared to European countries, according to Table 6 and Figure 2, the DRL for "with contrast" agent injection is higher in DLP values [17].

The DRL for $CTDI_{vol}$ values in with contrast agent injection is greater against European countries, as shown in Table 6 and Figures 2 and 3 [17].

In comparison to published studies, Figures 2 and 3 show the $CTDI_{vol}$ (mGy) and DLP (mGy.cm). In comparison to earlier studies published, the current DRL values for CT procedures involving the abdomen and pelvis are comparable. The DRL value for triple phase and contrast agent injection into DLP is higher, compared to the studies that have been published so far, but $CTDI_{vol}$ does not fall within these studies [12, 18-22].

The value of $CTDI_{vol}$ in the research by Osman *et al.* [20] is higher due to the use of higher mAs (mean 240) compared to the results of our research.

The total dose in the triple-phase protocol is higher compared to other protocols because it includes all four phases (precontrast, arterial, portal, and delay). Each individual phase in the triple-phase protocol, however, typically has a similar dosage to that of other protocols. The cumulative effect of performing multiple phases in the triple-phase protocol leads to a higher overall dose.

In comparison to the research conducted by Almujal *et al.* [12], our research showed lower values of DLP in the contrast agent injection protocol and almost equal values of $CTDI_{vol}$. This difference could be attributed to the choice of mAs (339–4461) and scan length (151–930 mm) in their protocol, which were higher than those used in our research.

Tables 7-13 demonstrates that the SSDE values for all protocols decrease as the effective diameter increases, which is attributed to the change in the values of $CTDI_{vol}$. This result was in accordance with the research results by Rajaraman *et al.* [23].

The value of SSDE in Ahmadifard *et al.* [24] research, where the abdomen and pelvis were without contrast agents, was equal to 13.58 in the body diameter of 26 cm, and this value in our research was equal to 13.94±0.2 in the same body diameter.

5. Conclusion

The proposed DRL values for all imaging protocols, especially triple-phase, are higher than the international guidelines for DRL values in DLP and $CTDI_{vol}$ (mGy). The studies showed a very small association between the dose of radiation, CT equipment type, and slice number. A similar dose per slice in all CT machines, although due to differences in scan duration and clinical indication, there is a reasonable variation in the doses used for different imaging procedures. Therefore, it is recommended to shorten the duration of imaging so that patients are provided with a minimum possible dose of radiation while preserving image quality. Among the methods that can be used to reduce the patient's dose is the use of advanced CT scanning equipment and proper training of imaging personnel.

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