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RESEARCH

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Recommended National diagnostic reference levels for adult abdomino-pelvic computed tomography examinations in Ethiopia

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Abstract

Background Computed Tomography (CT) plays a crucial role for diagnostic purpose; however, delivering optimal radiation dose to patients is the common challenge.

Objective The main objective of this study was to establish abdomino-pelvic national diagnostic reference levels (NDRL) in Ethiopia.

Methods A quantitative cross-sectional study design was employed in 23 health facilities. A total of 800 abdomino-pelvic CT scans of patients were evaluated from January, 2023 to March, 2024. Scan parameters, patient profile and CT dose describers were collected using a structured data collection format. Third quartile median values of the volumetric CT dose index ($CTDI_{vol}$) and total dose length product (TDLP) were calculated using Microsoft Excel 2016 and SPSS software version 26. Finally, the results were compared with national, regional, and international DRL.

Result The third quartile values obtained from the median values of TDLP and $CTDI_{vol}$ that were used as NDRL were 1387 mGy.cm and 10.5 mGy, respectively. This study found the highest and lowest median TDLP values of 3370mGy.cm and 273.7mGy.cm respectively.

Conclusion The authors of this manuscript recommend that the NDRLs presented in this document can be used as a baseline against which hospitals future CT abdomino-pelvic median dose describers in Ethiopia can be compared.

Keywords Volumetric computed tomography dose index, Abdomino-pelvic computed tomography, Dose length product, National diagnostic reference levels

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Introduction

Computed tomography (CT) scanners have been used in diagnostic radiology since the early 1970s and have gained popularity worldwide owing to their substantial and life-saving clinical benefits for patients [1, 2]. By its nature, CT involves larger radiation doses than the more common, conventional x-ray imaging procedures [3, 4]. The CT radiation dose pertains to several factors including the type of scanner, the filtration, the scan time, the body thickness; as well as the exposure parameters and imaging protocols [5, 6].

The International Commission on Radiological Protection (ICRP) [7–10] has recommended diagnostic reference levels (DRLs) as operational instruments for optimising patient safety in radiological imaging. DRLs are used to identify imaging procedures, that cause unusually high patient doses and should therefore be reviewed concerning their optimization and corrective action applied where needed [11]. To ensure that the dose to each patient is as low as reasonably achievable (ALARA) for the clinical purpose of the CT examination, examination-specific scan protocols that are tailored to the patient's age or size, region of imaging, and clinical indication must be applied in order to optimize patient protection in CT [11–13].

Optimization of CT examination through comparison of patient dose is encouraged by international organization [14–16] to establish local and national DRLs to be used as describers, provide guidance for dose optimization, and ensure justification of appropriate dose for a given clinical indication. The standardized CT measurements used to set up DRLs are volumetric CT dose index ($CTDI_{vol}$) measured in milli-gray (mGy) and total dose length product (TDLP) measured in milli-gray centimeter (mGy.cm) [11, 17, 18].

Recently, several studies on CT DRLs have been conducted in different countries, and some of which have been updated subsequently [19–21]. In Ethiopia, the number of CT scanners in direct medical use is increasing from time to time at a higher rate. Almost all CT examinations are performed using manufacturer-prescribed protocols, resulting in multiphase protocols and inadequate professional effort geared towards developing local optimal conditions commensurate with specific patient needs and indication [22]. Because Ethiopia does not have well established national diagnostic reference levels (NDRLs); the radiation exposure to patients is not adequately managed; creating a need for optimization and patient dose monitoring, record keeping, analysis as well as tracking of high dose facilities. The dose quantities that characterize CT patient radiation exposure like $CTDI_{vol}$ and TDLP that are currently displayed by CT scanners are not always recorded nor utilized to monitor optimization of CT practice. Therefore, this research, the first of its kind in the country, aims to establish anatomical NDRLs for abdomino-pelvic CT examinations in Ethiopia.

Materials and methods

Study area

Ethiopia is a Federal Democratic Republic composed of 12 national regional states and two chartered administrative cities with 17,187 health posts, 3724 health centers, 302 public hospitals and 62 private hospitals. According to existing data, out of 90 CT scanners both in the public and private health facilities, only 50 CT scanners were found to be functional during the study period. Hence, this research tried to involve all functional Multi-slice CT scanners operating across the twelve regions and the two federal cities of Ethiopia with capability to display dose parameters on its consoles from January, 2023 to March, 2024.

Study design

A quantitative cross-sectional study design was employed to establish national DRLs (NDRLs) from all CT facilities that are accredited and registered by the Ethiopian Technology Authority (ETA). After accepting the letter of request together with ethical approval granted from the Institutional Research Ethics Review Board of the College of Health Sciences in Addis Ababa University (AAU-CH-IRB); the approached hospital administrations approved the data collections for the study from their facilities. Centers with functional CT scanners which did not store patient data due to limited storage space and centers with functional CT scanners that lost their data due to recent repairs were excluded from the study. All identified CT facilities which have multi-slice CT scanner with a capacity to display dose parameters on its console and all CT scanner that is licensed and registered by ETA were contacted by the researcher to participate in the study. However, only 23 health facilities and or diagnostic centers with functional CT facilities who consented to the study were surveyed. Accordingly, one Canon, one Neuviz128; eight Siemens; seven General Electric; and six Philips CT scanners were among those utilised in this study. The scanners in each of the locations where the data was gathered were manufactured between 2006 and 2021. Additionally, the installations of the several radiology institutes across the country where data collocated span from 2008 to 2022. The CT scanners that were utilised to obtain the data had operating tube voltages ranging from 100 kV to 140 kV, automatic exposure control (AEC), and variable or fixed tube current settings systems were engaged.

Sample size and sampling technique

The European Commission (EC) stipulated that data could be obtained either from standard-size patients or a phantom. Therefore, the use of standard-size patients was employed in this study. Standardization of patient size is accomplished through weight restriction with very large and very small patients being excluded [11, 23]. Patients whose weights below 40 Kg, and above 80Kg were not included in the study.A convenience sampling technique was used to study a total of 800 abdomino-pelvic adult patients. According to ICRP 135 [11] patient dose studies should include at least 20–30 standard size patients. To increase precision, a minimum of thirty five (35) adult patients were included from each multi-slice CT scanner. As evidence shows, the mean standard size of the Ethiopian adult weight is 62 kg [6]. In order to obtain an average weight of 62 kg all patients between 40 and 80 kg who were undergoing the abdomino-pelvic CT examination were included from each health center. All CT data sets acquired between January 2023 to March 2024 were collected from all multi-slice CT scanners that displayed dose description parameter. In Ethiopia, although there were 50 health facilities with functional CT scanners during the study period, a total of 23 multi-slice CT scanners were willing to participate in the study. There were tweleve CT scanners with 16 slice, six with 64 slice, four with 128 slice, and one with 160 slice. Patients referred for special CT examinations such as CT urography, perfusion studies, CT angiography were excluded from this study.

Data collection technique and statistical analysis

Initially, a structured and pilot-tested data collecting format that has been in use by the International Atomic energy agency (IAEA) and International Centres for Theoretical Physics (ICTP) has been distributed by the researcher in both soft copies (via email) and hard copies to the radiologic technologists working at the participating health facilities.

In-depth questions about each patient's age, sex, weight, and body region were included in the data collection tool. During data collections manufacturer, model of the CT scanner, date of manufacture, date of installation and also, the two dose describers $CTDI_{vol}$ and TDLP were recorded from each CT scanners. In addition to this tube voltage (kV), tube current (mA), rotation time, number of detector rows, beam width, pitch factor, and number of phases used, were also recorded by radiologic technologists from each CT scanner on Microsoft 2016 Excel sheets. After entering the data in Microsoft Excel 2016, the excel sheet were send back to the researcher. The researcher exported the data from the excel sheet to SPSS version 26.0 for analysis. The researcher also examined each piece of data for consistency, completeness, clarity, and precession. Assuming, the type and model of a CT scanner contributed to dose variations due to its impact on filtration, geometry of the beam, number of detector rows, scattered X-ray beams and number of scan series performed by the operators; the researchers decided to make separate statistics for each CT groups. All recorded scan parameters, demographic distribution and dose indicators were expressed in mean, median (50th percentile) values. Ultimately, the NDRLs were established as the median values at the third quartile of the $CTDI_{vol}$ and TDLP deliveries of patient doses collected from a representative sample of radiology departments nationwide.

To compare the study results, 23 multi-slice CT scanners were categorized based on the manufacturing of the scanners. Facilities using Philips CT scanners were classified as GP. Among the 23 scanners, six were Philips scanners, including three with 16 slices, two with 64 slices, and one with 128 slices. Facilities with Siemens CT scanners were categorized as GS, comprising of eight scanners: four with 16 slices, two with 64 slices, and two with 128 slices. Facilities using General Electric (GE) CT scanners were grouped as GG, consisting of seven scanners—five with 16 slices and two with 64 slices. The remaining scanners were classified as "Other," including one Canon scanner with 128 slices and one Neusoft scanner with 160 slices.

Result

In this study a total of 800 abdomino-pelvic adult patients were investigated during the study period. The entire data set was developed from helical scan method. The demographic distribution and characteristics of study participants were presented in Table 1. To compare TDLP and $CTDI_{vol}$ among scanners, descriptive statistics were computed for three groups of CT scanners as shown in Figs. 1 and 2 respectively. Table 2 shows median values of technical factors and dose describers of all adult patients undergoing abdomino-pelvic CT examination in all twenty three hospitals. Table 3 shows the p-value which indicates the relationships between patient weight with TDLP and $CTDI_{vol}$. Table 4 shows a comparison of the third quartile values of abdomino-pelvic $CTDI_{vol}$ of this study with NDRLs values given in some other studies.

Discussion

It is crucial to analyse scanning methods, evaluate patient dose, and compare with other studies and reference levels in order to accomplish radiation protection for patients. This study found differences in the values of CT dose indicators for adult abdomino-pelvic patients CT scans across all ages above 15 years of age. Variability of CT dose describers were observed from the same CT scanner (Table 2). Significant discrepancies of dose describers were found (Table 3) for the same CT scanner model

Table 1 Demographic distribution and characteristics of study participants: Abdomino-pelvic

Facilites	Sex		Age (year)		Weight (Kg)		
	M *n* (%)	F *n* (%)	Range (Min, Max)	Mean ± SD	Range (Min, Max)	Mean ± SD	Median
Adama G	20 (57.10)	15 (42.9)	56 (22, 78)	49.00 ± 14.00	22 (53,75)	62.34 ± 5.67	62.00
ADH	21 (58.30)	15 (41.70)	61 (19, 80)	44.75 ± 16.32	52 (58, 110)	69.28 ± 7.87	70.50
ADMC	17 (48.60)	18 (51.40)	60 (21,81)	50.66 ± 18.07	38 (42, 80)	63.48 ± 11.31	64.00
Alert H	15 (42.90)	20 (57.10)	51 (20,71)	41.89 ± 15.75	22 (49,71)	57.74 ± 6.89	56.00
ALG H	18 (51.40)	17 (48.6)	64 (18, 82)	45.49 ± 17.50	39 (41, 80)	60.49 ± 12.41	64.00
ASRG	17 (48.60)	18 (51.40)	63 (22,85)	40.23 ± 16.24	31 (49,80)	68.74 ± 7.72	70.00
Ayder	23 (65.70)	12 (34.30)	61 (18,79)	48.14 ± 16.62	38 (40,78)	56.51 ± 9.96	54.00
BMY	20 (57.10)	15 (42.90)	58 (27,85)	48.49 ± 15.11	40 (40, 80)	58.43 ± 12.58	59.00
BZH	20 (57.10)	15 (42.90)	48 (23,71)	43.26 ± 14.49	33 (45,78)	66.57 ± 7.71	68.00
CMC	14 (40.00)	21 (60.00)	57 (19,76)	44.09 ± 16.45	53 (27,80)	62.74 ± 1327	65.00
DCHOH	20 (57.10)	15 (42.90)	58 (18, 76)	45.89 ± 15.98	35 (45,80)	61.03 ± 8.83	62.00
DUGH (afar)	18 (51.40)	17 (48.6)	50 (20, 70)	37.40 ± 13.16	35 (45, 80)	61.31 ± 9.41	62.00
DURH	15 (42.90)	20 (57.10)	71 (24,95)	45.83 ± 16.50	24 (54,78)	63.82 ± 6.75	62.00
FHH	20 (57.10)	15 (42.90)	46 (19,65)	41.74 ± 13.58	29 (48, 77)	62.08 ± 8.38	61.00
GH	14 (43.80)	18 (56.30)	60 (22, 82)	46.59 ± 16.10	40 (40, 80)	58.93 ± 11.28	59.00
HLH	15 (42.90)	20 (57.10)	52 (23, 75)	49.43 ± 16.17	30 (49, 79)	65.97 ± 6.94	68.00
HUCSH	26 (74.30)	9 (25.70)	72 (18,90)	40.57 ± 16.50	35 (45, 80)	63.00 ± 10.26	62.00
ICMC	15 (42.90)	20 (57.10)	47 (23,70)	39.14 ± 13.03	28 (46, 74)	56.83 ± 7.54	58.00
TASH	11 (31.40)	24 (68.60)	52 (26,78)	51.34 ± 14.30	35 (45,80)	61.88 ± 9.67	62.00
THH	15 (42.90)	20 (57.10)	63 (16,79)	41.66 ± 16.29	46 (34,80)	66.25 ± 11.52	67.00
Vision	19 (54.30)	16 (45.7)	62 (18, 80)	46.57 ± 14.25	35 (45, 80)	66.26 ± 10.24	69.00
WUDC	13 (37.10)	22 (62.90)	59 (18,77)	43.51 ± 15.99	39 (40,79)	55.17 ± 10.78	55.00
Yer H	20 (57.10)	15 (42.90)	33 (38, 71)	47.29 ± 11.67	21 (59, 80)	70.34 ± 6.83	71.00
Total	403 (50.60)	397 (49.40)	79 (16, 95)	44.90 ± 15.67	53 (27, 80)	62.56 ± 10.25	62.00

Adama G- Adama General Hospital, ADH- Addis Hiwot Hospital, ADMC- Adera Medical Center, ALGH- Alation General Hospital, ASRG- Addis Silk Road General Hospital, AlertH- Alert Hospital, Ayder- Ayder Hospital, BMY- BMY Diagnostic Center, BZH- Betezata General Hospital, CMC- Korea General Hospital, DCHOH-Dill Chora Hospital, DUGH- Dubti University General Hospital, DURH- Dilla University Referral Hospital, FHH- Felege Ghion Specialized Hospital, GH- Girum General Hospital, HLH- Haleluya General Hospital, HUCSH- Hawassa University Specialized Hospital, ICMC- International Cardiovascular and Medical Center, TASH- Tikur Anbessa Specialized Hospital, THH- Teklehaimanot General Hospital, Vision- Vision Medical Center, WUDC- Wudassie Diagnostic Center, YerH- Yerer General Hospital

and anatomical location, despite the fact that all hospitals were implementing dose optimization techniques including tube current modulations, which could significantly lower patient exposure. These variations may result from user selections of parameters such as sequence, scan range, number of scan series and pitch for the same anatomical region as well as manufacturer-specific variations due to its impact on filtration, geometry of the beam, number of detector rows and scattered X-ray beams in the design of CT equipment. The study also investigated if weight had a significant impact on the CTDI-vol and TDLP using multiple regressions t-test analysis. The hypothesis tests if weight as significant impact on $CTDI_{vol}$ and TDLP. The dependent variable $CTDI_{vol}$ and TDLP was regressed on predicting variable weight to test the hypothesis tests if weight as significant impact on CTDIvol and TDLP. As indicated in Table 3; the p-values of the facilities GP CT scanners groups THH and BZH CT scanner are (r_s = 0.4, p-value = 0.518) and (r_s = 0.6, p-value = 0.273) respectively. This shows that statistically there is no significant relationship between patient weight and TDLP in these facilities. For example, the highest variation of TDLP for equal median weight (Table 1) was seen in GP CT scanners groups between THH (67 kg) and BZH (68 kg) CT scanner with median values of 3370 (mGy.cm) and 276 (mGy.cm) with maximum to minimum ratio of 12.2 (Fig. 1; Table 2). This is primarily related to increased usage of sequence, mAs, scan range and $CTDI_{vol}$ with maximum to minimum ratio of 2, 7.4, 1.5, 6.7 respectively (Table 2). In the contrary there is statistically significant relationship between the GS CT scanners groups ADMC and GH with p-value (r_s= 0.559, p-value = 0.001) and (r_s= 0.63, p-value = 0.013) respectively. The result shows that there was a moderate positive significant relationship between $CTDI_{vol}$ and weight. Similarly, the smallest variation of median values of TDLP was seen in the GS CT scanners groups between ADMC and GH with maximum to minimum ratio of 2.5 for median weight of 64 kg and 59 kg (Tables 1 and 2) respectively. The main causes of this small differences in GS CT scanners were its small variation in the usage of sequence, kVp, scan range and $CTDI_{vol}$ with the corresponding maximum to minimum ratio of 1.5, 1.18, 1.02, 1.3 respectively (Figs. 1 and 2; Table 2). These shows, median CT DRLs vary among hospitals due to differences

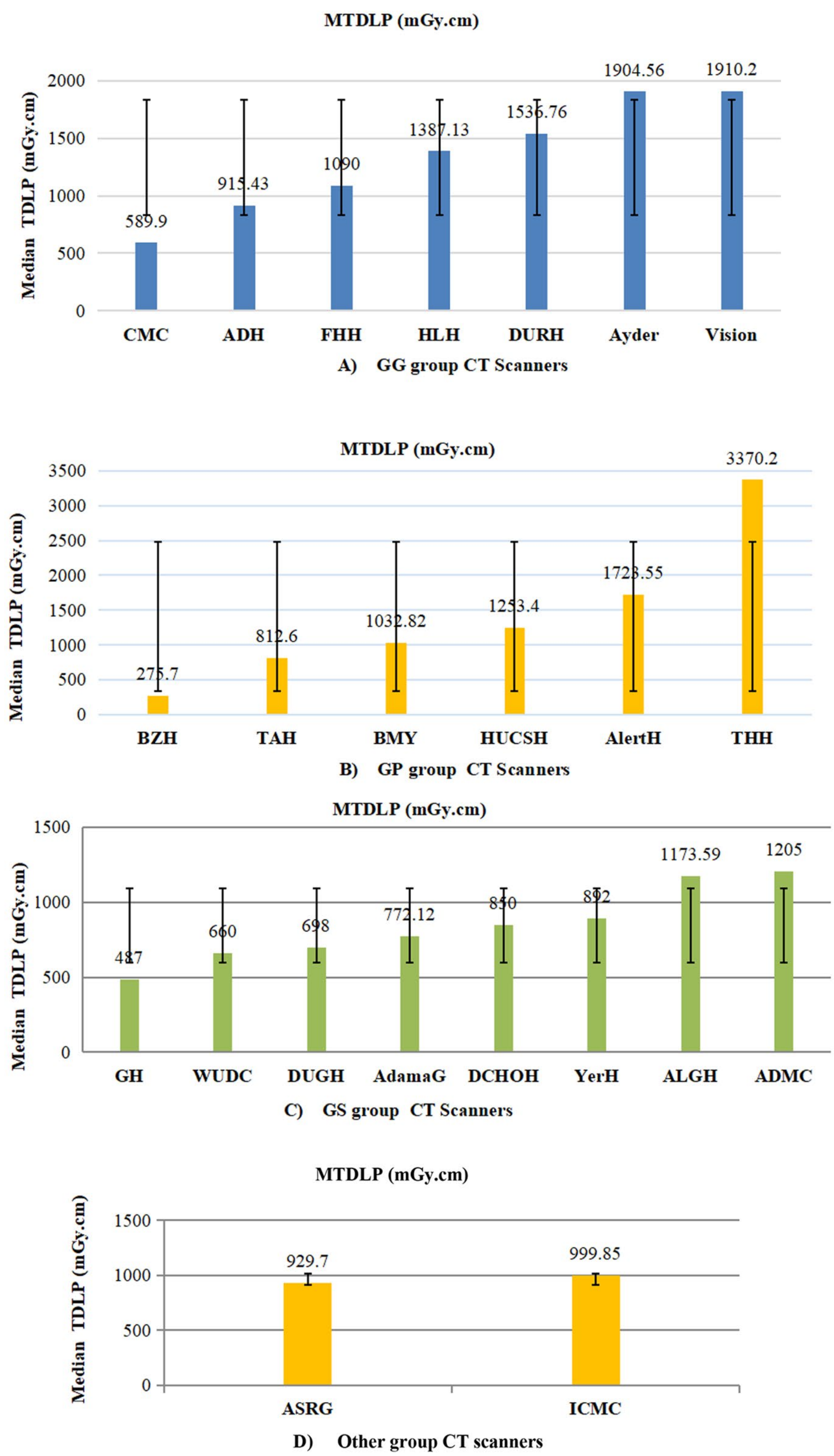

Fig. 1 Increasing median TDLP distribution for abdomino-pelvic adult CT examination using Group (**A**) GG- General Electric CT Scanner, Group (**B**) GP-Philips CT Scanner, Group (**C**) GS- Siemens CT Scanner and Group (**D**) Others CT Scanner - Canon and Neusoft

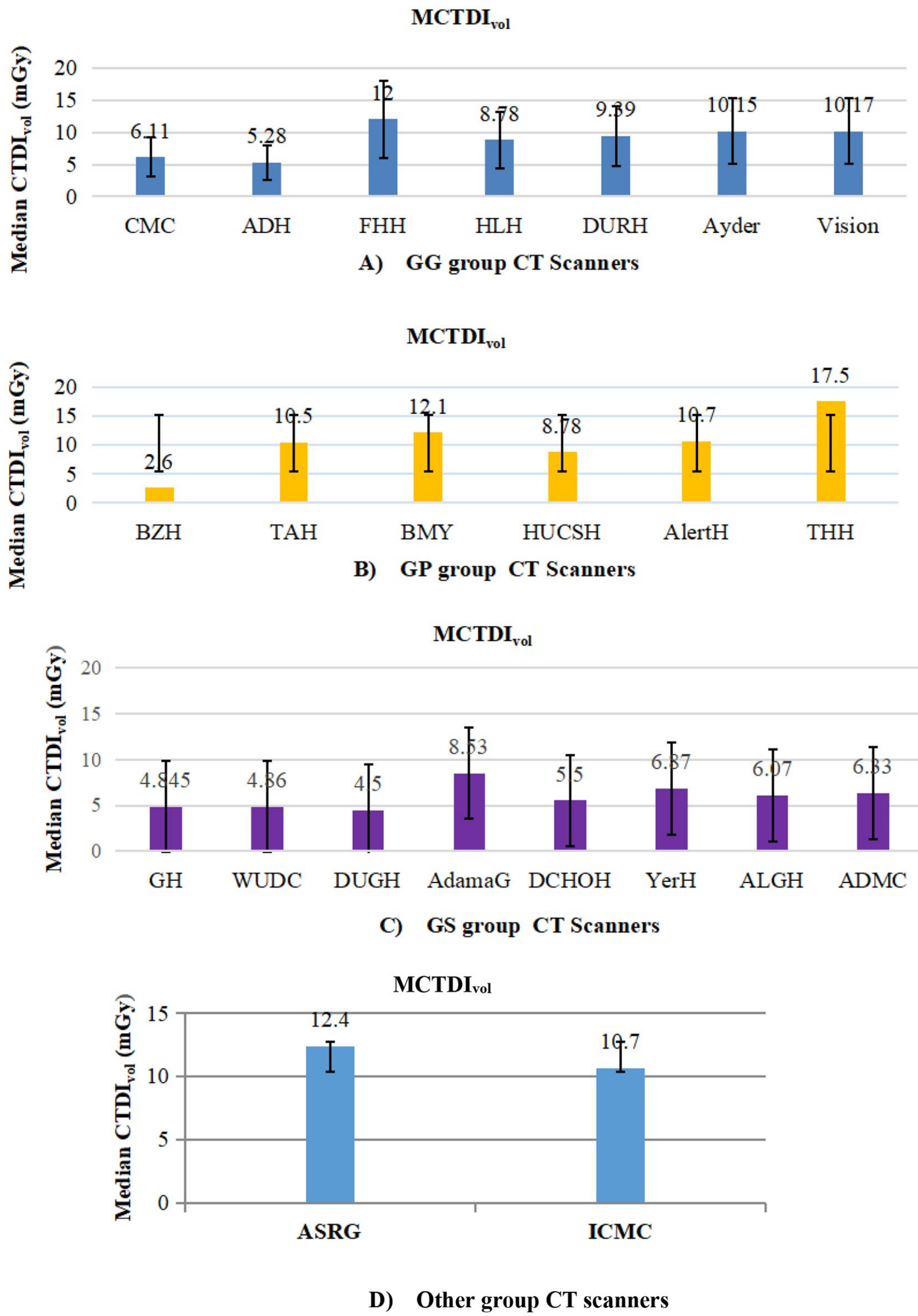

Fig. 2 The corresponding median $CTDI_{vol}$ distribution for abdomino-pelvic adult CT examination using Group (**A**) GG- General Electric CT Scanner, Group (**B**) GP-Philips CT Scanner, Group (**C**) GS- Siemens CT Scanner and Group (**D**) Others CT Scanner - Canon and Neusoft

Table 2 Hospitals, year of CT installations, slice number, number of sequences, median values of technical factors and median dose indicators for all adult patients undergoing abdomino-pelvic CT examination during the study period

CT scanners groups	Hospitals (year of CT installations)	Slice number	Number of sequence	Pitch	kV	mAs	Scan range (cm)	MCTDIvol	MTDLP (mGy.cm)
GP	BMY (2022)	16	2	1.10	120	157	45	12.1	1032.82
	BZH (2023)	16	2	0.94	120	34	33	2.6	275.7
	TAH (2008)	128	2	0.98	120	163	50.3	10.5	812.6
	HUCSH (2013)	64	3	0.8	120	130	45.7	8.78	1253.4
	Alert H (2015)	64	3	1.03	120	164	35	10.7	1723.55
	THH (2018)	16	4	0.94	120	250	50	17.5	3370.2
GS	Adama G (2022)	16	2	0.8	130	68	45.7	8.53	772.12
	GH (2018)	16	2	1	110	76	43.98	4.845	487
	ADMC (2021)	64	3	0.8	130	59.5	45	6.33	1205
	DUGH (2022)	16	3	1.3	110	50	46.33	4.5	698
	DCHOH (2022)	128	3	0.8	90	254	337	5.5	850
	Yer H (2020)	16	3	1.07	130	99	51.2	6.87	892
	WUDC (2019)	128	3	1.2	120	92	48.6	4.86	660
	ALGH (2020)	64	4	1.5	130	71	52.66	6.07	1173.59
GG	ADH (2018)	64	2	0.9	120	80	41.15	5.28	915.43
	CMC (2015)	16	2	1.38	120	64	49.5	6.11	589.9
	FHH (2016)	16	2	0.9	120	352	46	12	1090
	DURH (2021)	64	3	0.6	120	133.2	49	9.39	1536.76
	HLH (2017)	16	3	1.38	120	200	40.3	8.78	1387.13
	Ayder (2013)	16	4	1.38	120	148	43.5	10.15	1904.56
	Vision (2020)	16	4	0.93	120	100	52	10.17	1910.2
Other	ASRG (2019)	160	1	1.2	120	200	51.5	12.4	929.7
	ICMC (2021)	128	2	0.8	100	110	42	10.7	999.85

Adama G- Adama General Hospital, ADH- Addis Hiwot Hospital, ADMC- Adera Medical Center, ALGH- Alation General Hospital, ASRG- Addis Silk Road General Hospital, AlertH- Alert Hospital, Ayder- Ayder Hospital, BMY- BMY Diagnostic Center, BZH- Betezata General Hospital, CMC- Korea General Hospital, DCHOH-Dill Chora Hospital, DUGH- Dubti University General Hospital, DURH- Dilla University Referral Hospital, FHH- Felege Ghion Specialized Hospital, GH- Girum General Hospital, HLH- Haleluya General Hospital, HUCSH- Hawassa University Specialized Hospital, ICMC- International Cardiovascular and Medical Center, TASH- Tikur Anbessa Specialized Hospital, THH- Teklehaimanot General Hospital, Vision- Vision Medical Center, WUDC- Wudassie Diagnostic Center, YerH- Yerer General Hospital, GG- General Electric CT Scanner, GP-Philips CT Scanner and GS- Siemens CT Scanner and Other- Cannon and Neusoft CT Scanners

Table 3 Regression analysis of dose indicators patient weight with same CT scanners

Patient weight of facilities, r_s (*P*-value)						
Dose indicators	**BMY (Philips)**	**BZH (Philips)**	**TAH (Philips)**	**HUCSH (Philips)**	**AlertH (Philips)**	**THH (Philips)**
$CTDI_{vol}$	0.79 (0.894)	0.59 (0.819)	0.7 (0.802)	0.44 (0.018)**	0.67 (0.292)	0.37 (0.900)
TDLP	0.81 (0.018)**	0.6 (0.273)	0.71 (0.276)	0.12 (0.555)	0.74 (0.761)	0.40 (0.518)

Patient Weight of Facilities, r_s(*P*-value)								
Dose indicators	**AdamaG (Siemens)**	**ADMC (Siemens)**	**DUGH (afar) (Siemens)**	**DCHOH (Siemens)**	**GH (Siemens)**	**YerH (Siemens)**	**WUDC (Siemens)**	**ALGH (Siemens)**
$CTDI_{vol}$	0.51 (0.137)	0.561 (0.001)*	0.48 (0.024)**	0.635 (0.097)	0.783 (0.004)*	0.955 (0.467)	0.566 (0.950)	1.00 (0.000)*
TDLP	0.59 (0.053)	0.559 (0.001)*	0.30 (0.089)	0.576 (0.345)	0.632 (0.013)**	0.362 (0.032)**	0.784 (0.000)*	0.814 (0.000)*

*Significant difference $p < 0.01$ **Significant difference $p < 0.05$

Table 4 Comparison of the established National diagnostic reference levels (NDRLs) of this study with other selected African and non-African NDRLs

CT dose describers	Ethiopia current study (2024)	Uganda (2022) [24]	Nigeria (2018) [25]	Australia (2020) [21]	Japan (2020) [26]	UK (2019) [20]	Ghana (2024) [27]	Egypt (2017) [28]	Kenya (2016) [29]
$CTDI_{vol}$ (mGy)	10.5	12.5	20	13	18	12	20.5	31	20
TDLP (mGy.cm)	1387	1418	1486	600	880	621	1393.5	1325	1845

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in CT scanner, scanning protocols and their staff expertise using different exposure parameters.

We have also compared the proposed NDRLs of the current study was also compared with other established NDRLs in Uganda (2022) [24], Nigeria (2018) [25], Australia (2020) [21], Japan (2020) [26], the UK (2019) [20], Ghana (2024) [27], Egypt (2017) [28], and Kenya (2016) [29] (Table 3). Even though, the $CTDI_{vol}$ of the current study is less than all African and non-African studies, when comparing the current NDRLs to those of selected African nations, the adult 75th percentile of TDLP values of our results were slightly less than Nigeria (2018) [25] and Uganda (2022) [24] but greater than Egypt (2017) [28]. The work from Kenya (2016) [29] showed the biggest variation, with a value of 1845 mGy.cm, higher than that of the current studies (1387 mGy.cm). However, the result of this study was comparable to that of Ghana (2024) [27] (Table 3). Possible explanation suggested in Nigeria (2018) [25] was, technological and technical factors appear to be significant contributors to high doses and dose variations. Whereas in Uganda (2022) [24] emphasized that the DLPs values were markedly high across all the facilities and higher than the regional and the international values due to differences in imaging protocols and use of equipment. Furthermore, the suboptimal protocols were associated, with the operator errors (wrong protocol selection), use of manufacturer-provided CT protocols may result for high DLP Similarly, when the present study was compared with other non-African countries the proposed TDLP of the current study were substantially higher than other similar studies in Australia (2020) [21], Japan (2020) [26], and UK (2019) [20] (Table 3). The main reason of Australia (2020) [21], Japan (2020) and UK (2019) [20] dose reduction is their use of post-contrast (oncology), drastic replacement with CT systems equipped with iterative image reconstruction, and use of more single phase than three phases respectively. For example, when this study was compared with that of the UK (2019) [20], irrespective of their clinical indication, our study showed only (4%) of CT scanners used single phase examinations as compared to 44% CT scanners using single phase. 11% (11%) of the CT examinations used three phases in the UK (2019) [20] while in our case more than 56% of examinations used three phases and above. Moreover, differences in the training and experiences of radiologic technologists may vary from place to place across the continents and this may cause dose variations.

The study's effort in establishing the first anatomical NDRLs of computed tomography examinations in Ethiopia from a nationwide survey using a range of multi-slice CT scanners is a key to facilitate further reduction in the CT radiation dose used nationally. Although radiographers and radiological technologists may require further training on appropriate $CTDI_{vol}$ and TDLP usage, the NDRLs that will be established will greatly contribute to the reduction of the CT radiation dose used in Ethiopia.

Limitations

We must admit that our study may have had three possible drawbacks. Firstly, we compared our proposed NDRLs of $CTDI_{vol}$ and TDLP with other studies without weight consideration. Secondly, the study compared the median $CTDI_{vol}$ and TDLP values across different health facilities without considering the specific clinical indications for the Abdomino-pelvic CT examinations or the type of reconstruction used. As a third limitation point, the number of scan phases was also not considered in this study. These limitations could affect the accuracy of the comparisons, as different clinical indications may require varying levels of radiation dose, scan parameters and different reconstruction methods that can influence the dose values.

Conclusion

The authors of this manuscript conclude that, the proposed Abdomino-pelvic NDRLs of $CTDI_{vol}$ is less than all African and non-African countries, while that of dose length product values were intermediate and substantially higher than African and non-African countries selected for this research purposes respectively.

Furthermore, the authors of this manuscript recommend that the NDRLs established for Ethiopia presented can be used as a baseline which hospitals future CT abdomino-pelvic median dose indicators in Ethiopia can be compared against. It is recommended that a similar type of large-scale survey be used to establish clinical indicated NDRLs for adult abdomino-pelvic CT examinations in Ethiopia.

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Author contributions

Mr. Solomon Getachew: data collection, prepared the figures and tables, data analysis, wrote the main manuscript text. Dr. Seife Teferi has made an assistance on interpretation of data. Mr.Teklehaimanot Mezgebe has assisted me on preparation of figures. Prof. Daniel Zewdeneh and Dr. Seife Teferi have reviewed the manuscript.

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Data availability

All the necessary data and materials have been included in this manuscript. However if it demands additional data that support the findings of this study, it will be available upon request.

Declarations

Ethics approval and consent to participate
Before the commencement of the study, ethical approval was granted from the Institutional Research Ethics Review Board of the College of Health Sciences in Addis Ababa University (AAU-CH-IRB) with protocol No 108/22/Radio. The Department of Radiology Research and Ethics Committee (with Ref No Rad/ 050/2015) also approved the waiver of informed consent due to the lack of direct patient contact during data collection. The study was also carried out in accordance with relevant guidelines and regulations according to the Helsinki declaration.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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