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Radiation Dose Measurement during CT Abdomen Examination of Adult Patients: A Cross-Sectional Study

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ABSTRACT

Background: Computed tomography (CT) has become a routine imaging modality for many clinical applications due to its wide availability, minimally invasiveness, short scan time, excellent anatomical resolution, and high diagnostic value. The radiation dose to patients from CT examinations is the highest contributor to diagnostic medical exposure, which is a growing public concern. The aim of this study was to measure radiation doses for abdominal CT examinations in adult patients and compared them to international standard dose values.

Methods: A cross-sectional study was conducted on 92 adult patients with abdomen CT scans using a 16-slice computed tomography scanner at the department of Radiodiagnosis & Medical Imaging, UCMS-TH, Bhairahawa, Nepal from August 2018 to January 2019. The radiation doses were measured by convenient techniques: volumetric computed tomography dose index (CTDIvol), dose length product (DLP) & effective dose (ED) and data were analyzed using SPSS version 20.

Results: The mean BMI of the study participants was 23.92±4.29 kg/m^2. The mean values of contrast-enhanced scan CTDIvol, DLP, and an ED in our study were 7.31 mGy, 421.46 mGy.cm and 6.31 mSv respectively which is very low as compared to European Guidelines (EG) & International Atomic Energy Agency (IAEA). There was a statistically significant association between patient BMI with CTDIvol, DLP and ED during non-contrast, contrast-enhanced and delayed scans.

Conclusion: The CTDIvol, DLP, and ED were lower than the European guidelines and IAEA standards. Toward preventing health effects from ionizing radiation, our study follows public concerns and minimizes radiation doses.

Keywords: computed tomography, CTDI, DLP, ED, radiation dose.

INTRODUCTION

Computed tomography (CT) has become a routine imaging modality for many clinical applications due to its wide availability, minimally invasiveness, short scan time, excellent anatomical resolution, and high diagnostic value.[1,2] The radiation dose to patients from CT examinations is the highest contributor to diagnostic medical exposure, which is a growing public concern. The CT contributes about 43% of the total global collective dose to diagnostic medical imaging.[3] It is possible that CT radiation was responsible for about 35% of the abdomen and pelvis.[4] The European Union has emphasized the need to reduce the dose of ionizing radiation to patients during CT scans.[5] Several international organizations have recommended efforts to reduce radiation dose in CT, including the ICRP, IAEA, and the European Commission. It has been recommended that CT dose guidance levels be set up and implemented for the most common CT examinations to promote radiation dose optimization strategies.[6] The aim of this study was to calculate radiation doses for abdominal CT examinations in adult patients at UCMS-TH, Bhairahawa, Nepal compared it to international standard dose values.

METHODS

A cross-sectional study was performed using a helical computed tomography scanner (16-slice GE, Brivo model) at the Department of Radiodiagnosis and Medical Imaging, Universal College of Medical Sciences and Teaching Hospital (UCMS-TH), Bhairahawa, Rupandehi, Nepal that was approved by Institutional Review Committee of UCMS-TH with registration number UCMS/IRC/104/18. A total of 92 abdominal CT scans were performed on adult patients with written informed consent. Data were collected from each patient who underwent a clinically indicated CT scan for 6 months between August 2018 and January 2019. The sample size was calculated using the formula: $n = Z^2\sigma^2/d^2$, where Z = 1.96 (level of significance at 5%), σ = 1.17 (Standard Deviation at NMDC),[7] d = allowable error at 0.24. The sample size was calculated approximately about 92.

CT Exposure Parameters: These studies were performed using only abdominal imaging and phases were recorded as non-contrast, contrast-enhanced, and delayed examinations. Scanning parameters included tube current (mA), exposure time (mAs), tube voltage (KVp), collimation, helical pitch, reconstruction interval, and automatic exposure control (AEC). These parameters are necessary and important for adjustment to adult body sizes, as they determine the radiation dose. However, the tube current used for adults was in the range of 85 mAs to 160 mAs throughout with a fixed tube voltage of 120 KV for the whole examination that was carried out during this research work with a pitch of 1.75:1 mm. DLP and CTDI values were recorded individually.

Radiation Dose Estimation

Computed Tomography Dose Index (CTDI) is the most widely used metric for estimating CT doses which incorporates both weighted and volume CT doses. In a CT scan, CTDIvol is a measure of radiation intensity that is independent of scan length. It is measured in milligrays. CTDIvol can be multiplied by the corresponding scan length to obtain the DLP, which measures the total amount of radiation used during a CT scan. In spite of this, the amount of radiation absorbed by a patient depends on his or her physical characteristics. Milligray-centimeters are used to measure it.[8-12] In clinical practice, CTDIvolume and DLP are displayed on the control panel of most CT scanners. 'Effective dose', which is often expressed in mSv, represents a dose that would result in similar health effects as partial body irradiation.[13] The effective dose can be calculated from the weighted sum of equivalent doses in tissues and organs that are sensitive to radiation, with the weighting factor determined by the relative risk of organ damage. Effective dose is not a quantity that measures radiation dose but reflects the stochastic radiation risk of a patient.[14,15]

Dose Reduction Technique: Iterative reconstruction algorithms (adaptive statistical iterative reconstruction and model-based iterative reconstruction) and routine dose CT with filtered back-projection reduced by 40 % and 33% of image noise, similarly reduced CTDIw and DLP values compared to the international standards.[16] TCM (tube current modulation) is another technique that reduces radiation exposure to the patient by reducing the X-ray exposure at specific tube positions or projection angles. The tube current is determined entirely with the localizer radiographic projection of the patient. Using a TCM protocol, tube current is automatically adjusted during each gantry rotation based on object thickness. TCM technology has been proven to reduce the radiation dose by up to 50%.[17] Beam filtration and beam collimation are key materials for patient dose reduction. Future dose reduction techniques involve adjusting the kV according to patient size. A lower tube potential (kV) in CT imaging has been shown to improve image quality or reduce radiation dose in several physics and clinical studies. Lower kV is beneficial in certain clinical applications.[18] All Adult patients of age ranging from 25 years to 80 years and who have come for abdominal CT examination were included in this research. Patients with any absolute contraindication for CT were excluded from this research.The collected data were analyzed using Microsoft Excel (2013) and Statistical Package for Social Sciences (SPSS) version 20. Dose length products and effective doses were calculated from the reported volume CT dose index (CTDIvol). Data were presented as the Mean ± Standard Deviation.

RESULTS

We performed abdominal scans on 92 patients (53 males and 39 females) ranging in age from 25 to 80 using the abdominal protocol. The radiation dose was calculated using volumetric computed tomography dose index (CTDIvol), dose length product (DLP), and effective dose (ED). The mean age was 42.24 years. The range of age was between 25-79 years. The mean weight and height were 63.97 kg ±10.17 kg and 162.26 cm ±6.51 cm respectively, with the range 45-88 kg and 151.0-173.0 cm respectively. The mean body mass index of the participants was 23.92± 4.29 kg/m^2. The highest BMI was 34 kg/m^2 and the lowest BMI was 17 kg/m^2. (Table 1).

Table 1. Descriptive Statistics of the participants (n=92).

Patient Parameter	Maximum	Minimum	Mean ± SD
Age (years)	79	25	42.24±16.75
Weight (kg)	88	45	63.97±10.17
Height (cm)	173	151	162.26±6.51
BMI (kg/m^2)	34	17	23.92±4.29

The exposure parameters were shown in (Table 2), with mAs ranged from 86-135 for non-contrast scans, 100-159 for contrast-enhanced scans. The kilovoltage peak remained in constant for each examination (Table 2). The abdominal CT scan protocol was used for males and females. The mean CTDIvol (mGy) values in males for non-contrast, contrast-enhanced, and delayed scans were 6.59±2.02 mGy, 6.82±2.19 mGy, and 5.89±1.49 mGy respectively, with their corresponding mean DLP (mGy.cm) values were 380.96±11.96 mGy.cm, 407.88±125.67 mGy.cm and 337.98±91.43 mGy.cm respectively; and the mean Effective dose (mSv) values were 5.67±1.73 mSv, 6.106±1.88 mSv and 5.06±1.37 mSv respectively. The mean body mass index was

22.74±3.99 kg/m2 with values ranging from 17 -32 kg/m2(Table 2).

Table 2. Parameter used in Abdominal CT examination (n=92)

Examination	Kilo-voltage	Milliam-pere	Mean scan	Slice	Pitch (P)	Beam
	(kVp)	Second (mAs)	length (L)	Thickness (T)		Collimation
Abdomen (NCCT)	120	86-135	391.70 mm	5 mm	1.75:1	16*0.625
Abdomen (CECT)	120	100-159	391.70 mm	5 mm	1.75:1	16*0.625
Abdomen (Delayed)	120	86-115	391.7	5 mm	1.75:1	16*0.625

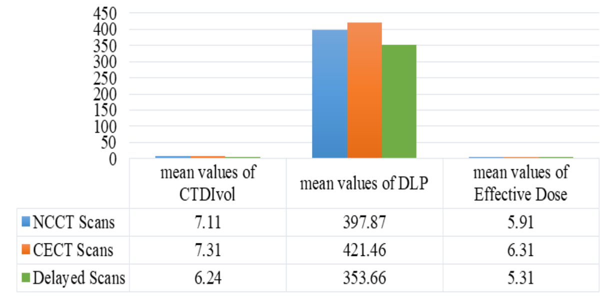
The mean CTDIvol (mGy) values in females for non-contrast, contrast-enhanced, and delayed scans were 7.79±1.83 mGy, 7.97±2.12 mGy and 6.71±1.56 mGy respectively, with their corresponding mean DLP (mGy.cm) values were 420.86±101.98 mGy.cm, 439.91±112.23 mGy.cm and 374.96±86.66 mGy.cm respectively; and the mean Effective dose (mSv) values were 6.22±1.53 mSv, 6.59±1.68 mSv and 5.63±1.32 mSv respectively. The mean body mass index was 25.54±4.21 kg/m2 with values ranging from 17-34 kg/m2 (Table 3).

Table 3. Descriptive statistics of Gender, BMI, CTDIvol dose, DLP, and Effective dose of non-contrast, Contrast-enhanced, and Delayed scan.

Statistics value	NCCT Scan	CECT Scan	Delayed Scan
BMI of the patient (Kg/m^2)	22.74±3.99	22.74±3.99	22.74±3.99
CTDIvol (mGy)	6.59±2.02	6.82±2.19	5.89±1.49
DLP (mGy.cm)	380.96±11.96	407.88±125.67	337.98±91.43
Effective dose (mSv)	5.67±1.73	6.106±1.88	5.06±1.37
BMI of the patient (Kg/m^2)	25.54±4.21	25.54±4.21	25.54±4.21
CTDIvol (mGy)	7.79±1.83	7.97±2.12	6.71±1.56
DLP (mGy.cm)	420.86±101.98	439.91±112.23	374.96±86.66
Effective dose (mSv)	6.22±1.53	6.59±1.68	5.63±1.32

In the present study, there is a statistically significance (p=0.001*) association between patient BMI with CTDIvol during non-contrast, contrast-enhanced and significance (p=0.007*) association between patient BMI with CTDIvol during delayed scans. The BMI with DLP and effective dose shows statistically significance (p=0.001*) to the patient during non-contrast, contrast enhanced and delayed scans (Table 4). Comparison of mean values of CTDIvol, DLP, and effective dose of NCCT, CECT, and delayed scans. We found that contrast-enhanced scans had higher volumetric CTDI radiation doses than non-contrast scans and delayed scans. Similarly, contrast-enhanced scans showed higher DLP dose values than non-contrast and delayed scans. The effective dose was also higher in contrast-enhanced scans compared to non-contrast and delayed scans (Figure 1).

Figure 1. Comparing mean volumetric CTDI, DLP, and ED of NCCT, CECT and Delayed abdominal Scans.



	mean values of CTDIvol	mean values of DLP	mean values of Effective Dose
🟦 NCCT Scans	7.11	397.87	5.91
🟧 CECT Scans	7.31	421.46	6.31
🟩 Delayed Scans	6.24	353.66	5.31

Radiation dose in UCMS was very low as compared to European Guidelines (EG) & IAEA. (Table: 5)

Table 5. Comparison of the mean value of contrast-enhanced volumetric computed tomography dose index (CTDIvol), dose length product (DLP), and an effective dose of UCMS with European Guidelines (EG) & IAEA.

Examination	Mean	Range	EG	IAEA
Abdomen				
CTDIvol (mGy)	7.31	2.84-12.35	15	10.9
DLP (mGy.cm)	421.5	159.83-679.76	780	696
Effective dose (mSv)	6.31	2.06-10.19	11.7	7.6

Table 4. Comparison of BMI with CTDIvol, DLP, and Effective dose during NCCT, CECT, and Delayed scan doses to the patient.

Scans	BMI	CTDIvol		DLP		Effective dose	
		Mean ±SD	p-value	Mean ±SD	p-value	Mean ±SD	P-value
Non-contrast	Normal	6.18±1.81	0.001*	337.88± 92.22	0.001*	4.98±1.36	0.001*
	Overweight	8.04±1.79		445.85±67.65		6.66±1.02	
	Obese	8.31±1.70		494.54±107.94		7.36±1.61	
	Total	7.11± 2.02		397.87± 110.85		5.91±1.66	
Contrast Enhanced	Normal	6.16±1.74	0.001*	368.68±111.46	0.001*	5.51±1.67	0.001*
	Overweight	8.13±1.94		477.18±82.89		7.14±1.24	
	Obese	9.28±1.95		487.74±125.703		7.32±1.88	
	Total	7.31± 2.22		421.46± 120.57		6.31± 1.81	
Delayed	Normal	5.80±1.58	0.007*	317.11±84.17	0.001*	4.76±1.29	0.001*
	Overweight	6.52±1.31		376.02±69.15		5.63±1.03	
	Obese	7.06±1.51		422.07±88.71		6.33±1.33	
	Total	6.24± 1.57		353.66± 90.83		5.31± 1.37	

DISCUSSION

Abdominal CT was performed on 92 patients, aged 25 to 80 years using a 16-slice CT scanner at Universal College of Medical Sciences and Teaching Hospital, Bhairahawa. In this study, CTDIvol, DLP, and effective dose were measured in patients without gross pathology and compared with IAEA and European guidelines. In this study, the mean age was 42.24±16.75 years. The study was done by Sagara Y et al.[16] and Kataria B et al.[19] where the mean age was 60.8 years and 65 years respectively. There were 59 males (64.1%) and 39 females (42.4%) in this study which is similar to study published by Kataria B et al.[19] where 53.3% male and 46.7% female respectively. In this study, the mean weight and height were 63.97 kg±10.17 kg and 162.26 cm±6.51 cm respectively, with a range of 45-88 kg and 151.0-173.0 cm respectively. The mean body mass index (BMI) was 23.92±4.29 kg/m^2, where the highest BMI was 34 kg/m^2 and the lowest BMI was 17 kg/m^2 which is approximately similar to sagara Y et al[16] and Kataria B et al[19] where the average BMI was 26.8 kg/m^2 (range, 17.8–43.9 kg/m^2), with lowest BMI < 20 kg/m^2 and highest BMI ≥ 25 kg/m^2 respectively, and lowest BMI was < 30kg/m^2 and highest BMI $\geq$30kg/m^2 respectively. In this study, the mean CTDIvol values in males for non-contrast, contrast-enhanced, and delayed scans were 6.59±2.023 mGy, 6.82±2.19 mGy, and 5.89±1.49 mGy respectively, with their corresponding mean DLP values were 380.96±11.96 mGy.cm, 407.88±125.67 mGy.cm and 337.98±91.43 mGy.cm respectively; and the mean effective dose (ED) values were 5.67±1.73 mSv, 6.106±1.88 mSv and 5.06±1.37 mSv respectively which is compare to study published by Smith-Bindman R et al[20] where the median CTDIvol values in men was 12 mGy (IQR, 8–17 mGy) with their corresponding median DLP values 580 mGy.cm (IQR 360–860 mGy.cm) in single phase, and 1220 mGy.cm (IQR, 850–1790 mGy.cm) in multiphase respectively; and the median values of effective dose was 10 mSv (IQR 6–16 mSv) in single phase and 22 mSv (IQR, 15–32mSv) in multiphase respectively. The CTDIvol, DLP and effective dose were minimum in this study as compared to Smith-Bindman R et al. The difference may have been due to the use of different statistic modes & parameters. The mean CTDIvol values in females for non-contrast, contrast-enhanced, and delayed scans were 7.79±1.83 mGy, 7.97±2.12 mGy and 6.71±1.56 mGy respectively, with their corresponding mean DLP values were 420.86±101.98 mGy.cm, 439.91±112.23 mGy.cm and 374.96±86.66 mGy.cm respectively; and the mean effective dose (ED) was 6.22±1.53 mSv, 6.59±1.68 mSv and 5.63±1.32 mSv respectively. The mean body mass index was 25.54±4.21 kg/m^2 with values ranging from 17-34 kg/m^2. The CTDIvol, DLP and effective dose were higher in females than males due to higher BMI in this study. A similar study was conducted by Adam EA[7] in two hospitals (NMDC and ASH) at suden, where the mean values of CTDIvol were 3.9±1.17 mGy and 36.2±12.3 mGy, with a range of 6.046±2.339 mGy and 68.3±11.6 mGy respectively, with their corresponding mean DLP values was 185.3±64.86 mGy.cm and 1736.7±762.9 mGy.cm, with a range of 339.3±96.17 mGy.cm and 4289.9±422 mGy.cm respectively; and the mean values of the effective dose was 2.86±0.9 mSv and 26.25±9.487 mSv, with range 4.49±1.39 mSv and 51.4±8.9 mSv respectively. Sagara Y et al[16] measured CTDIvol, DLP, and radiation dose for low-dose CT with ASIR was 17 mGy, 860 mGy.cm, and 13 mSv respectively, followed by 25 mGy, 1,193 mGy.cm, and 18 mSv for routine-dose CT with FBP, which was representing an approximate overall dose reduction of 33%. Low-dose CT with ASIR had significantly reduced ($p < 0.001$) quantitative and qualitative assessment of image noise. The average CTDIvol dose reduction was 66% for patients with a BMI of less than 20 and 23% for patients with a BMI of 25 or greater. It was concluded that CT with FBP and CT with ASIR significantly reduces noise, thereby permitting diagnostic abdominal examinations with lower (by 23-66%) radiation doses. The DLP dose and effective dose were higher as compared to the present study. The difference may have been due to the use of different parameters. In this study, there is a statistical significance association between patient BMI with CTDIvol radiation dose during non-contrast and contrast-enhanced scans (p=0.001*) and significance during delayed scans (p=0.007*). Similarly, there is a significant association between BMI with DLP and ED during non-contrast, contrast-enhanced, and delayed scans (p=0.001*). It demonstrates that obese patients (BMI=30-34) received the highest radiation dose followed by overweight patients (BMI=25-29). Patients with normal BMI (17-24) received the least amount of radiation dose. In this study, we found that variations in radiation dose were caused by differences in hospital parameters and equipment.

CONCLUSION

The Volumetric Computed Tomography Dose Index was lower than the European guidelines and IAEA standards. Dose length product values and effective dose values were also lower in comparison to European Guidelines & the IAEA. We found that contrast-enhanced scans exposed patients to more radiation than non-contrast scans and delayed scans. A patient's body mass index was also an important factor in determining the radiation dose. Patients with a higher BMI received higher radiation doses than those with a lower BMI.

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Conflict of Interest: None.

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