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Original Article

Assessment of radiation exposure: An in-depth analysis of dose evaluation in contrast-enhanced computed tomography abdomen imaging

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ABSTRACT

Objectives: The advancement of diagnostic imaging highlights the critical role of computed tomography (CT) scans in disease diagnosis. contrast-enhanced computed tomography (CECT) abdomen is widely utilized for detailed visualization of abdominal structures. However, it entails exposure to ionizing radiation, raising concerns, particularly regarding cancer risk. The radiation dose from CECT varies based on scan parameters, patient size, and imaging protocols. Medical professionals aim to optimize scanning parameters to minimize radiation exposure while preserving diagnostic quality. The objective of this study was to assess the variance in estimated doses received during CECT abdomen scans.

Material and Methods: Data from patients undergoing CECT abdomen from March 2023 to March 2024, including volumetric CT dose index (CTDIvol) and dose length product (DLP), were analyzed by a medical physicist and Radiation Safety Officer. Mean and cumulative doses were calculated using CTDIvol and DLP, with the effective dose determined using total DLP and a k-factor of 0.015 for the abdomen.

Results: This study comprised 296 patients (211 males and 85 females), primarily presenting with abdominal symptoms, with an age range of 18–85 years. Mean CTDIvol varied from 5 mGy to 26.42 mGy in males and from 4.96 mGy to 21.9 mGy in females, with similar trends observed in DLP values and effective doses. Statistical analysis indicated no significant difference in radiation dose by sex, though variations in effective dose were noted, possibly due to differences in exposure parameters and patient demographics.

Conclusion: While CECT scans effectively diagnose abdominal conditions, they do pose radiation risks. Radiology departments should monitor doses, standardized protocols, refine imaging techniques, and collaborate to ensure safety. Diagnostic reference levels are crucial for balancing the need for diagnostic information with the necessity to minimize patient exposure to radiation.

Keywords: Contrast enhanced computed tomography, Computed tomography dose index, Dose-Length product, Dose, Effective dose

INTRODUCTION

Contrast-enhanced computed tomography (CECT) of the abdomen is a technique for accurately visualizing anatomy and achieving precise diagnosis by the use of radiopaque dye. Despite having invaluable diagnostic information it offers, the consideration of radiation exposure becomes essential, requiring careful management. Conversely to conventional X-rays computed tomography (CT), CT scans utilize highly energetic ionizing radiation to generate detailed images, which presents inherent risks, including the potential for long-term adverse effects such as radiation-induced cancer. In the complex field of abdominal imaging, the concept of “differential dose” emerges as a crucial factor to be taken into account. Differential dosing in CECT abdomen cases involves customizing the administration of contrast agents and radiation dosage according to individual patient characteristics and diagnostic needs. This refined strategy enables healthcare providers to refine imaging protocols, guaranteeing both diagnostic precision and patient well-being. While exploring the domain of differential dosing in CECT abdomen cases, it reveals a complex terrain that includes clinical indications and imaging objectives. Effective comprehension and application of these dosing strategies empower healthcare providers to refine diagnostic accuracy, reduce radiation exposure, and ultimately enhance patient outcomes. It is crucial to consider the associated radiation

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dose when conducting these examinations to ensure patient safety and optimize imaging protocols. When considering CT imaging, especially for younger female patients, it's essential to weigh the advantages against the potential risks posed by radiation exposure.[1] Due to the use of high-density contrast agents, the dose received in the CECT is much higher (30%) than the noncontrast scans.[2] Significant apprehensions have arisen due to the possible escalation in long-term radiation-induced cancer, leading some researchers to assert that the diagnostic application of CT scans could contribute to a notable number of fatalities annually. Based on the figures, 1 in every 250 CECT examinations may result in the development of cancer.[3] The advantages of CT scans outweigh the negative impacts of radiation exposure in patients, and the rising radiation doses across the population make a strong argument for lowering exposure from CT scans. Photon counting detector-CT facilitates oncologic abdominal CT scans with a substantially lower dose, maintaining image quality comparable to that of a -second-generation Dual Slice CT scanner.[4] In abdominal pelvic CT scans, direct radiation exposure affects the prostate and uterus, potentially posing health hazards to patients. A research investigation illustrated a notable linear dose-response relationship concerning prostate cancer, indicating an estimated excess relative risk per Gy of 0.57. This study's findings led to the conclusion that "the observed dose-response reinforces the evidence suggesting a radiation impact on the likelihood of prostate cancer incidence among atomic bomb survivors."[5] There is no distinction in diagnostic efficacy between hepatic venous phase (HVP)-CT alone and multiphasic CT for identifying the causes of abdominal pain in patients admitted to the emergency department without preexisting chronic conditions or neoplasms.[6] It is possible to maintain the amplitude of signal and contrast to noise ratios while achieving a balance between the radiation and contrast dose.[7] In routine contrast-enhanced CT scans of the abdomen and pelvis, an extra delayed phase is included that is of minimal importance, especially when dependable follow-up imaging is accessible to provide further clarification of ambiguous findings.[8] Obtaining a low-dose scan necessitates collaborative efforts, involving customizing the scan to suit the patient and medical inquiry, alongside ongoing quality improvement to incorporate evolving strategies for optimizing dose.[9] Due to multiple scans in CT, the radiation increases subsequently, unlike X-rays, producing higher absorbed doses; hence, radiologists need to ensure that the patient's benefit is much greater than the risk produced by the exposures, which may depend on the patient.[10] The radiation should be kept lower than the diagnostic reference levels (DRLs) to increase patient safety and maintain image quality resulting in precise diagnosis.[11] DRL is an existing standard for specific imaging procedures designed to optimize radiation exposure levels and ensure they remain within a safe and acceptable range. The relationship between DRL and computed tomography dose index (CTDI) is that DRL serves as a reference point to evaluate CTDI values, ensuring that they remain within acceptable limits and that radiation exposure is optimized and safe.

Aim and Objectives: This study is aimed to assess radiation exposure levels associated with CECT scans of the abdomen, and also to estimate DRL for CECT abdomen studies. The primary objective of this study was to measure levels of radiation exposure related to CECT abdomen and to compare radiation dose among the genders.

MATERIAL AND METHODS

Patient selection

This retrospective study was approved by our institutional review board. A total of 296 patients with clinical/laboratory/ultrasonography diagnosis of different abdominal findings who were referred for multiphasic CECT abdomen from March 2023 to March 2024 were included in this study. Patients who had recently undergone abdominal surgery, individuals with renal failure, patients who were allergic to contrast media, pregnant patients, and patients lacking proper radiation dose reports were excluded. The minimum age of the patient was 18 years and maximum was 86 years.

CT technique

For a contrast study, SmartPrep technique was activated in general electric Revolution Evo 128 Slice CT scanner to chase the uniform flow of contrast to the region of interest. On the whole, the contrast study of the abdomen consisted of three phases, namely the arterial phase, which was acquired after 18s, the venous phase after the 60s, and delayed phase after 5–7 minutes. Finally, the patient was instructed to drink plenty of water for the washout of the administered contrast. Retrospectively, image data of the patients who have undergone CECT abdomen for different clinical indications were assessed to evaluate the radiation dose.

Radiation dose analysis

Dose information was available in the CT unit. The details of the dose report, including volumetric CT dose index (CTDIvol) and dose length product (DLP) for all patients, were recorded for each phase. Radiation doses were analyzed by a medical physicist and radiation safety officer. The data was obtained from the digital imaging and communications in medicine server and radiology information system using a filtered data form (age, sex, diagnosis on CT, CTDIvol [mGy]), dose length product (DLP [mGy.Cm]). CTDI is a dose descriptor that provides a measurement of the radiation dose due to the primary and scatter radiation per slice of tissue and is expressed as mGy. DLP, another CT dose descriptorprovides a measurement of the total amount of dose to the entire scan coverage and in mGy.Cm. CTDIvol and DLP were used to calculate the average and mean patient dose and compared with each other throughout the study. Effective dose, a dose descriptor reflecting the biological sensitivity of irradiated regions of interest, was calculated by taking the product of total DLP and the k-factor (the proportionality constant between the effective dose and the DLP). The k-factor for the abdomen is 0.015.

Statistical analysis

The statistical analysis of radiation dose involved examining various parameters such as mean, maximum/minimum dose values, and effective doses, which were calculated for all patients. The data has been analyzed using the Microsoft Excel 2016 calculation software. Descriptive statistics, including bar graphs and pie charts, have been employed to visualize the distribution of radiation doses.

RESULTS

This study revolves around two sections, including the sociodemographic characteristics of the participants as well as parameters associated with radiation exposure and dose evaluation comprising 296 patients (211 males and 85 females). Males comprised an age range of 18–83 years while females of 20–86 years; the average age of males was 47.8 years, and 51.2 years for females. A majority of the patients had a history of abdominal pain (n = 162), constipation (n = 65), recurrent vomiting (n = 37), and follow-up of different diagnosis (n = 17) and others (n = 15), respectively [Table 1].

Table 1: Table showing demographic details of the patients

Gender	Age	Total number of patients	Symptoms
Males	Mean: 47.8	211	Abdominal pain: 117
	Min: 18		Constipation: 55
	Max: 83		Vomiting: 23
			Follow-up cases: 7
			Others: 9
Females	Mean: 51.2	85	Abdominal pain: 45
	Min: 20		Constipation: 10
	Max: 86		Vomiting: 14
			Follow-up cases: 10
			Others: 6

Tube voltages ranged from 80 kVp to 140 kVp, pitch of 1 mm, tube current-time ranged from 150 mAs to 280 mAs, slice thickness of 5 mm, contrast amount of 1.2 mL per kg of body weight with a flow rate of 3–4 mL per second. These factors of radiation exposure, including current and potential of tube, thickness of slices, slice number, and pitch, were taken into account [Table 2].

The minimum and maximum CTDIvol for abdominal CT were found to be 5 mGy and 26.42 mGy in males and 4.96 mGy and 21.9 mGy in females, with a mean of 11.54 and 12.77 mGy in males and females, correspondingly. The minimum and maximum DLP for CECT abdomen was 1004.62 mGy.cm and 6484.2 for males and 1040 mGy.cm and 4964.1 mGy.cm for females, respectively, with a mean of 2734.56 mGy.cm. and 2842.61 mGy.cm. The minimum and maximum effective dose was determined to be 15.06 mSv and 97.2 mSv for males and 15.6 mSv and 74.4 mSv for females, respectively, with a mean of 40.93 mSv for males and 42.63 mSv for females [Table 3].

The DRLs for CTDIvol and DLP values were established for this study; DRLs for CTDIvol: 34 mGy, 45.9 mGy, and 56.4 mGy for the 25th, 50th, and 75th percentile, respectively, and the proposed DRLs for DLP are 2018.7 mGy.cm, 2679.4 mGy.cm, and 3363.125 mGy.cm for 25th, 50th, and 75th percentile, respectively. The established local DRL for CECT abdomen is shown in Table 4.

Table 2: Image acquisition parameters according to different genders

Gender	Tube voltage (kVp)	Tube current (mA/mAs)	Pitch	Slice thickness (mm)
Male	Mean: 110	Mean: 215	1	5
	Min: 80	Min: 150		
	Max: 140	Max:280		
Female	Mean: 110	Mean: 215	1	5
	Min: 80	Min:150		
	Max: 140	Max: 280		

Table 3: Dose data of CECT abdomen examinations

Gender	Computed tomography dose Index (CTDI) (mGy)	Dose length product (DLP) (mGy*cm)	Effective dose (mSv)
Male	Mean: 11.54	Mean: 2734.56	Mean: 40.93
	Min: 5	Min: 1004.62	Min: 15.06
	Max: 26.42	Max: 6484.22	Max: 97.26
Female	Mean: 12.77	Mean: 2842.61	Mean: 42.63
	Min: 4.96	Min: 1040	Min: 15.6
	Max: 21.9	Max: 4964.1	Max: 74.46

CECT: Contrast-enhanced computed tomography

Table 4: DRL for CECT abdomen

Percentile	25th	50th	75th
CTDI (mGy)	34	45.9	56.4
DLP (mGy.cm)	2018.725	2679.4	3363.125

DRL: Diagnostic reference levels, CECT: Contrast-enhanced computed tomography, CTDI: Computed tomography dose index, DLP: Dose length product

An independent sample t-test was done to check if there was any statistically significant difference between the radiation dose with sex, but it was not statistically significant. There was a difference in the calculated mean values of the effective dose that could have possibly occurred due to the different exposure settings and patient aspects.

DISCUSSION

Ever since its introduction into clinical practice, CT scanning has been acknowledged as a diagnostic imaging technique associated with higher radiation doses compared to other modalities. As scanner technology has evolved and its utilization has become increasingly widespread, concerns regarding patient radiation doses from CT scans have escalated.[12] Switching from conventional X-rays to CT results in a very sharp increase in the effective doses received by the patient. A study done by Yadav *et al*. (2023) examined 92 adult patients undergoing abdominal CT scans at a Nepalese medical imaging department from August 2018 to January 2019 using a 16-slice CT scanner. Radiation doses were assessed using CTDIvol, DLP, and effective dose and analyzed with SPSS version 20, which were 7.31 mGy, 421.46 mGy.cm, and 6.31 mSv, representing a lower value than the standards established by European guidelines and International Atomic Energy Agency. A direct relation was found between the dose and body mass indexof individuals in multiple scan types.[13] Choudhary *et al*. (2019) used a 16-slice scanner and evaluated radiation exposure in the head, thorax, abdomen, and pelvis. The CTDI results were adjusted for patient size using the size-specific dose estimate (SSDE) technique. The CTDIvol readings of 26.76 mGy, 16.27 mGy, 14.74 mGy, and 29.81 mGy were observed, respectively. A 4–8% variance from American Association of Physicists in Medicine-reported CTDI values were indicated by SSDE-calculated median doses, which raised concerns about depending exclusively on CTDI for accurate patient dose determination during CT operations.[14] The CTDI and SSDEs among the 75 patients in El Mansouri *et al*.'s (2022) study were also determined using an algorithm that showed the values for CTDI varied from 4.8 mGy to 12.2 mGy and for SSDE from 8.01 mGy to 14.15 mGy.[15]

The variation in mA and scan volume DLP value variations were calculated in this study. In the majority of cases, the radiation dose and mA were linear. As a result, lowering the tube current value lowered the radiation dose to the patient. Table 2 provides details of mean and range values for CTDIvol (mGy), DLP (mGy*cm), and effective (mSv). For males and females, the mean effective dose was around 40.93 mSv and 42.63 mSv, respectively. Women's effective dose was slightly greater (42.63 mSv) than men (40.93 mSv). Compared to 32- and 64-slice CT scanners, 16-slice CT scanners gave patients the least amount of radiation and produced images good enough for diagnosis.[16] This study investigated the sociodemographic characteristics and parameters related to radiation exposure and dose evaluation in 296 patients undergoing abdominal CT scans. The patients presented with symptoms such as abdominal pain, constipation, and recurrent vomiting. Factors including tube voltage, tube current, slice thickness, and contrast amount were considered in assessing radiation exposure. Analysis revealed a range of CTDIvol, DLP, and effective dose values, with slight variations between males and females. While statistical analysis did not show a significant difference in radiation dose by sex, differences in effective dose may be attributed to varying exposure parameters and patient body. The findings highlight the need for dose optimization techniques to reduce exposure while maintaining diagnostic accuracy. Establishing DRLs for CT scans is an essential tool for optimizing and ensuring safe radiation exposure for patients. This study has established DRLs for CTDIvol and DLP values, which are crucial for evaluating patient radiation doses during CT examinations. The proposed CTDIvol DRLs are 34 mGy, 45.9 mGy, and 56.4 mGy for the 25th, 50th, and 75th percentiles, respectively, comparable to those in similar studies, indicating our CT scanner's compliance with acceptable dose limits. These values help radiologists and radiographers optimize scanning protocols and minimize patient radiation exposure. The proposed DRLs for DLP are 2018.7 mGy.cm, 2679.4 mGy.cm, and 3363.125 mGy.cm for the 25th, 50th, and 75th percentiles, respectively, suggesting our scanner delivers acceptable doses. DLP values provide a comprehensive assessment of radiation exposure by considering scan length. These DRLs significantly impact radiation safety in our imaging department, guiding protocol optimization, reducing patient exposure, and improving care quality. They also serve as benchmarks for other departments, promoting radiation safety and dose optimization.

CONCLUSION

CECT scans are vital for diagnosing abdominal conditions, yet their high radiation doses pose risks to sensitive organs. Significant dose variation was observed throughout the study and this variation may have been due to differences in the scan protocol and parameters associated with the scanners and patient demographics. Radiology departments must monitor doses and follow standardized protocols to optimize radiation levels across facilities. Refining imaging protocols is crucial to reducing patient exposure without compromising diagnostic accuracy. Collaboration among radiologists, physicists, and technologists is essential for ongoing improvement. Establishing national DRLs for CT examinations is recommended to ensure consistency in dose optimization efforts. DRLs in CT imaging serve as benchmark radiation dose levels for standard procedures, aiding in optimizing patient safety. This practice helps standardizing radiation doses across different institutions, promoting consistent and safe imaging practices. Implementing these measures enhances patient safety and mitigates risks associated with radiation exposure during CECT abdomen imaging.

Authors' contributions: BA: Concept and design; JUI: Data analysis and interpretation; MRB: Manuscript preparation; AAW: Manuscript preparation.

Ethical approval: The ethical committee waved off the ethical clearance for the study as the study only focused on the technical aspects which included dose factors of the scans. There was no patient involvement in the study.

Declaration of patient consent: Patient's consent not required as patients identity is not disclosed or compromised.

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REFERENCES

1. Smith-Bindman R, Lipson J, Marcus R, Kim KP, Mahesh M, Gould R, *et al*. Radiation dose associated with common computed tomography examinations and the associated lifetime attributable risk of cancer. Arch Intern Med 2009;169:2078–86.
2. Mazloumi M, Van Gompel G, Kersemans V, de Mey J, Buls N. The presence of contrast agent increases organ radiation dose in contrast-enhanced CT. Eur Radiol 2021;31:7540–9.
3. Sulieman A, Tamam N, Elnour A, Alkhorayef M, Babikir E, Al-Mohammed HI, *et al*. Effective radiation dose and radiogenic cancer risk during contrast enhanced abdominal computed tomography examinations. Radiation Physics and Chemistry 2022;200:110328.
4. Wrazidlo R, Walder L, Estler A, Gutjahr R, Schmidt B, Faby S, *et al*. Radiation dose reduction in contrast-enhanced abdominal CT: Comparison of photon-counting detector CT with 2nd generation dual-source dual-energy CT in an oncologic cohort. Acad Radiol 2023;30:855–62.
5. Shubayr N, Alashban Y. Estimation of radiation doses and lifetime attributable risk of radiation-induced cancer in the uterus and prostate from abdomen pelvis CT examinations. Front Public Health 2023;10:1094328.
6. Hwang SH, You JS, Song MK, Choi JY, Kim MJ, Chung YE. Comparison of diagnostic performance between single- and multiphasic contrast-enhanced abdominopelvic computed tomography in patients admitted to the emergency department with abdominal pain: Potential radiation dose reduction. Eur Radiol 2015;25:1048–58.
7. Fält T, Söderberg M, Hörberg L, Carlgren I, Leander P. Seesaw balancing radiation dose and i.v. contrast dose: Evaluation of a new abdominal CT protocol for reducing age-specific risk. AJR Am J Roentgenol 2013;200:383–8.
8. Chan MG, Cassidy FH, Andre MP, Chu P, Aganovic L. Delayed imaging in routine CT examinations of the abdomen and pelvis: Is it worth the additional cost of radiation and time? AJR Am J Roentgenol 2014;202:329–35.
9. Trattner S, Pearson GDN, Chin C, Cody DD, Gupta R, Hess CP, *et al*. Standardization and optimization of CT protocols to achieve low dose. J Am Coll Radiol 2014;11:271–8.
10. Fujii K, Aoyama T, Yamauchi-Kawaura C, Koyama S, Yamauchi M, Ko S, *et al*. Radiation dose evaluation in 64-slice CT examinations with adult and paediatric anthropomorphic phantoms. Br J Radiol 2009;82:1010–8.
11. IAEA. Radiation protection and safety of radiation sources: International basic safety standards. General safety requirements part 3, No GSR Part 3 Interim. Vienna: International Atomic Energy Agency, 2014; p. 1–303.
12. Valentin J. The 2007 recommendations of the international commission on radiological protection. ICRP publication 103. Ann ICRP. 2007;37:1–332.
13. Yadav SC, Banstola S, Mukhi S, Palikhey A. Radiation dose measurement during CT abdomen examination of adult patients: A cross-sectional study. J Nat Heart Lung Soc Nep 2023;2:26–30.
14. Choudhary N, Rana BS, Shukla A, Oinam AS, Singh NP, Kumar S. Patients dose estimation in CT examinations using size specific dose estimates. Radiat Prot Dosimetry 2019;184:256–62.
15. El Mansouri M, Choukri A, Semghouli S, Talbi M, Eddaoui K, Saga Z. Size-specific dose estimates for thoracic and abdominal computed tomography examinations at two Moroccan hospitals. J Digit Imaging 2022;35:1648–53.
16. Mettler FA, Wiest PW, Locken JA, Kelsey CA. CT scanning: Patterns of use and dose. J Radiol Prot 2000;20:353–9.

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