Influence of the Different Multi- Detectors CT scans in Radiation Dose and Image Quality in Brain Examinations

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Abstract

Background: Multidetector computed tomography (MDCT) has become a standard imaging modality for many clinical applications due to its wide availability, reduced invasiveness, rapid scanning time, superior anatomical resolution, and increased diagnostic value. Both the patient's radiation exposure and the level of anxiety surrounding this matter have increased. Objective: The aim of this study is to assess image quality related to patient radiation dose for multidetector computed tomography in abdomen CT examinations. Patients and Methods: 30 patients from four hospitals underwent abdomen scans using 16, 32, and 64-slice (CT) scanners. To calculate image quality and estimate dosage, clinical image data were employed. CNR and SNR's calculation of image quality. From the image display, the CT dose volume index (CTDIv) and dose length product (DLP) were recorded Results: Regarding the radiographic parameters, the mean value of radiation doses (CTDIv, DLP and ED) to patients were higher from 64 slice scanner for the abdomen CT scan examination (19.56±3.2, 1046±247.4 and 15.68±3.71) respectively. It was significantly lower in 32 and 16 slice multi detector CT (17.71±2.62, 718±5.88 and 10.76±0.09) (15.63±0.311, 619±101.5 and 9.3±1.52) respectively. Regarding image quality assessment, the SNR and CNR are compared among the patients examined in three types of MDCT. The higher SNR associates a multi-detector row 64-MDCT. The means of SNR and P-value are (3.52±1.98, 3.62±1.61, 7.47±2.07 and 0.001) respectively. Conclusion:, The mean value of radiation doses (CTDIv in mGy, DLP in mGy.cm, and ED in mSv) was higher in 64 than 32 and lower in 16 in an abdominal CT scan. Image quality SNR and CNR of abdomen MDCT scan images improve with increase the detector of CT scan.

Keywords: Multi-detector CT scan, Radiation dose, Image quality, Contrast to Noise Ratio, Signal to Noise Ratio.

1. Introduction

Clinical applications of CT technology have been established as effective and well-known diagnostic techniques, and they are now more potent than ever (1).

MDCT systems refer to computed tomography scanners with detector array that is made up of several rows of detectors. With regard to MDCT scanners, the application of several detector arrays (i.e. rows) in the longitudinal direction has been known as "multi-detector-row" (that is, along length of a patient lying over patient table) (2).

Future years are expected to see the commercial availability of even larger detector arrays with longitudinal coverage per a rotation > 4cm. A 256-detector scanner with 12.8cm of the longitudinal coverage in rotation's center has already produced preliminary results that were published (3). Additionally, the development of commercially viable MDCT system that include 2 sources of the x-ray shows that the technology and the applications of the computed tomography are still developing (4). The radiation protection concepts of the ICRP include optimization, justification, and dose limitation (5). The International Basic Safety Standards (BSS) and International Commission on Radiological Protection (ICRP) both seek both general and individual justification (5,6). The professional organizations frequently work with regulatory organizations to develop guidelines for both individual and collective justification. The most effective method of reducing unnecessary exposure and, as a result, a strong radiation protection measure is justifying radiation-based tests like CT. Both poor and rich nations are thought to experience a significant number of unjustified exposures. There are few published data on the amount of radiation emitted due to unneeded CT use and the amount that might be prevented by engaging in different activities. Referring physicians, medical physics experts, and radiology societies must work together to research the practice, count the amount of unwarranted exposures, and devise measures to avoid unwarranted exposures. In contrast to justification, optimization has received considerable attention, and the literature is well-researched with regards to the extent of the dosage reduction which could be attained by optimization operations. Professional societies must agree on a solution and make recommendations. According to the clinical context, works from Royal College of Radiologists (U.K.) and American College of Radiology (US) have demonstrated why certain examinations must be conducted over others and in what order (7). When

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adequate dose limits were established, International Commission on Radiation Protection (ICRP) and International Basic Safety Standards (BSS) have consistently held that the dose restriction system must be applied to occupational exposures (5,6). While achieving the intended clinical purpose, exposure must be kept as low as reasonably practicable through a process of optimization and justification since there are no dosage restrictions in place for patients. This rule is still in effect (8).

MDCT has seen a dramatic rise in use since its introduction. Because of the common use of smaller sections, a higher collection volume, and multiple-phase acquisitions, MDCT increases diagnostic potential and permits additional clinical uses, yet it also can increase radiation exposure. According to literature (9).

2. Patients and Methods

The study presented here was conducted on 30 patients who had consecutive CT scans from March 2022 to August 2022, ages 18 to 70. The study's findings were distributed to numerous hospitals and private clinics in Baghdad.

The experiments were carried out on three different multiple slices computed tomography (MSCT) scanners. (16 slice MDCT, PHILIPS & SIEMENS),(32 slice MDCT, SIEMENS) and (64 slice MDCT, TOSHIBA & SIEMENS). The abdominal examinations were performed with ten patients assigned to each type of examination (MSCT).

The primary scan parameters that can be changed by technicians or operators are kVp and mAs, which significantly affect image quality and patient radiation dose. This study's protocol was (120 kVp, automatic modulation mAs). DLP and CTDIv were computed using dose information obtained from the protocols prescribed for each device.

CTDI represents the key dosage measurement concept in the CTDI. It is the average dose that has been absorbed across a number of continuous z-axis exposures. It is determined through dividing the integrated absorbed dose from a single axial computed tomography scan (one x-ray tube spin) by total beam width (10). Because a sequence of adjacent and overlapping slices is typically obtained, the amount of dosage in one slice grows in CT scan applications. The surrounding slices' contribution has been represented by MSAD. Multiple Scan Average Dose is a sign of the total dose volume in addition to the different positions within the volume scanned during scans for a constant distance and scan interval. The increase in single-slide dose for CT scan applications is a result of a series of contiguous and overlapping slices (8). The CTDIw, which is estimated from the CTDI readings of 100mm at the periphery and the center of 32cm phantom for the body and a 16cm phantom for head, is the best way to characterize average dosage in scan plane. The average dose is represented by CTDIw under the supposition that dosage reduces in a linear manner with radial position from surface to phantom's centre:

CTDIw= 1/3 CTDI100(central) + 2/3 CTDI100(peripheral)

The ratios 1/3 and 2/3 resemble relative areas that are indicated by values for the centre and edge (11). The CTDIw represents an accurate scanning radiation output predictor for a given mAs and kVp. Volume Computed tomography dose index measures exposure per tissue slice over the whole scan duration, assuming no gaps or overlapping in the scan slices. There is a direct relationship between CTDIvol and pitch parameter (12).

CTDIvol= 1/p ·CTDIw

Dose length product measures radiation output length along patient's long axis. It determines total exposure for a set of the scans. It may be estimated in the case where irradiated volume length (i.e. length of the Scan) and the CTDIvol are known by the use of the following equation (13):

DLP = CTDI vol × Scan length.

This equation predicts that as the scan time is increased, the DLP will increase as well. Although the DLP more correctly depicts the radiation dose for a specific CT scan, patient anatomical variations reduce its usefulness. For comparing radiation doses among procedures, CTDI vol is a valuable tool.

Effective dose calculations need precise knowledge of unique scanner features, the relationship may be used to provide a good estimate of effective dosage regardless of scanner type (12).

Effective Dose = k • DLP

where k values (0.015) is a weight factor in (mSv/mGy cm) which has been mainly determined by the body region (Abdomen) (14).

The photographs have been seen on E film workstation. Each image at a thickness of 5.0 mm has been recreated using images in the axial plane. As illustrated in figure 1, standardized (2) mm-diameter circular regions of interest (ROIs) depicting mean attenuation and SD in Hounsfield units (HU) were used to record signal and noise for the liver during the abdominal examination. Images' noise (magnitude) is frequently measured using the SNR and CNR ratios. Yet, because CNR and SNR only assess noise, the SD utilized in the computations varies based on where the ROI is located in the human body image with a non-homogeneous medium (15).

CNR=HU Target-HU BG air/SD BG air (8)

SNR=HU Target /SD Target

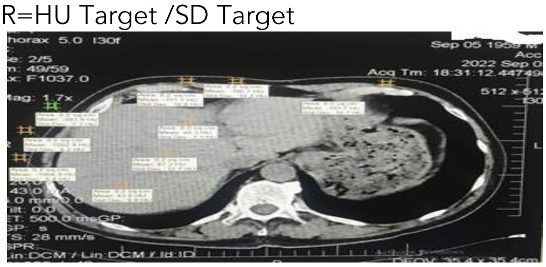

Figure 1: The values of standard deviation (SD) and Hounsfield units (HU) for the liver in the abdomen examinations.

3. Statistical Analysis in Methods

IBM SPSS version 26 was used to enter, verify, and analyze the obtained data. In this study, descriptive statistics were utilized to qualitatively summarize the properties of the collected data. The significance between the study's groups (abdomen, chest, and brain) and their subgroups of multi-detector rows of CT scan was also determined using the ANOVA test (16-MDCT, 32-MDCT, and 64-MDCT). Additionally, it was recommended that the study's p-value, which shows differences across groups, be less than 0.05.

4. Results

A total 30 of three equally collected group samples were investigated radiographically for three types of MDCT abdomen body part after following the inclusion and exclusion criteria.

In terms of radiographic parameters, the mean value of radiation doses (CTDlv in mGy, DLP in mGy.cm, and ED in mSv) to patients from the 64-slice scanner for abdomen was the higher as they found to be (19.56±3.2, 1046±247.4 and 15.68±3.71) respectively. In case of 32 slice scanner, it was found to be (17.71±2.62, 718±5.88 and 10.76±0.09) respectively, which is lower than the values obtained in 64 slice scanner. The lowest values of radiation doses were found to be (15.63±0.311, 619±101.5 and 9.3±1.52) in 16 slice scanners respectively, as listed in Table 1. Figure 2 indicate how the (DLP in mGy.cm, CTDlv in mGy, and ED in mSv) are considerably different among of the abdomen examination.

Table 1: Mean value of radiation dose among the study groups examined by 16, 32, and 64 MDCT in abdomen examination.

	Measures	Study Groups (Means ± SD)			P-value
		16 (n=10)	32 (n=10)	64 (n=10)	
Abdomen	CTDLv in mGy	15.63±0.311	17.71±2.62	19.56±3.2	<0.001
	DLP in mGy.cm	619±101.5	718±5.88	1046±247.4	<0.001
	Effective dose in mSv	9.3±1.52	10.76±0.09	15.68±3.71	<0.001

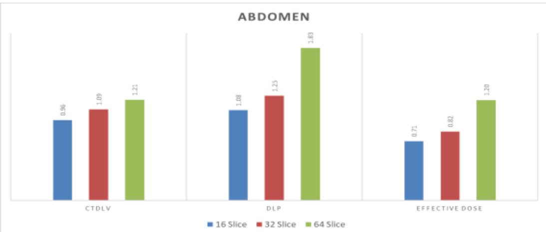

Figure 2: Normalized means of CTDLv, DLP, and Effective dose of abdomen diagnosis.

Concerning SNR and CNR, the means of SNR and P-value are (3.52±1.98, 3.62±1.61, 7.47±2.07 and 0.001) respectively and mean of CNR and P-value are (131.3±46.4, 153.8±61, 190.14±79.73 and 0.135) respectively. Where, the higher SNR associates a multi-detector row 64-MDCT, is significantly higher than what achieved in 32-MDCT and 16-MDCT, as listed in Table 2.

Figures 2: Representing scatter plot of DLP measured in three MDCT (16, 32 and 64 rows) and SNR and CNR calculated from image display which shows the higher SNR associates a multi-detector row 64-MDCT for abdomen examinations.

Table 2: ANOVA Test of SNR and CNR among CT detectors 16, 32, and 64.

	Measures	Study Groups (Means ± SD)			P-value
		16 (n=10)	32 (n=10)	64 (n=10)	
Abdomen	SNR	3.52±1.98	3.62±1.61	7.47±2.07	0.001
	CNR	131.3±46.4	153.8±61	190.14±79.73	0.135

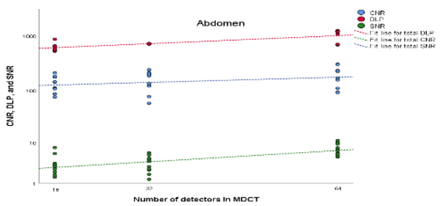

Figure 3: Scatter plot of DLP, SNR and CNR as a function of MDCT for abdomen including data fitting of total DLP, SNR and CNR as a coloured line.

5. Discussion

The radiation dose is a source of concern due to the widespread use of MDCT, and the population's total radiation problem is growing. Because of the small gaps in sampling, a higher dose of radiation is required for a higher image quality. This demonstrates an intricate relationship between dose reduction and image quality (16).

The goals of this study were to estimate typical CT dosage descriptors such as DLP, ED, and CTDlv, as well as to evaluate image quality metrics in non-contrast abdomen computed tomography scans performed in several hospitals using various MDCT scanners.

CT images were obtained for patients with standard body size using three types of MDCT scans with a fixed tube voltage of 120 kV and automatic modulation mAs. Three different slices were investigated (16, 32 and 64 slices).

The CT dose index was first proposed by Shope & Gagne et al. (1981)(17) as a metric for measuring the output of radiation from a computed tomography examination that includes several contiguous CT scans (i.e. several adjacent transverse rotations regarding x-ray tube along longitudinal axis of a patient) that cannot be evaluated using conventional dosimetry procedures. The CTDI approach set out to create an index to reflect the average dose to a cylindrical phantom in the core region of a series of scans. DLP is one of the CTDIvol derivatives. DLP is formed by the combination of CTDI and the irradiation scan length. This allows for direct comparison of radiation dosage between scanners from different manufacturers and at different scanning parameter settings. The CT dose index, on the other hand, does not represent the precise dosage for any particular patient; rather, it represents a dose index as determined and estimated in a poly-methylmethacrylate phantom.

Despite the fact that CTDI is a useful tool for comparing protocols, patient-associated factors such as shape, size, and inhomogeneous composition are not considered. The dose index and patient size can be combined to calculate the absorbed dose. The patient's attenuation (the greater the patient's attenuation, the smaller the patient's dosage) and size influence the patient's dosage for any given scanning method. As a result, the CTDI indicated is lower than the actual dosage given to infants and young children. The CTDI is currently frequently determined after 1 axial scanner rotation using a 100mm pencil-sized chamber of ionization. The average (weighted) CTDI is calculated by adding two-thirds of the peripheral value and one-third of the central value. When scanning with a pitch greater than one, weighted CTDI must be corrected by pitch factor (dosage index divided by pitch), after which it is referred to as volume CTDI. Product with a Dose-Length (DLP) The DLP, as the name implies, indicates the total integrated radiation dose of a CT scan. DLP = volume CTDI total scan length (in centimeters) includes both scan width and scan count. The mGy.cm is the unit. The total sum of all section collimations determines the scan length for conventional (non-spiral) scanning; for high-resolution CT, this is 25 mm (25 × 1 mm).

In this research, we discovered that the mean radiation doses (CTDIv in mGy, ED in mSv and DLP in mGy.cm). The CTDIvol of the abdomen case for slices 32 is (17.71±2.62 mGy), whereas the CTDIvol for slices 16 is (15.63±0.311 mGy), and the CTDIvol for slices 64 is (19.56±3.2 mGy). Additionally, the 64 slices (1046±247.4 mGy.cm) has a greater DLP than the 32 slices (718±5.88 mGy.cm) for the abdomen (16 slice DLP is 619±101.5 mGy.cm). Our measured CTDIvol and DLP show significant variations between the 16 slices and 64 slices.

The mean effective dosage for the abdomen in this work was computed and was found to be 9- 15.68 mSv. As a result, the effective dose as determined is within the acceptable range. Diagnostic CT's allowable dose range is 2–20 mSv Rawashdeh & Saade et al. (2023) (18).

Because good contrast resolution necessitates a high SNR during CT acquisition, the radiation dose to the slice volume is significantly higher Summerlin & Willis et al. (2022) (19). CNR determines the signal amplitude even when there is noise present in a homogeneous object (measures signal amplitude despite the presence of noise, regardless of its size). SNR defines things that are not homogeneous in a homogeneous object using shape and size in conjunction with object conspicuity (incorporates shape and size for describing object conspicuity and could be used for non-homogeneous objects) Ma & Fan et al. (2020) (20). Both SNR and CNR are indicators of image quality. Small lesions require a high SNR to be detected, and all lesions require a high CNR to be distinguished from background parenchyma. To maintain diagnostic image quality at low dosages, the CNR and SNR must be conserved. SNR and CNR are image quality metrics.

In this study the image quality assessment done quantitatively by comparison between the different MDCT scanners at abdomen region by measurement of CNR and SNR, both parameters were used in many studies for same purpose Yoon & Kim et al. (2021) (21) in his study on assessment of pediatric CT scan at chest and abdomen he depend on the quntitaive evaluation of his result on CNR and SNR, the same parameter used by Yan et al. (2016) (22) the study depend on 4 parameters in assessment of PET image quality SNR, CNR, bias and image noise.

In regard to SNR, in our study it is noted that the higher SNR at abdomen associates a multi-detector row 64-MDCT, is significantly higher than what achieved in 32-MDCT and 16-MDCT as the P value is 0.001.This result at this region might be explained by the relatively short time of examination if compared to other scanners which may reduce the bowel motion effect that affect the image quality and the higher noise at the abdominal region which make the difference is significant at this particular exam. This result is agreed by Anam & Budi et al. (2019) (23). In this study they compared between different regions area according to dose and noise and the result was The noise in abdomen, pelvis, and thorax images have been similar with average values of 5.20 ± 1.4HU, 5.90 ± 1.50HU, and 4.90 ± 0.80HU, respectively, whereas in head images, noise is considerably lower at 3.90 ± 0.20HU.

Although no study assess the MDCT according to SNR and CNR, but many researchers use different criteria to assess image quality, our result was agreed to Rao & Andersen et al. (2015) (24) and his collage as he assessed image quality for 6 separate computed tomography scanners from 4 different vendors, results from this research have indicates that there has been minor drifting in image noise and uniformity and in spatial resolution over the time for the compute tomography scanners, despite MDCT and vendors.

Our result shows that by assessment of the image quality by the measurement of CNR and SNR was higher at 64 slice MDCT this result was no significant statistically, we have compared our result to different articles dealing with image quality, Fair et al. (2022) (25). In the presented work, 48 patients had their image quality quantitatively assessed in three areas (chest abdomen and pelvis). The findings of this work revealed that, even though lowering the dose and utilizing various constrictive techniques might still produce comparable performance or at presently acceptable dose levels, the single-source rapid kilovoltage switching method has enhance performance due to using higher performance x-rays. The outcome of this investigation supported the findings of our work, which showed that the image quality was higher at high image tube dose in 64 MDCT scan, yet remained comparable and lower dose in 32 and to a lesser extent 16 MDCT.

6. Conclusion

The mean value of radiation doses (CTDIv in mGy , DLP in mGy.cm and ED in mSv) higher in 64 than 32 and less than that in 16 in abdominal CT scan. There are no significance differences of CNR among abdomen examination according to the three multi-detector rows of 16-MDCT, 32-MDCT, and 64-MDCT. SNR was higher in 64 MDCT than other CT scanner mainly in abdominal CT exam. The dose of radiation was within the international limit of radiation doses in all MDCT scanners.

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