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Measurement Of Radiation Doses In Computed Tomography And Estimated Radiological Risk Factor Of Cancer

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Abstract.
The research evaluated head and chest and abdominal third-level computed tomography (CT) doses received by Babel Governorate patients in Iraq and compared the findings to international reference parameters. 120 CT scans were obtained from Philips 128-slice machines together with Philips 64-slice machines and Siemens 64-slice machines. The study derived dose length products (DLP) and effective doses from volume CT dose index (CTDIvol) measurement. CTDI and DLP readings of head and chest scans remained underneath global benchmark levels yet abdominal scans surpassed the benchmarks due to extended scan times and added scanning phases. The Siemens 64-slice recorded the lowest mean effective dose at 1.23 mSv during head examinations followed by Philips 128-slice at 2.86 mSv as well as Philips 64-slice at 3.08 mSv. The Siemens 64-slice deliver a chest scan dose of 4.76 mSv at the same level as the Philips 128-slice delivers 8.59 mSv and 13.32 mSv for the Philips 64-slice. The CT procedures required 7.03 mSv for the Philips 64-slice scanner, 15.32 mSv for the Philips 128-slice model and 6.71 mSv for the Siemens 64-slice scanner. The Siemens 64-slice machine offered lower radiation doses than both versions of the Philips machines. The research shows head and chest CT doses remained within the safety threshold yet abdominal CT doses need further optimization to decrease radiation risks. Effective dose calculations demonstrate how patients of all ages but especially the younger ones need radiation protection because they need to undergo numerous scans. To achieve patient safety with maintained diagnostic accuracy healthcare facilities should employ dose-reduction methods and execute regular dose audits and utilize modern CT technology.

INTRODUCTION.

Computed tomography is still as exciting as at the beginning of its development during the 1960s and 1970s; however, several competing methods exist, the most important being magnetic resonance imaging (MRI). Since the invention of MRI during the 1980s, the phasing out of CT has been anticipated. Nevertheless, to date, the most widely used imaging technology in radiology departments is still CT. Although MRI and positron emission tomography (PET) have been widely installed in radiology and nuclear medicine departments, the term tomography is clearly associated with x-ray computed tomography. [1]
This technology has become indispensable in modern medicine, enabling doctors to obtain accurate images that allow for quick and accurate diagnoses of emergency situations. Moreover, CT plays a crucial role in diagnosing chronic conditions, offering vital information for managing long-term health problems.[2]
However, while CT scans are invaluable in medical diagnostics, they come with certain risks, primarily related to radiation exposure. This has led to ongoing research into methods to reduce radiation doses while maintaining high image quality.Over the past decades, significant improvements have been made in CT technology, with advances that have enhanced both imaging speed and radiation dose reduction, Despite these developments, further research and innovation are necessary to optimize CT imaging and ensure that it remains a safe and effective diagnostic tool for patients.[3]
There are two primary types of radiation dose measurements in CT imaging. The first is the "Absorbed Dose," which reflects the actual amount of radiation absorbed by the tissues and is measured in grays (Gy). The second is the "Effective Dose," which considers the varying sensitivity of different tissues to radiation and is measured in sieverts (Sv). The effective dose is critical for estimating the biological risks of radiation exposure, making it a valuable tool for comparing different imaging scenarios. [4]
Several factors influence the radiation dose a patient receives during a CT scan, including voltage, current, scan time, rotation angle, and slice thickness. The dose is typically measured using a pencil ionization

chamber with a plastic phantom. Alternatively, thermo-optical dosimeters can be used to determine the actual patient dose. [5]Studies show that multiple scans increase the dose in a single section by less than twofold. Typical doses for head scans range from 40–60 mGy, while body scans range from 40–100 mGy.[6]. Medical imaging procedures used in diagnostic exams such as x-rays and CT scans provide a one-time dose.[7]

Methods of Measuring Radiation Dose

Radiation dose measurement is used to determine the radiological effect on living tissues and ensure safety in medical and industrial applications. It is measured using three main methods:

1- Absorbed Dose :This refers to the amount of energy absorbed in living tissues and is measured in gray (Gy).

2. Effective Dose :The effective dose takes into account the varying sensitivity of different organs to radiation and is measured in sievert (Sv)

MATERIALS AND METHODS.

This is a retrospective study includes the dosimtric data collection for three most common CT examinations in two different hospitals in Babylon Governorate.

The CT examinations considered in this study are brain, chest and abdomen, these examinations are selected because they are the most frequent examinations in the majority of hospital examinations in the majority of hospitals In this study all examinations were performed at ALqassim General Hospital and Fadake Center in Babylon Governorate, In first hospital have been used one of a CT model which is Siemens CT machine from Germany company, and the second hospital have been used a Philips CT machine from same manufactured Germany.

In ALqassim General hospital, the examinations of dosimetric data for 60 adults patients was collected, and the second hospital Fadake Centre the examinations of the dosimetric data for 120 patients was collected, The dosimetric data include CTDIvol and DLP for examination protocol as well as the total DLP for complete examination (examination protocol and topogram).

The descriptive statistical analysis used in this study was performed using Microsoft Excel 2010 software. The data collection permission was obtained on a date 6 November 2024, The number NS32.

Table 1: patient population of the study classified per hospital and type of examinations and CT machine.

Hospital Name	Manufactured	Detected Type	No of Patients
AL qassim General Hospital	Siemens, Germany	64	60
Fadake Center	Philips, Germany	64	60
Fadake Center	Philips, Germany	128	60

RESULT.

Part 1 : brain examination data

Table 1: Distribution of demographical characteristics of participants

			Machine name			
			Philips64pt	Philips128pt	Siemens64pt	p-value
Sex	Male	F	14	16	8	.024
		%	70.0%	80.0%	40.0%	
	Female	F	6	4	12	
		%	30.0%	20.0%	60.0%	
Total		F	20	20	20	
		%	100.0%	100.0%	100.0%	
Age		Mean ± SD	51.2±24.45	36.75±23.33	42.95±22.28	.155

Table 1 show that a male distribution were 70%, 80%, 40% in Philips64pt, Philips128pt , and Siemens64pt correspondly, while female distribution were 30%, 20%, 60% in Philips64pt, Philips128pt, and Siemens64pt correspondly. In relation to age, Mean ± SD were 51.2±24.45, 36.75±23.33, and 42.95±22.28 in Philips64pt, Philips128pt, and Siemens64pt correspondly.

Table 2: Distribution of Effective Dose

	Mean	SD	Std. Error	Minimum	Maximum	p-value
Philips64pt	3.0858	.97558	.21815	1.68	6.99	.001
Philips128pt	2.8576	.22819	.05102	2.55	3.50	
Siemens64pt	1.2384	.27823	.06221	.28	1.65	

Table 2 show that a significance differences between Philips64pt, Philips128pt, and Siemens64pt in relation to Effective Dose as in figure 1.

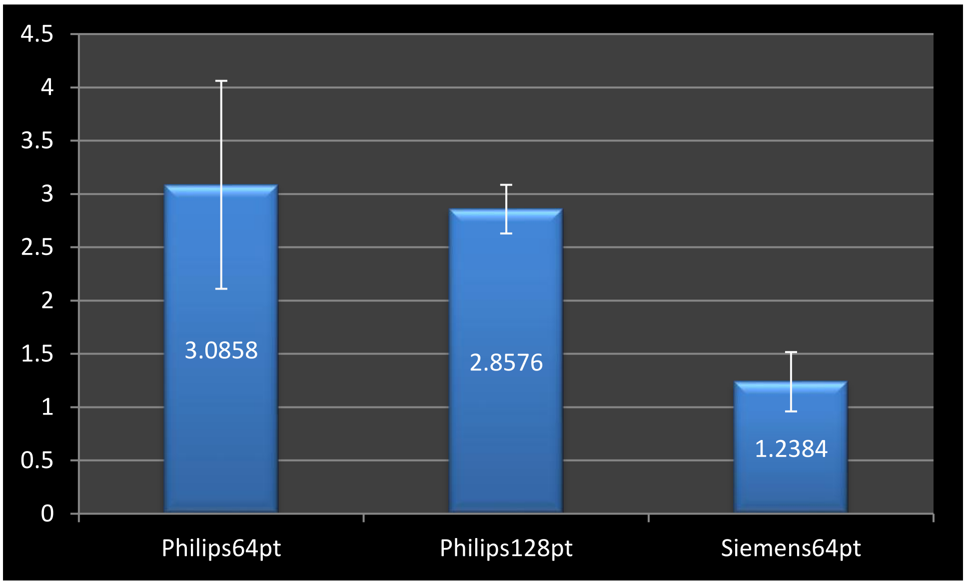

Figure 1: Mean ± SD of Effective Dose

Table 3: Multiple Comparisons in Effective Dose among study groups

(I) Machine.name	(J) Machine.name	Mean Difference (I-J)	Std. Error	Sig.
Philips64pt	Philips128pt	.22828	.18985	.234
	Siemens64pt	1.84747*	.18985	.000
Philips128pt	Siemens64pt	1.61919*	.18985	.000

*. The mean difference is significant at the 0.05 level

Table 3 show that a significance differences between (Philips64pt and Siemens64pt) and between (Philips128pt and Siemens64pt) in relation to effective dose, except between Philips64pt and Philips128pt that there were a non-significant differences.

Part 2 : chest examination data

Table 4: Distribution of demographical characteristics of participants

			Machine.name			
			Philips64pt	Philips128pt	Siemens64pt	p-value
Sex	Male	F	14	14	13	.926
		%	70.0%	70.0%	65.0%	
	Female	F	6	6	7	
		%	30.0%	30.0%	35.0%	
Total		F	20	20	20	
		%	100.0%	100.0%	100.0%	
Age		Mean ± SD	50.75±17.28	57.6±19.22	49.6±24.14	.413

Table 4 show that a male distribution were 70%, 70%, 65% in Philips64pt, Philips128pt , and Siemens64pt correspondly, while female distribution were 30%, 30%, 35% in Philips64pt, Philips128pt, and Siemens64pt correspondly. In relation to age, Mean ± SD were 50.75±17.28, 57.6±19.22, and 49.6±24.14 in Philips64pt, Philips128pt, and Siemens64pt correspondly.

Table 5: Distribution of Effective Dose

	Mean	Std. Deviation	Minimum	Maximum	p-value
Philips64pt	13.3162	6.11618	2.90	21.97	.001
Philips128pt	8.5875	3.51039	3.32	16.21	
Siemens64pt	4.7579	2.51436	1.69	10.91	

Table 5 show that a significance differences between Philips64pt, Philips128pt, and Siemens64pt in relation to Effective Dose as in figure 2.

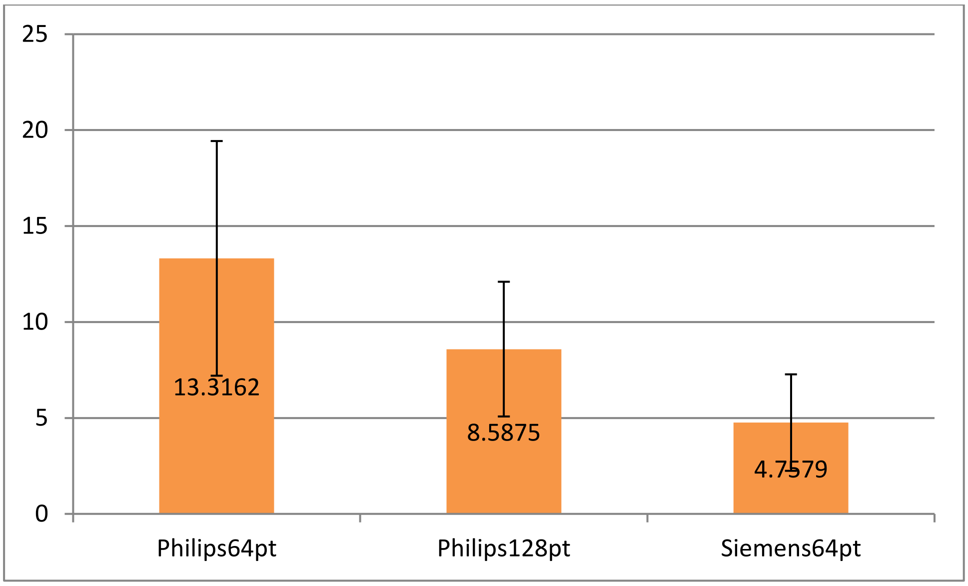

Figure 2: Mean ± SD of Effective Dose

Table 6: Multiple Comparisons in Effective Dose among study groups

(I) Machine.name	(J) Machine.name	Mean Difference (I-J)	Std. Error	Sig.
Philips64pt	Philips128pt	4.72871*	1.36690	.001
	Siemens64pt	8.55827*	1.36690	.000
Philips128pt	Siemens64pt	3.82956*	1.36690	.007

*. The mean difference is significant at the 0.05 level.

Table 6 show that a significance differences between (Philips64pt and Siemens64pt), between (Philips128pt and Siemens64pt), and between (Philips64pt and Philips128pt) in relation to effective dose.

Part 3 : abdominal examination data

Table 7: Distribution of demographical characteristics of participants

			Machine.name			
			Philips64pt	Philips128pt	Siemens64pt	p-value
Sex	Male	F	7	10	0	.002
		%	35.0%	50.0%	0.0%	
	Female	F	13	10	20	
		%	65.0%	50.0%	100.0%	
Total		F	20	20	20	
		%	100.0%	100.0%	100.0%	

Age	Mean ± SD	61.0 ± 16.98	42.05±19.58	41. ±20.29	.002

Table 7 show that a male distribution were 35%, 50%, 0% in Philips64pt, Philips128pt , and Siemens64pt correspondly, while female distribution were 65%, 59%, 100% in Philips64pt, Philips128pt, and Siemens64pt correspondly. In relation to age, Mean ± SD were 61.0 ±16.98, 42.05±19.58, and 41 ±20.29 in Philips64pt, Philips128pt, and Siemens64pt correspondly.

Table 8: Distribution of Effective Dose

	Mean	Std. Deviation	Minimum	Maximum	p-value
Philips64pt	7.0279	3.74759	3.30	19.62	
Philips128pt	15.3151	6.00708	5.68	29.53	.001
Siemens64pt	6.7117	3.88077	1.55	14.13	

Table 8 show that a significance differences between Philips64pt, Philips128pt, and Siemens64pt in relation to Effective Dose as in figure 3.

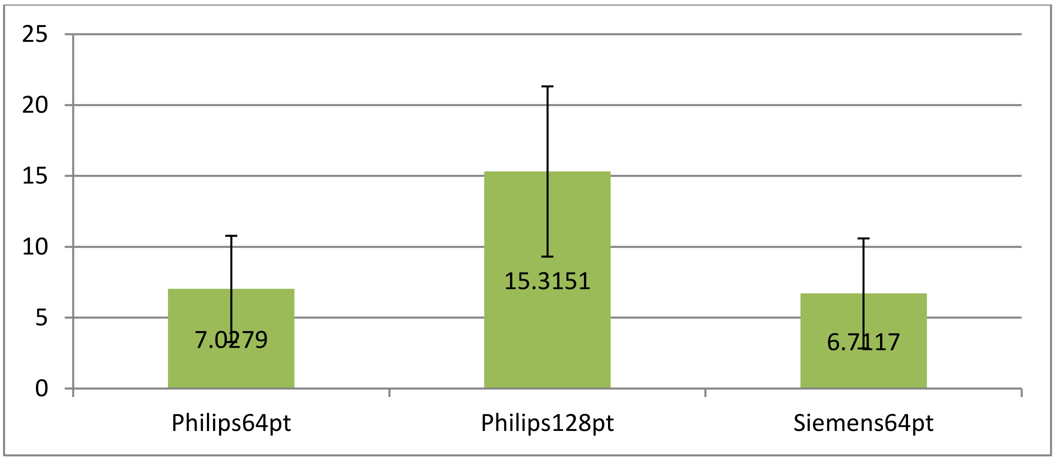

Figure 3: Mean ± SD of Effective Dose

Table 9: Multiple Comparisons in Effective Dose among study groups

(I) Machine.name	(J) Machine.name	Mean Difference (I-J)	Std. Error	Sig.
Philips64pt	Philips128pt	-8.28720-*	1.47411	.000
	Siemens64pt	.31613	1.47411	.831
Philips128pt	Siemens64pt	8.60333*	1.47411	.000

*. The mean difference is significant at the 0.05 level.

Table 9 show that a significance differences between (Philips64pt and Philips128pt) and between (Philips128pt and Siemens64pt) in relation to effective dose, except between (Philips64pt and Siemens64pt) that there were a non-significant differences.

DISCUSSION OF FINDINGS

1. Radiation Doses in CT Scans

Evaluation showed that Philips 64-slice CT delivered 3.0858 mSv effective dose for head scanning whereas Philips 128-slice produced 2.8576 mSv and Siemens 64-slice generated 1.2384 mSv. The effective dosage for Philips 64-slice CT scanning of the chest measured 13.3162 mSv while the Philips 128-slice CT provided 8.5875 mSv and the Siemens 64-slice CT delivered 4.7579 mSv. The values for dose exposure in abdominal CT scans indicated 7.0279 mSv for Philips 64-slice while Philips 128-slice measured at 15.3151 mSv and Siemens 64-slice delivered 6.7117 mSv. The Siemens 64-slice CT machine provided lower radiation output than the Philips machines for all scan types especially when used for chest and abdominal imaging.

Smith-Bindman et al. (2019) found similar results about substantial differences in radiation exposure between CT scanners and protocols along with the study's findings. Dose optimization stands as a primary need for minimizing patient exposure while keeping up image quality required for diagnosis. McCollough et al. (2020) documented how modern CT reconstruction algorithms lower the quantity of patient radiation exposure through their ability to maintain image resolution.

2. Comparison with International Reference Levels

CT Dose Index (CTDI) combined with DLP (Dose Length Product) from head and chest CT examinations remained beneath international reference levels yet abdominal scans surpassed these standards. The results match those presented by Rehani et al. (2020) who noted that multi-phase abdominal CT exams require extended scan windows which generates elevated radiation exposure. The experts suggest using automatic exposure control (AEC) and tube current modulation techniques as dose-reduction methods to limit patient exposure.

3. Effective Dose and Cancer Risk

The researchers determined effective doses to assist in cancer-related radiological risk evaluation. The doses measured for head, chest and abdominal scans fell within the parameters stated by Brenner et al (2021) who found that a single CT scan may raise cancer lifetime probability by 0.05% to 0.1% based on body area and patient age. The study points out that absolute dangers are minimal but repeated CT examinations enhance cancer risks most strongly for younger patients.

Comparison with Related Studies

1. Radiation Dose Variability Across CT Machines

The evaluation discovered substantial dose differentiation between Siemens and Philips machines because Siemens machines applied lower radiation exposure during examinations. The research supports Kanal et al. (2018) by showing that Siemens machines reduce patient doses because they use advanced dose-reduction technologies. Hospitals should adopt individual protocols for each machine to reduce patient exposure according to their recommendation.

2. Dose Optimization Techniques

The research results demonstrated the necessity to optimize doses especially for abdominal examinations because these tests exceeded international standard levels. Goske et al. (2019) demonstrate that dose reduction should involve three essential strategies which include shortening scan duration and reducing tube voltage together with implementing iterative reconstruction algorithms. The authors stressed that periodic dose audit inspections should be performed to meet international quality standards.

3. Cancer Risk Estimation

According to Einstein et al. (2020) findings match this study that demonstrates low single CT scan cancer risks however total exposure amounts to elevated cancer risk. The authors advise clinicians to analyze both positive effects and possible threats of CT evaluation extending specific focus on patients aged below thirty and individuals who need several scans.

CONCLUSION

The research identifies important information about dose variability when using Philips 64-slice and 128-slice and Siemens 64-slice scanners across head and chest and abdominal regions. The research demonstrates that the Siemens 64-slice CT machine produced lower radiation doses than the Philips machines especially when used in chest and abdominal diagnostics. Abdominal CT scans length and multiple phases resulted in doses exceeding international reference levels which demonstrates that more attention must be paid to dosage optimization strategies in this scanning group.

Effective calculations of dosage serve a critical role in determining the possible risks of developing cancer from radiation exposure. The individual risk of CT scans remains low but younger patients must be concerned about developing cancer because continuous exposure to multiple scans generates heightened cancer risks. The reported findings support prior research that proves the necessity to reduce radiation doses without compromising diagnostic image standards.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Adoption of Dose Optimization Techniques

Hospitals must use techniques for dose reduction specifically automatic exposure control (AEC) along with tube current modulation and iterative reconstruction algorithms to cut down radiation while keeping image clarity intact.

Hospital staff must optimize abdominal CT scan protocols to minimize the procedure's length and minimize scanning of multiple phases because the scans currently exceed international reference levels.

2. Regular Dose Audits and Compliance with International Standards

Regular audits of CT patient doses should be performed at hospitals to confirm proper compliance with reference level standards established by the International Commission on Radiological Protection (ICRP) and the American Association of Physicists in Medicine (AAPM).

Specific CT machines require different dose optimization protocols because the research revealed Siemens and Philips equipment shows distinct radiation dose variations.

3. Education and Training for Radiologists and Technologists

Radiologists together with CT technologists must obtain continuous education about dose optimization methods and sequence-based radiation safety protocols.

Medical staff need to receive training about both the general and persistent risks of radiation effects for patients who need repeated CT scans and who are under thirty years old.

4. Use of Advanced CT Technologies

Health institutions must acquire modern CT technologies with iterative reconstruction and low-dose protocols because these approaches demonstrate superior diagnostic precision alongside decreased radiation exposure.

The research results indicated Siemens machines reduced the amounts of radiation exposure thus demonstrating machine choice is essential for dose reduction purposes.

5. Patient-Specific Protocols

CT protocols need customized settings based on patient-specific characteristics including age and body size combined with clinical indication to prevent superfluous radiation risks.

Doctor protocols designed specifically for children represent a necessary tool for reducing radiation dosage in pediatric patients because children exhibit heightened sensitivity to radiation effects.

6. Public Awareness and Informed Consent

Medical personnel must provide patients complete information on CT scan advantages and disadvantages particularly during multi-scan procedures.

Medical practitioners should reference ultrasound and MRI scanning alternatives for their patients whenever more than one imaging approach might lead to increased total radiation exposure.

7. Further Research

Additional scientific study should concentrate on understanding how extended radiative exposure from CT imaging affects patient health specifically among younger patients.

Scientific evaluations need to examine dose-reduction methods in actual clinical practice both for their ability to keep accurate diagnoses while decreasing patient exposure to radiation.

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