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Assessment of Radiation Exposure, Safety Practice, and Awareness Among Healthcare Providers Utilizing CT Units in Jazan Area Hospitals

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Abstract: As medical imaging technology in CT scanners improves to provide an accurate and safe diagnosis, the potential hazards of ionizing radiation remain a significant issue in daily medical practice for medical staff. To reduce excessive radiation exposure, computed tomography (CT) parameters must be optimized. By utilizing a dose length product (DLP), this study aims to determine the diagnostic reference level (DRL) for CT in Jazan. Data sheets were sent to all three hospitals in the Jazan area that have CT scanners, and 300 patients were collected. From July 2022 to November 2022, data were collected for all patients undergoing CT CAP (Chest, Abdomen, and Pelvis). The DRL for CT CAP with contrast in venous phase examination was 981.9 mGy.cm in the Jazan area of the southern region of Saudi Arabia in 2023. Vast heterogeneity in radiation doses across hospitals suggests the need for the implementation of a national diagnostic reference level (NDRL) in Saudi Arabia. A phantom study experiment that was successful in this scientific paper helped to explain the optimization strategies in the CT unit. The dose report result was comparable with the three sections of the phantom experiment in that the high image quality at even lower radiation exposure was also achieved by the dose reduction methods employed in the CT phantom study experiment parameters such as tube voltage (kV), tube currents (mA), detector coverage (mm), helical thickness (mm), table pitch (mm/rot), and rotation time (s or sec). The phantom study experiment concluded that high image quality at very low dose levels can be achieved using a 100 kV protocol with 300 mA for head CT scans. An online survey was done to assess radiation exposure and safety practice awareness among hospital medical staff to establish the level of awareness among healthcare professionals in the Jazan area. The results of the online survey showed a lack of knowledge regarding radiation exposure, safety practices, and the precise amount of radiation in each imaging procedure. It is recommended to implement educational programs and comprehensive training to increase awareness of radiation protection knowledge.

Keywords: Assessment, Radiation exposure, CAP, Diagnostic reference levels (DRL), Radiation awareness.

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1. Introduction

Since its invention in the early 1970s, computed tomography (CT) has been widely used in medicine to diagnose and manage human diseases. From the first-generation, single-slice "stop-and-go" technology to multi-slice volume CT scanning, the technical development of CT has been fast. The development of volume CT scanners, which range from 16-slice to 64-slice systems and include the 320-slice CT scanner, is progressing quickly [1]. These advances have resulted in many therapeutic applications, including colonoscopy, cardiac CT imaging, CT screening, and virtual reality imaging [1].

The use of computed tomography (CT) as a diagnostic tool has grown significantly, increasing radiation exposure to the public and raising the possibility of future public health concerns [2]. Ionizing radiation exposure during computed tomography (CT) scans is potentially hazardous. Despite the clinical benefits and increasing use of CT imaging, significant health risks are associated with the potential for ionizing radiation exposure [2], [3].

The duration, dose, and frequency of exposure have significant adverse biological consequences according to a study done by (Brenner et al., 2003; Hauptmann et al., 2003; Lee et al., 2004) [13]. These consequences include an elevated risk of birth defects, cataracts, cancer, and reduced lifespan according to a study conducted by (Karjodkar, 2006) [13]. Insufficient familiarity with this subject matter heightens the potential for radiation exposure among both patients and medical personnel. The objective of this study is to assess the level of knowledge regarding radiation hazards among healthcare professionals.

Justification, optimization, and dose limitation are the protection principles vital to radiation protection regulation. All CT professionals should ask these three key questions: Why are CT doses so very high? What is the patient's dose at my hospital? What can be done to reduce the high CT exposure so that both patients and staff are protected? [1].

For radiation exposure and safety practice in the CT unit, the professionals' collaboration is highly needed for the imaging process [4] to promote and facilitate the implementation of patient dose minimization. The most significant CT parameters that affect the amount of dose received by a patient are automatic exposure control, Bow-tie/beam shaping filter, use of the anti-scatter grid, tube current modulation, selective in-plane shielding, thyroid، and breast shields [4], [5], [6]. The exposure control setting techniques for different CT scanners vary due to factors related to the equipment and the operator, which are specific to the clinical protocols being used [7].

When discussing dose reduction for patients, the International Commission on Radiological Protection advises using the "as low as reasonably achievable" (ALARA) principle. The words "dose reduction" and "dose optimization" are most frequently used in the literature to describe how the ALARA principle should be used while balancing the requirement to preserve diagnostic quality pictures. Reducing or lessening in size, amount, extent, or number is what "dose reduction" refers to. Making a design, system, or decision as absolutely perfect, functional, or effective as feasible is what is meant by the definition of optimization. Consequently, optimization addresses both radiation dose reduction and image quality according to (Ramirez-Giraldo et al., 2014) [8].

Using beam filters, tube current modulation, thyroid and breast shields, low tube voltage for abdominal CT, and automated pitch adaptation, patients' doses can be reduced by 50%, 40–60%, 20–30%, 20–40%, and 30–50%, respectively [9]. The employment of these dose reduction methods and strategies while still maintaining diagnostic image quality is strongly advised for CT users [9]. To reduce patient radiation exposure during CT scans without degrading the accuracy of the diagnostic information, the phantom study experiment in this study offers revised radiation protection techniques and strategies.

Key and complementary principles of radiological safety are justification and optimization of protection. The International Commission on Radiological Protection (ICRP) refers to a type of investigation level as a DRL to aid in the safety of patients during medical exposure for diagnostic and interventional procedures [10]. The DRL is a useful tool that helps with protection optimization when patients are exposed to medical treatments for diagnostic and interventional procedures [10]. DRLs are derived as an artificial threshold from metric radiation data gathered nationally, regionally, and locally. The DRL is a tool to support professional judgment; it does not draw the line between best and worst medical practice [10].

Application of the DRL technique alone is insufficient for protection optimization. The major goal of optimization is to keep radiation exposure to patients as low as reasonably possible while still keeping the standard of diagnostic information offered by the examination in line with the intended medical use [10].

Numerous additional phases of chest, abdomen, and pelvic CT scans are performed without a clear clinical justification, increasing the patient's radiation dose. There is a non-trivial probability that patients who undergo radiation from CT scans may develop cancer. The scan range of successive scans can be chosen to lower the radiation dose [10]. The purpose of this study is to compare radiation doses among individuals undergoing CAP (Chest/Abdomen/Pelvis) CT imaging and to develop diagnostic reference levels (DRLs).

The dose length product in short (DLP) and CT dose index volume in short (CTDIvol) are employed in a CT dose study, and the findings are shown on the CT scanner's monitor. DLP measures the total exposure of a series of scans, while CTDI volume measures the exposure of each slice of a tissue, as shown in equation (1-1) :

$$DLP = CTDIvol \times Scan\ length \qquad 1\text{-}1$$

The CTDI volume is independent of the scan length, and the irradiated volume's length (the DLP) is directionally proportionate to the scan length [1]. In DLP, the unit is mGy.cm.

The 75th percentile a method that has been used the most frequently, is the diagnostic reference level (DRL), which is the 75th percentile of the mean doses for a group of patients with relatively average body weights, approximately 70 kg or so more or less ± 5 kg [11]. DRLs are referred to as the 75th percentile (3rd quartile value of the median dose) of a group of patient dose data, meaning that 75% of the data should fall below the DRL (Mould, 1998) [12].

The International Commission on Radiological Protection (ICRP) recommends determining DRL levels based on surveys of the optimal DRL volumes for procedures performed on an appropriate sample of patients.

This study aims to find an assessment of radiation exposure and safety practice in CT units by establishing diagnostic reference levels (DRLs) for CT trunk (CT CAP) examinations, a phantom study (Dose Optimization Strategy Experiment), and an assessment of radiation dose and safety awareness among hospital medical staff in the Jazan area of Saudi Arabia's southern region.

2. Materials and Methods:

2.1 Diagnostic Reference Levels (DRLs)

The weight range for patients of average size was 50 to 90 kg in the DRL part of this paper. The evaluation also gathered radiation dose information for 300 adult patients who underwent CT CAP tests over five months from July 2022 to November 2022, displaying the dose length product (DLP) and CT dose index volume (CTDIvol). DRLs are referred to as the 75th percentile (3rd quartile value of the median dosage) of a group of patient dose data, meaning that 75% of the data should fall below the DRL. The 75th percentile method that has been used the most frequently to calculate DRL is the 75th percentile of the mean doses for a group of patients with relatively average body weights, approximately 70 kg or so more or less ± 5 kg.

This part of the study was performed within the radiology departments of three hospitals in southern Saudi Arabia: King Fahad Central Hospital (KFCH), Abu Arish General Hospital, and Saba General Hospital. The data were obtained concerning the use of three multislice CT scanners (MSCT), as presented in Table 1.

Table 1: The three multislice CT scanners (MSCT) were used in the study.

Hospital	CT manufacturer company	Detector configuration	Quality control
KFCH	GE	128-slice (MSCT)	regular
Abu Arish	GE	16-slice (MSCT)	regular
Sabia	Toshiba	64-slice (MSCT)	regular

2.2 Phantom Study Experiment

The method of the phantom study (Dose Optimization Strategy Experiment) was to lower radiation exposure by using CT dose reduction techniques while maintaining the high quality of diagnostic images. This experiment consists of three sections:

- **Section 1:** CT procedure on a phantom with the high parameters setting (the default parameter of the CT scanner system is performed by physicists, or CT scanner engineers working for the device manufacturer. The default settings are usually high and require adjustment by the CT technician depending on the weight and size of the patient).
- **Section 2:** CT procedure on the phantom with middle parameters setting.
- **Section 3:** CT procedure on the phantom with low parameters setting.

The phantom was scanned with a 128-slice CT scanner using the GE system in the three sections of the experiment using the parameters in order from high to low factors to achieve the best parameters for low radiation dose and high-quality image, as shown in Table 2.

Table 2: The three sections' parameters of the experiment.

Parameter / Experiment section	Tube voltages	Currents	Rotation times
Section 1	120 kV	400 mA	0.6 sec
Section 2	100 kV	300 mA	0.5 sec
Section 3	80 kV	200 mA	0.4 sec

2.3 Assessing the Level of Awareness of Radiation Exposure and Radiation Safety Among Hospital Medical Staff

The last part of this scientific paper was an online survey. This part of the research is based on a descriptive survey that asked medical staff 13 multiple-choice questions about their awareness of radiation exposure, safety practices, and risks associated with routine radiography and CT scan exams in CT units in general hospitals. Between (October and December 2023), 132 medical staff workers of all hospitals in the Jazan area, participated in a questionnaire survey with 13 questions.

Participants' replies were examined statistically using the SPSS software tool, version 22.

3. Results

3.1 Diagnostic Reference Levels (DRLs) Results

The three hospitals contributed information on 300 patients, which was used in the study. Some patients were excluded from this study because missing information from the patient file, such as the weight and dose report, was not transmitted to the PACS system.

Most CT examinations are done in King Fahad Central Hospital (KFCH) in the Jazan area in the south region of Saudi Arabia; even if they are done in terminal general hospitals, they will be repeated in KFCH hospital because no images on a CD or DVD are sent with the referral patients, as shown in Figure 1.

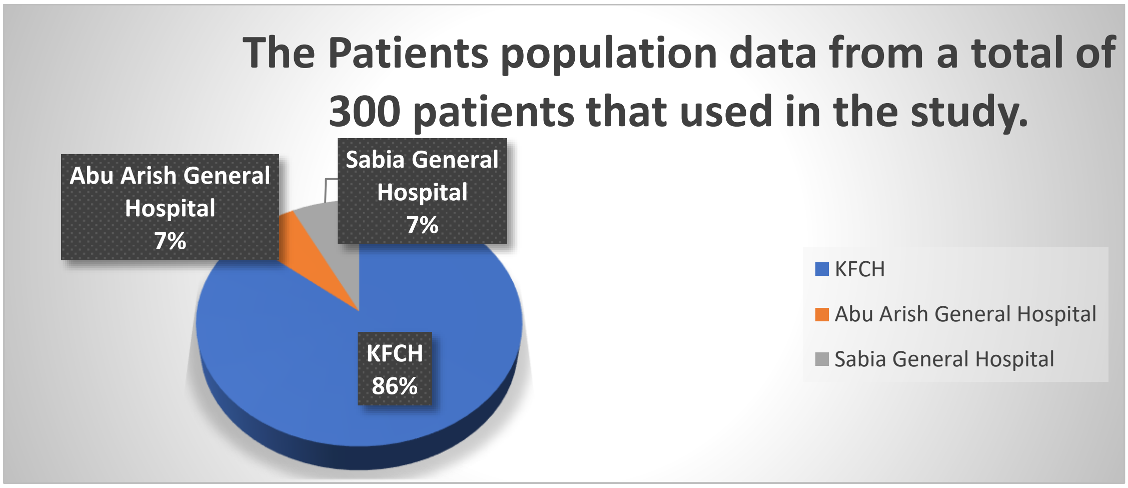


Figure 1: The patient population data from a total of 300 patients were used to calculate DRL in the study.

The data collected from 300 adult patients who have undergone CT CAP with contrast procedure during the five months from (July 2022) to (November 2022) were (n = 216, 72%) males and (n = 84, 28%) females.

Tables 3 and 4 show the descriptive statistics of the dose distribution across the three hospitals surveyed with CT scanners using CAP exams, as well as the mean patient parameters and standard deviation averaged across all hospitals included in the study.

Table 3: Descriptive statistics of the dose distribution across the three hospital-surveyed CT scanners with CAP CT exam.

Hospital / Descriptive statistics	KFCH (128 Scanner)	Abu Arish General Hospital (16 Scanner)	Sabia General Hospital (64 Scanner)
Number of patients with CT CAP exam	258	20	22
Mean DLP mGy.cm (range)	1064.33 (410.94 - 2172.85)	692.62 (284.08 - 1230.87)	899.47 (364.8 - 2711.8)
Mean CTDIvol mGy (range)	15.24 (6.34-29.25)	8.76 (3 - 16.3)	13.47 (5.3 - 36.1)
75th percentile DLP mGy.cm	1387.93	865.25	976.26
75th percentile CTDIvol mGy	20.05	10.17	16.66
(Median)50th percentile DLP mGy.cm	1004.33	684.41	697.65
(Median)50th percentile CTDIvol mGy	14.475	8.125	12
25th percentile DLP mGy.cm	734.35	490.56	582.8
25th percentile CTDIvol mGy	10.67	5.86	8.26

Table 4: Mean patient parameters ± standard deviation averaged and the P-value over all the hospitals included in the study.

Hospital	Age Mean ± SD	Weight Mean ± SD	DLP mGy.cm Mean ± SD	CTDIvol mGy Mean ± SD	P-value
KFCH (128 Scanner)	37.36 ± 16.79	70.49 ± 14.65	1064.34 ± 379.88	15.25 ± 5.13	9.6×10^{-5}
Abu Arish General Hospital (16 Scanner)	25.15 ± 8.44	69.35 ± 13.61	692.62 ± 285.85	8.759 ± 3.79	
Sabia General Hospital (64 Scanner)	40.09 ± 24.09	65.05 ± 13.51	899.47 ± 590.39	13.47 ± 7.8	

Figure 2 depicts the dose distributions for the CAP CT scan surveyed examinations, with the 75th percentile DRL identified by the horizontal line.

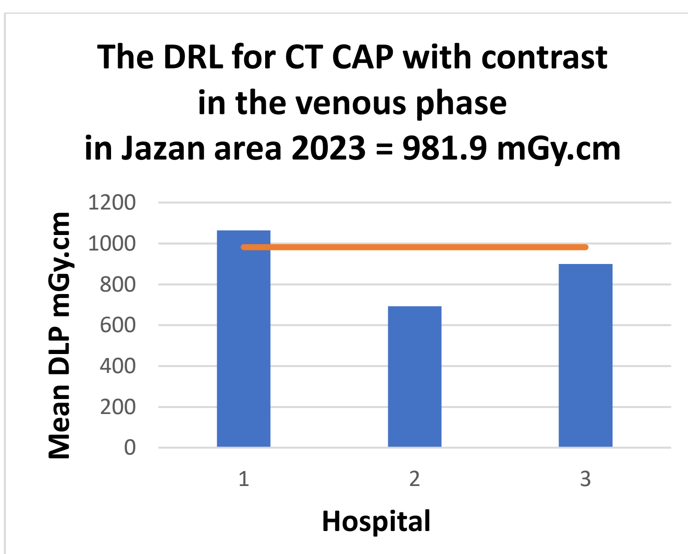


Figure 2: The DRL for CT CAP with contrast in the venous phase in Jazan area 2023. 1: King Fahad Central Hospital (KFCH); 2: Abu Arish general hospital; and 3: Sabia general hospital.

The comparison of DRLs [CTDIvol (mGy) and DLP (mGy.cm)] with other Saudi Arabian surveys on the CT CAP procedure exams is shown in Table 5.

Table 5: Comparison of DRLs [CTDIvol (mGy) and DLP (mGy.cm)] with other Saudi Arabian surveys on the CT CAP procedure exam [3], [12].

Date of study	Region of Saudi Arabia	DLP mGy.cm	CTDI vol mGy
Saudi Arabia 2023.	Southern Region	981.9	14.36
Saudi Arabia 2022 [3].	Southern Region	1199.67	-
Saudi Arabia 2013 [12].	Western Region	1040	16

As indicated in Table 6, these suggested regional DRLs are compared with research published nationally.

Table 6: Comparison of DRLs (DLP mGy.cm and CTDIvol mGy) with other European surveys on the CT CAP procedure exam [12].

Survey / DRL	Saudi Arabia 2023	Ireland 2010	Italy 2013	Switzerland 2010
DLP (mGy.cm)	981.9	850	1200	1000
CTDIvol (mGy)	14.36	10/12	17	15

The DRL for CT CAP with contrast in venous phase examination was 981.9 mGy.cm in the Jazan area of the southern region of Saudi Arabia in 2023.

3.2 Phantom Study Experiment Results

Figures 3, 4, and 5 show the CT images of the first, second, and third sections, respectively, of the experiment.

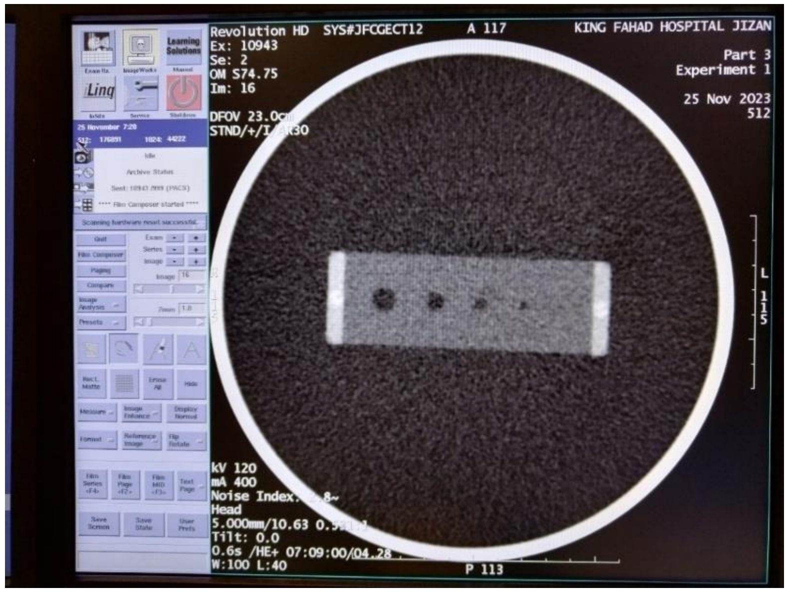


Figure 3: The CT image of the first section with the high parameters of the experiment.

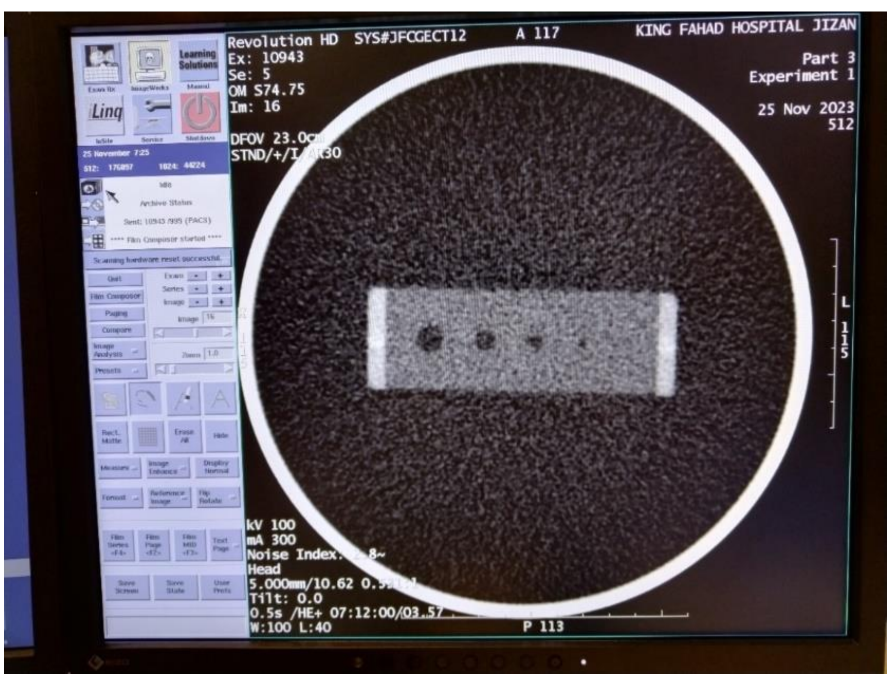


Figure 4: The CT image of the Second section with the middle parameters of the experiment.

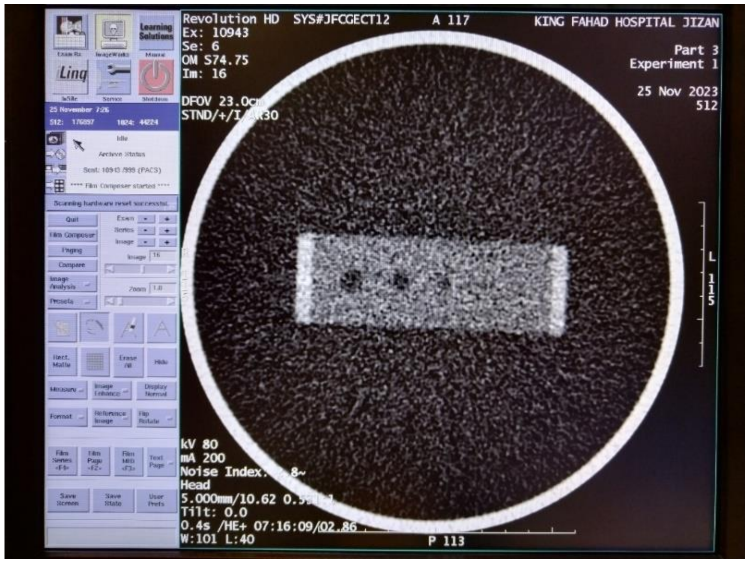
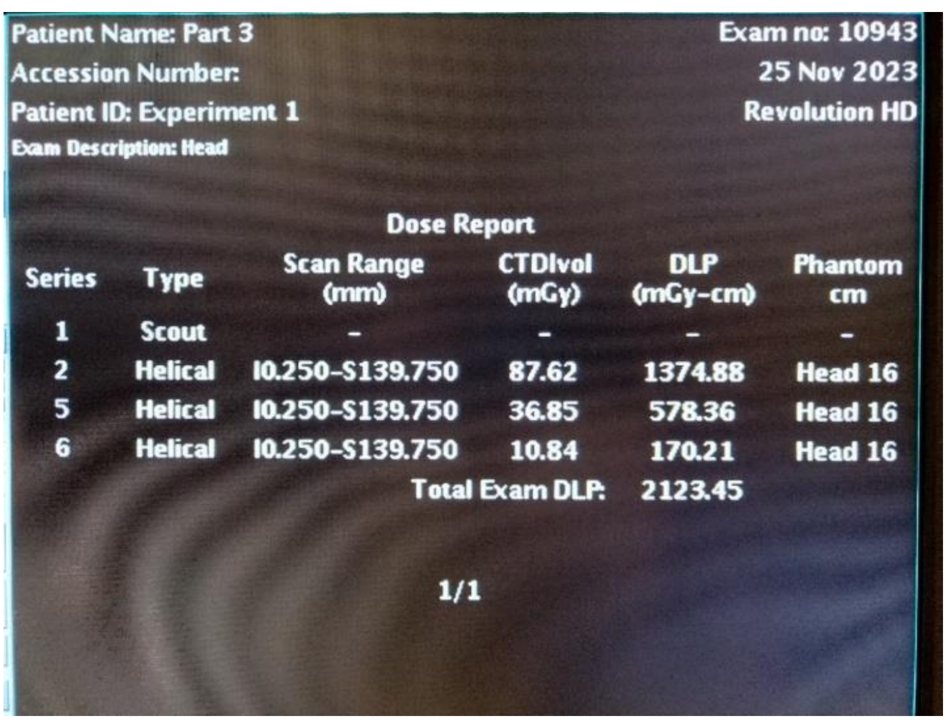


Figure 5: The CT image of the third section with the low parameters of the experiment. The image noise appeared, and the fourth hole in the phantom did not appear.

The dose report in Figure 6 displays the DLP results for the experiment's high parameters (default parameters), middle parameters (optimization parameters), and low parameters.



Patient Name: Part 3 Exam no: 10943
Accession Number: 25 Nov 2023
Patient ID: Experiment 1 Revolution HD
Exam Description: Head

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I0.250-S139.750	87.62	1374.88	Head 16
5	Helical	I0.250-S139.750	36.85	578.36	Head 16
6	Helical	I0.250-S139.750	10.84	170.21	Head 16
			Total Exam DLP:	2123.45	

1/1

Figure 6: Study phantom experiment dose report.

3.3 Assessing the Level of Awareness of Radiation Exposure and Radiation Safety Among Hospital Medical Staff Results

The questionnaire was sent to 200 healthcare professionals in all hospitals in the Jazan area. A total of 132 (66%) participants or respondents responded and completed the questionnaire, as shown in Tables 7 and 8.

Table 7: Demographic characteristics of medical staff who participated in the online study survey.

Questions	n = 132	Responses %
1. (a) What is your gender? o – Male o – Female	 Male =83 Female = 49	 62.9% 37.1%
1.(b) In which hospital do you work? o – A: (Abu Arish General Hospital) o – S: (Sabia General Hospital) o – K: (King Fahad Central Hospital) o – other.	 A = 40 S = 20 K = 54 Other = 18	 30.3% 15.2% 40.9% 13.6%
2. What is your job? o – doctor. o – nurse. o – technician.	 Doctor = 39 Nurse = 46 Technician = 47	 29.5% 34.8% 35.7%
3. What type of department is yours? o – medical. o – oncology. o – radiology. o – emergency. o – surgery. o – other.	 Medical = 15 Oncology = 2 Radiology = 55 Emergency = 31 Surgery = 25 Other = 4	 11.4% 1.5% 41.7% 23.5% 18.9% 3%

4. How long have you been serving? o – no more than a year. o – from 1 to 5 years. o – from 6 to 10 years. o – from 11 to 15 years. o – more than 16 years.	 21 37 27 20 27	 15.9% 28 % 20.5% 15.1% 20.5%

Table 8: Distribution of the multiple-choice answers of the online study survey.

Questions	n= 132	Responses %
5. How often do you visit the CT scan unit with your patients for imaging? o – none. o – several times a month. o – several times a week. o – several times a day.	 4 44 42 42	 3.03% 33.33% 31.82% 31.82%
6. Do you think X-ray radiation doses used for diagnostic imaging tests may increase patients' risk of getting cancer later in life? o – no opinion. o – yes. o – no.	 5 95 32	 3.8% 72% 24.2%
7. Do you think performing more CT scans on one person increases their risk of radiation exposure and getting cancer? o – no opinion. o – yes. o – no.	 2 109 21	 1.5% 82.6% 15.9%
8. Identify the patient's radiation protection measures you are aware of: (You may check off more than one). o – none. o – lead aprons. o – shields. o – distance from the source of radiation. o – time of exposure. o – collimation of the radiation beam.	 0 119 87 72 71 64	 0% 90.2% 65.9% 54.5% 53.8% 48.5%
9. Which modality is exposed to more radiation, do you think: a CT scan or a general X-ray? o – General X-ray. o – CT scan. o – I do not know.	 40 89 3	 30.3% 67.4% 2.3%

10. Based on your estimation, how much radiation would a patient have gotten during each of the following operations, expressed in equivalents of a single chest X-ray (answer by marking with an X)? The results are shown in Table 9. The correct answers are based on European Commission guidelines [14].		
11. Which of the following radiation side effects will you consider? (You may check off more than one). o – Cell death. o – Cataract. o – Fetal anomaly. o – Cancer. o – I don't know.	75 46 67 128 2	56.8% 34.8% 50.8% 97% 1.5%
12. Did you attend an introductory lecture or course on radiation exposure and safety practices? o –Yes. o –No.	51 81	38.6% 61.4%
13. Did your radiology department in your hospital use the National Diagnostic Reference Levels (NDRL) that the MOH of Saudi Arabia sent? o – Yes. o – No. o – I don't know if my hospital's radiology staff uses (NDRL). o – I don't know what (NDRL) is.	40 26 14 52	30.3% 19.7% 10.6% 39.4%

The population and distribution of participants according to exposure to ionizing radiation are shown in Figure 7.

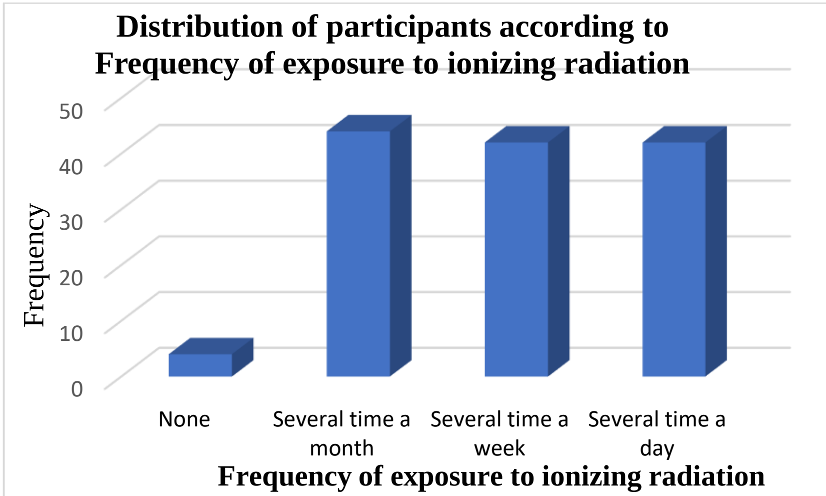


Figure 7: Distribution of participants according to Frequency of exposure to ionizing radiation.

The proportion of participants who answered question 10 correctly regarding dose estimation was 27.7%, whereas the remaining proportion of incorrect answers was 72.3%, as shown in Table 9. The percentage of participants with correct answers to question 10 was calculated mathematically and shown statistically by the SPSS version 22 software program.

Table 9: The correct answers of participants concerning the knowledge of radiation dose estimations.

Imaging Procedure	The Correct Answer	Technicians and Technologists	Nurses	Physicians and Doctors	Total of Correct Answers by Question
Plain Abdominal Radiograph	50 – 99	(n = 15, 11.36%)	(n = 4, 3.03%)	(n = 2, 1.52%)	21
Head CT	200 – 299	(n = 14, 10.61%)	(n = 0, 0%)	(n = 3, 2.27%)	17
Chest CT	300 – 499	(n = 15, 11.36%)	(n = 1, 0.76%)	(n = 2, 1.52%)	18
Abdominal and Pelvis CT	500 – 600	(n = 17, 12.88%)	(n = 1, 0.76%)	(n = 1, 0.76%)	19
Abdominal Ultrasound	0	(n = 44, 33.33%)	(n = 9, 6.82%)	(n = 28, 21.21%)	81
Thyroid Isotopes Scan	10 – 49	(n = 16, 12.12%)	(n = 5, 3.79%)	(n = 5, 3.79%)	26
Brain MRI	0	(n = 44, 33.33%)	(n = 6, 4.55%)	(n = 24, 18.18%)	74

Total of Correct Answers by Group	**(n =165,17.86%)**	**(n = 26, 2.82%)**	**(n = 65, 7.03%)**	**256**
Overall Percentage of Correct Answers	**(n = 256/7 = 36.57) , (36.57*100/132 = 27.7%)**			

4. Discussion

4.1 Diagnostic Reference Levels (DRLs) Discussion

DRLs can inform CT staff or technologists to take corrective action when high radiation doses are being given. Examining DRL readings can also help identify the departments delivering excessive doses. In this study, CT CAP scans with contrast in the venous phase were conducted in the Jazan region of southern Saudi Arabia. Table 3 revealed significant dose disparities between the departments examined for the CT CAP evaluation. The inter-hospital comparison revealed that specific sites or facilities exceeded the proposed 75th percentile, as shown in Table 3, where the King Fahad Central Hospital (KFCH) exceeded the mean and median (50th percentile) for the CT CAP procedure compared to all other hospitals. DRLs outperformed the population of 86 % of patients examined in King Fahad Central Hospital (KFCH) during five months for chest, abdomen, and pelvic examinations, as shown in the patient population data from a total of 300 patients used in the study, as shown in Figure 1. Because 14% of patients only went to these two hospitals, (Abu Arish General Hospital) and (Sabia General Hospital) have nearly identical means, 50th percentiles, and 75th percentile results. This may suggest that there are scanning technique-related issues here or be caused by the image quality of the CT examination meetings that happen every week between the radiologists and CT technologists to discuss the image quality and suboptimal CT studies. These meetings solve the problem of CT doses vs. image quality with the CT CAP protocol, which changes according to radiologists' opinions to give a high-quality diagnostic report for the patients. This variation in dose administration between hospitals may point to protocol-related problems, such as the need for improved image quality standards for those exams in those three hospitals. This again underlines the necessity of treading carefully while analyzing CT doses throughout the entire spectrum of CT CAP procedure assessment. Moreover, steps should be taken to investigate potential solutions for this inconsistency by evaluating scanning procedures at least once a year. A unified protocol is sent to all radiology departments in all hospitals in the Jizan area of the southern region of Saudi Arabia to solve the problem of the bad quality of CT image procedures. These unified CT procedure protocols also solve the problem of high CT doses received by patients without benefit. The problem here is that most CT technicians do not adhere to these standardized protocols and do not operate them to protect patients from unnecessary doses. In this study, KFCH, Abu Arish General Hospital, and Sabia General Hospital performed three separate acquisitions according to each CT detector's slice system machine; thus, these centers, which also had an iterative reconstruction algorithm, had a lower 75th percentile DLP (1387.93, 865.2475, and 976.26 mGy.cm, respectively), as shown in Table 3.

In this assessment of KFCH, Abu Arish General Hospital, and Sabia General Hospital, the median DLP was 1004.325 mGy.cm, 684.41 mGy.cm, and 697.658 mGy.cm, respectively. The very low decrease required shows that it may be possible if efforts were made to lower the DLPs of the 50% of the hospitals with DLPs below that level. It is simple to speculate that if this were the case, "achievable dose" would possibly turn into another objective beyond which no more optimization was required.

The DRL for CT CAP with contrast in the venous phase in Jazan Area 2023, which equals 981.9 mGy.cm as shown in Figure 2, was also lower when compared with other studies in 2022 done by Y. Alashban & N. Shubayr [3], as shown in Table 5. Table 4 displays the mean patient parameters and standard deviation averaged over all hospitals included in this research. Consequently, a one-way ANOVA was performed to indicate whether the differences in DLP were statistically significant (p-value ≤ 0.05) between the hospitals, as shown in Table 4. The probability value, or P-value, was shown, and the result was 0.000096, which indicates there were statistically significant differences in DLP for CT CAP with contrast venous phase procedures in all hospitals. For instance, recent research on CT doses in the Jazan area of southern Saudi Arabia reveals that the DRL there was 1199 mGy.cm in 2022, which is higher than both this study and the western region's DRL, which was 1040 mGy.cm in 2013 [3], [12] as shown in Table 5. Table 6 compares the regional DRLs proposed in this scientific paper with nationally published studies. The results showed that the DRL of CT CAP doses in this study was lower than that in Italy in 2013 and Switzerland in 2010, but higher than that previously reported in Ireland in 2010. This study's DRL dose was 6–18% lower than the Saudi survey's findings from the 2013 (A. A. Qurashi) study and the 2022 (Y. Alashban and N. Shubayr) study [3], [12].

4.2 Phantom Study Experiment Discussion

The phantom was scanned with a 128-slice CT scanner using the GE system in the three sections of the phantom study experiment using the parameters shown in Table 2.

The first section of the study phantom experiment is called the default parameters and it has the highest factors. The parameters with tube voltage (120 kV), currents (400 mA), pitch = 0.531:1, table speed = 10.62 mm/rot, and rotation times = 0.6 sec, demonstrated the best image quality but with a high radiation dose (1374.88 mGy-cm), as shown in Figures 3 and 6.

The second section of the phantom study experiment used middle parameters with tube voltage (100 kV), currents (300 mA), pitch = 0.531:1, table speed = 10.62 mm/rot, and rotation times = 0.5 sec, which demonstrated the best image quality with a low radiation dose (578.36 mGy-cm), as shown in Figures 4 and 6. It has similar image quality and similar noise compared to the image of the first section, as shown in Figures 3 and 4. Automatic tube current modulation was applied in this section of the experiment.

On the other hand, the third section of the experiment had the lowest parameters which were tube voltage (80 kV), currents (200 mA), pitch = 0.531:1, table speed = 10.62 mm/rot, and rotation times = 0.4 sec, which demonstrated the image with low quality and low radiation dose (170.21 mGy-cm), as shown in Figures 5 and 6. The CT image of the third section with the lowest parameters of the experiment showed image noise, and the fourth hole in the phantom did not appear due to the smaller number of X-ray photons reaching the detector, as shown in Figure 5. The three protocol settings were done, and the result was associated with a very low radiation exposure protocol in the phantom study experiment's second section of optimization parameters, as shown in Figure 4. The phantom study shows that CT imaging is achievable with low radiation exposure when utilizing optimized scan procedures at the lowest dose for specific purposes. Hence, it is imperative to get a comprehensive understanding of image quality assessment techniques to differentiate between superior and worse image quality and to achieve an optimal balance while minimizing the dose. To achieve ALARA (as low as reasonably achievable), it is necessary to optimize the low dose in a manner that is compatible with the image quality. For the implementation of these advanced CT protocols, it is necessary to have dependable and well-established scientific methods for assessing the quality of the images. Image quality is a difficult concept to quantify since it is a subjective and nonspecific measure of how readable an image is. In two distinct processes, an image is displayed and obtained:

1. Depending on the technical and physical properties of the equipment or technological capabilities, this step involves image generation and data acquisition. This step is called technical capacity [15].

2. Image display and processing, depending on how well the radiologist can identify, interpret, detect, and classify the structures in the image. This step is called diagnostic accuracy [15].

4.3 Assessing the Level of Awareness of Radiation Exposure and Radiation Safety Among Hospital Medical Staff Discussion

Regarding assessing the awareness of radiation exposure and safety practices among hospital medical staff, the distribution of the multiple-choice answers to the survey is summarized in Tables 7 and 8. Table 7 shows a summary of demographic data for exposed healthcare workers. The gender distribution showed the majority (n = 83, 62.9%) were male and (n = 49, 37.1%) were female as shown in Table 7. The population through hospitals is shown in the second part of question one, which demonstrated the place of work distribution among respondents, which included King Fahad Central Hospital (n = 45, 40.9%), Abu Arish General Hospital (n = 40, 30.3%), Sabia General Hospital (n = 20, 15.2%), and the other hospitals (n = 18, 13.6%) as shown in Table 7.

All respondents were divided into five groups based on length of service or work experience. About (n = 21, 15.9%) had no more than a year of experience, (n = 37, 28%) had from 1 to 5 years of experience, (n = 27, 20.5%) had from 6 to 10 years of experience, (n = 20, 15.1%) had from 11 to 15 years of experience, and in the last (n = 27, 20.5%) had more than 16 years of clinical service experience. The most populous groups consisted of responders with 1–5 years of clinical service experience, as shown in Table 7.

Across all respondents, (n = 42, 31.82%) stated that they performed imaging examinations of patients and visited the CT scan unit with their patients for imaging several times a day; also, (n = 42, 31.82%) were exposed to CT imaging procedures several times a week, (n = 44, 33.33%) had contact with CT procedures several times a month, and (n = 4, 3.03%) reported that they do not have any type of contact with CT scan medical imaging procedures at all. Regarding the question about exposure to ionizing radiation during tests, the largest group of participants had frequent interactions, many times a month, with various CT scan imaging procedures as shown in Table 8 and Figure 7. In total, (n = 95, 72%) of respondents correctly acknowledged that X-ray radiation doses used in diagnostic imaging examinations may elevate the probability of patients developing cancer in the future. Additionally, (n = 109, 82.6%) of respondents believed that exposing an individual to multiple CT scans increased their risk of radiation exposure and subsequent cancer development. The results provided positive responses to questions 6 and 7 on the possibility of causing cancer that is affected by ionizing radiation as shown in Table 8.

Meanwhile, (n = 32, 24.2%) believed that X-ray imaging radiation does not cause cancer, whereas (n = 5, 3.8%) reported that they have no idea (no opinion). About (n = 21, 15.9%) believed that performing more CT scans on one person does not increase their risk of radiation exposure and getting cancer, whereas (n = 2, 1.5%) reported that they have no idea (no opinion) as shown in Table 8. Here lies the problem: this group of medical staff contains residents and doctors who issued orders and requests to perform CT scans on patients, and they believe that performing more CT scans on one person does not increase their risk of getting cancer.

Overall, (n = 128, 97%) of the participants' answers considered that cancer was the most common side effect of radiation as shown in Table 8. Unfortunately, this knowledge seems to be acquired from media rather than training and specialist journals, according to Szarmach A. et al., (2015) [14], and this was obvious when analyzing the correct and incorrect answers to question 11 between professions' answers in this study.

The correlation between radiation knowledge and cancer risk differs among professions, with no significant differences detected between them. For instance, (n = 31, 75.6%) of radiographers and technologists correctly answered question 11, which was about the side effects of radiation that ionizing radiation could cause as follows: cancer, cell death, cataracts, and fetal anomalies. The radiographers and technologists had the highest level of correct answers for the side effects of radiation because of their background in radiological science. Meanwhile, (n = 8, 19.5%) of physicians and (n = 2, 4.9%) of nurses were the least knowledgeable group that provided the correct answers (p-value = 0.968) and (X^2 = 5.2547 x10^{-9}).

There were significant differences in understanding among departments about the correlation between ionizing radiation and cancer. Medical staff in radiology departments had the highest level of correct answers (82.9%) compared with 7.3%, 4.9%, 2.4%, and 2.4% in emergency, surgery, medical, and oncology departments, respectively (p-value = 0.01) and (X^2 = 0.027).

Furthermore, a significant difference was noted between the level of awareness about radiation risk and the frequency of exposure of medical staff to CT radiological tests or their visits to

CT scan units with their patients. Employees who interacted with imaging examinations daily and regularly visited CT scan units with their patients had a higher proportion of correct answers (n = 26, 63.4%) compared to those who only had an occasional interaction with CT scan radiological tests or several times a week (n = 6, 14.6%). Although (n = 7, 17.07%) who were exposed to radiation multiple times a month and (n = 2, 4.9%) who claimed to have never been exposed to imaging examinations answered the questions correctly, (p-value = 0.009) and (X^2 = 0.004).

Regarding the knowledge of patient radiation protective techniques and methods, (n = 119, 90.15%) of participants' answers reported that they would use a lead apron on unimaged parts of patients would effectively reduce radiation exposure risks for patients arising from radiation potential hazards, as shown in Table 8. Additionally, (n = 72, 54.5%) said that increasing the distance from the source of radiation would be the most effective method to reduce radiation risk for patients. Furthermore, (n = 71, 53.8%) of participants stated that reduced exposure time was an effective factor in protecting the patients from high radiation as shown in Table 8. The correct answers to the radiation protection methods question were only (n = 51, 38.6%) of participants who selected all methods of patient radiation protection. However, a p-value < 0.05 means there was a significant difference detected in patient radiation protection methods among the participants from hospitals in the Jazan area.

Participants struggled to accurately determine an accurate radiation dose equivalent to that of a chest X-ray in the various diagnostic modalities mentioned in question 10. For instance, the category with the highest proportion of incorrect answers (n = 115, 87.12%) was related to the estimation of radiation dose equivalent for a head CT scan. The participants with the highest rate of correct responses or answers (n = 81, 61.4%) stated that no radiation dose is equivalent to an abdominal ultrasound scan, which is the same highest rate of correct answers about this question as the study that was conducted and done by Szarmach A. et al., (2015). Notably, (n = 51, 38.6%) of participants wrongly believed that abdomen ultrasound utilizes more ionizing radiation than a chest X-ray, while (n = 58, 43.93%) had the same misconception about brain MRI. The proportion of participants who answered question 10 correctly regarding dose estimation was 27.7%, whereas the proportion of incorrect answers was 72.3%, as shown in Table 9. These findings indicate that healthcare professionals have an insufficient understanding of the exact dose of radiation associated with each imaging procedure. This can be attributed to a lack of comprehensive educational courses and inadequate training in radiation protection. Furthermore, this outcome is connected to the results of question 12 about the attendance of participants in an introductory lecture or course on radiation exposure prevention and safety practice. The high percentage of participants (n = 81, 61.4%) did not attend any of the introductory lectures or courses on radiation exposure protection and safety practice, while the low percentage (n = 51, 38.6%) attended an introductory lecture and course on radiation exposure protection and safety practice as shown in Table 8. This study found that medical staff with less than one year of work experience had a lower level of overall knowledge compared to those with 6 to 10 years and 11 to 15 years of experience, who were the most aware group. Radiology department employees, particularly radiographers and technologists, were required to possess a more extensive awareness and knowledge of various aspects of radiation in comparison to physicians and nurses, due to their scientific knowledge in radiological science. The findings of this scientific work show the necessity of implementing educational programs and extensive training for medical staff. Prior research has also proposed the inclusion of radiation protection courses in fundamental healthcare education, alongside classes, workshops, seminars, and training programs for those who are exposed to radiation examinations, as indicated by Ohno and Kaori (2011), Yurt et al. (2014), and Alghamdi A. et al. (2020) [13]. In addition, visually appealing posters that convey fundamental scientific ideas related to radiation dangers and radiation protection could enhance the knowledge and consciousness of both healthcare practitioners and patients. This study suggests implementing efforts to enhance the knowledge and understanding of healthcare professionals.

However, during this research in radiology departments through hospitals in the Jazan area, the only posters that presented radiation risks for pregnant women were in radiology departments only, not in other hospitals' words. There were no attractive posters that presented basic scientific principles toward radiation risks and radiation protection that increased the awareness of both medical professionals and patients.

The last question about assessing the awareness of the online survey study was about the diagnostic reference level (DRL). There were no significant differences noted between the level of awareness about DRLs and the frequency of participants, according to the hospital (p-value = 0.61); also, there were no significant differences noted between the level of awareness about DRLs and the frequency of participants, according to the profession (p-value = 0.41). Overall, (n = 40, 30.3%) of participants said that the radiology department in their hospital used the NDRL that the MOH of Saudi Arabia sent. Most of this group (n = 28, 70%) was from KFCH hospital. Meanwhile, (n = 26, 19.7%) reported that the radiology department in the hospital did not use the national diagnostic reference level (NDRL), whereas (n = 14, 10.6%) reported that they have no idea if their hospital's radiology staff uses (NDRL) or not. The majority of participants (n = 52, 39.4%) said that they did not know what NDRL is, as shown in Table 8.

4.4 Limitations

This study was subject to several limitations, which are as follows:

- The study did not include any private hospitals. However, since there are many private centers in the area, it may be more advantageous to include them. Therefore, further studies in other geographical regions are necessary to provide comparison and extrapolation of these findings to the Saudi public.
- Another restriction is the frequency of some CT CAP exams, and the addition of more contrast-filled phases in departments, as in the protocols that were implemented in December 2022 for the RTA CT CAP process protocol at KFCH. This protocol adds CT arterial and venous phases to the CT CAP procedure in patients with RTA.
- This study did not identify the specific educational and training programs attended by the participants, which is

essential in determining the potential causes of a lack of awareness.

- ❖ The questionnaire was reduced to 13 questions, specifically addressing the radiation exposure dose, the radiation risk, and safety practices in CT units inside general hospitals. The radiation dose estimation question was limited to a total of seven imaging procedures. Thus, it is unable to accurately correlate complete radiation knowledge.
- ❖ Multiple questions entailed exact numerical responses that proved challenging to determine, even for extensively trained and seasoned experts.

5. Conclusion

The DRL value for trunk CT CAP procedures with contrast examinations is established for the southern region of Saudi Arabia. The DRL for CT CAP with contrast in venous phase examination is 981.9 mGy.cm in the Jazan area of the southern region of Saudi Arabia in 2023. This issue is an important step in radiation safety since it can raise awareness of dose use and promote optimization among hospitals. The radiation exposure, safety practices, and dose reduction methods utilized in computed tomography were listed in the phantom study experiment (dose optimization strategy experiment) to assess the impact and effect of radiation dose on image quality as a part of radiation exposure and safety practices in the CT unit. The dose report result was comparable with the three sections of the phantom experiment in that the high image quality at even lower radiation exposure was also achieved by the dose reduction methods employed in the CT phantom study experiment parameters such as tube voltage (kV), tube currents (mA), detector coverage (mm), helical thickness (mm), table pitch (mm/rot), and rotation time (s or sec). The phantom study experiment concludes that high image quality at very low dose levels can be achieved using a 100 kV protocol with 300 mA for head CT scans. The unified CT protocols and establishment of diagnostic reference levels (DRL) in the hospitals of the region or country solve the problem of CT dose optimization and achieve the best use of radiation exposure in CT units in every general hospital. The assessment of radiation exposure and safety practices awareness in CT units among hospitals' medical staff was conducted using an online survey. The online survey concludes that there is a requirement for improved emphasis on comprehensive and systematic education of healthcare workers on radiation protection. This issue underscores the importance of intensifying attention on this field of research through educational programs and comprehensive training, which may be utilized to enhance awareness and reduce the potentially harmful effects of ionizing radiation on medical staff and patients.

Recommendations

Vast heterogeneity in radiation doses across hospitals suggests the need for the implementation of a national diagnostic reference level (DRL) in Saudi Arabia. This issue is critical to the goal of optimizing radiation dose. Also, it is recommended to implement educational programs and comprehensive training to increase awareness of radiation protection knowledge.

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تقييم التعرض للإشعاع وممارسات السلامة والوعي بين مقدمي الرعاية الصحية الذين يستخدمون وحدات الأشعة المقطعية في مستشفيات منطقة جازان

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مستخلص. مع تحسن تكنولوجيا التصوير الطبي في الماسحات الضوئية المقطعية لتوفير تشخيص دقيق وآمن، تظل المخاطر المحتملة للإشعاع المؤين مشكلة كبيرة في الممارسة الطبية اليومية الطاقم الطبي. للحد من التعرض المفرط للإشعاع، يجب تحسين عوامل واعدادات التصوير المقطعي المحوسب (CT). من خلال استخدام منتج طول الجرعة (DLP)، تهدف هذه الدراسة إلى تحديد المستوى المرجعي التشخيصي (DRL) للتصوير المقطعي المحوسب في منطقة جازان. تم إرسال أوراق البيانات إلى جميع المستشفيات الثلاثة في منطقة جازان التي تحتوي على أجهزة التصوير المقطعي المحوسب، وتم جمع ٣٠٠ مريض. من يوليو ٢٠٢٢ إلى نوفمبر ٢٠٢٢، تم جمع البيانات لجميع المرضى الذين يخضعون للتصوير المقطعي المحوسب (الصدر والبطن والحوض). كان DRL لـ CT CAP مع التباين في فحص الطور الوريدي ٩٨١٫٩ ملي جراي. سم في منطقة جازان بالمنطقة الجنوبية من المملكة العربية السعودية في عام ٢٠٢٣. يشير عدم التجانس الكبير في جرعات الإشعاع عبر المستشفيات إلى الحاجة إلى تنفيذ مستوى مرجعي تشخيصي وطني (NDRL) في المملكة العربية السعودية. ساعدت تجربة الدراسة الوهمية (الفانتوم) التي نجحت في هذه الورقة العلمية على شرح استراتيجيات التحسين في وحدة التصوير المقطعي المحوسب. كانت نتيجة تقرير الجرعة قابلة للمقارنة مع الأقسام الثلاثة للتجربة الوهمية حيث تم تحقيق جودة الصورة العالية عند التعرض للإشعاع بشكل أقل أيضًا من خلال طرق تقليل الجرعة المستخدمة في تجربة الدراسة الوهمية المقطعية (تجربة الفانتوم) مثل جهد الأنبوب (كيلو فولت)، والتيارات الأنبوبية (مللي أمبير)، وتغطية الكاشف (مم)، والسمك الحلزوني (مم)، ودرجة حركة الطاولة (مم/الدورة)، ووقت الدوران (ثانية). خلصت تجربة الدراسة الوهمية إلى أنه يمكن تحقيق جودة صورة عالية بمستويات جرعة منخفضة جدًا باستخدام بروتوكول ١٠٠ كيلو فولت مع ٣٠٠ مللي أمبير لفحص الرأس بالأشعة المقطعية. تم إجراء مسح عبر الإنترنت لتقييم التعرض للإشعاع والوعي بممارسات السلامة بين الطاقم

الطبي في المستشفى لتحديد مستوى الوعي بين المتخصصين في الرعاية الصحية في منطقة جازان. أظهرت نتائج الاستطلاع عبر الإنترنت نقص المعرفة فيما يتعلق بالتعرض للإشعاع، وممارسات السلامة، والكمية الدقيقة للإشعاع في كل إجراء تصوير. يوصى بتنفيذ برامج تعليمية وتدريبية شاملة لزيادة الوعي بمعرفة الحماية من الإشعاع.
الكلمات المفتاحية: التقييم، التعرض للإشعاع، CAP، المستويات المرجعية التشخيصية (DRL)، الوعي الإشعاعي.
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