Jurnal
Teknologi

Full Paper

ASSESSMENT OF SCATTERED X-RAYS TO THE THYROID GLAND OF RADIATION WORKERS IN COMPUTED TOMOGRAPHY (CT) ROOM

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Article history
Received
22 July 2024
Received in revised form
10 December 2024
Accepted
23 December 2024
Published Online
22 August 2025

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Graphical abstract

Abstract

Computed tomography (CT) scan is widely used as a rapid and decisive diagnostic method. During CT examinations part of the radiation is scattered from the device. In normal practice, only the patient is allowed to be present inside the CT room during examination. However, in certain cases medical staff are required to remain inside the CT room. This work aims to study the amount of scattering radiation during CT examinations at Al-Zahraa Hospital, Diyala, Iraq and assess the radiation impact on the thyroid gland hormones for radiation workers to evaluate the severity of the radiation exposure. All data were collected during the month of May to June, 2022. The results showed that the highest amount of scattered radiation was 18.55 mSv in front of the CT gantry head and the lowest scattered radiation was found at both sides of the CT scan device with values of 0.28 mSv and 0.27 mSv. The study also evaluated the impact of scattering radiation on the thyroid gland by testing the triiodothyronine and thyroxine hormones, together with the stimulation hormone in blood from 50 respondents of different gender, age and working time in the CT examination room. The test results showed that the probability of developing thyroid gland disorder increases for radiation workers in comparison to non-radiation workers. These effects were more severe for radiation workers with longer duration of work inside the ionizing radiation units. Thus, exposure to ionizing radiation increases the risk of developing a thyroid gland disorder for workers in CT scan unit.

Keywords: Computed tomography (CT), scattered radiation dose, thyroid gland disorder, triiodothyronine; thyroxine; stimulation hormones

Abstrak

Imbasan tomografi berkomputer (CT) digunakan secara meluas sebagai kaedah diagnostik yang cepat dan tepat. Semasa pemeriksaan imbasan CT, sebahagian daripada sinaran terserak daripada mesin. Kebiasaannya, hanya pesakit dibenarkan berada di dalam bilik CT semasa pemeriksaan. Walau bagaimanapun, dalam sesetengah kes kakitangan perubatan diperlukan berada di dalam bilik CT. Kerja ini bertujuan mengkaji jumlah sinaran terserak semasa pemeriksaan CT di Hospital Al-Zahraa, Diyala, Iraq dan menilai kesan sinaran ke atas hormon kelenjar tiroid pekerja sinaran bagi menilai tahap keparahan pendedahan sinaran. Kesemua data telah dikumpulkan semasa bulan Mei hingga Jun, 2022. Keputusan menunjukkan jumlah sinaran terserak tertinggi 18.55 mSv di hadapan kepala gantri CT dan sinaran terserak paling rendah di kedua-dua belah mesin CT dengan nilai 0.28 mSv and 0.27 mSv. Kajian ini juga menilai kesan sinaran serakan pada kelenjar tiroid dengan menguji hormon tiroksina dan triiodotironina, bersama-sama dengan hormon rangsangan dalam darah dari 50 responden yang berlainan jantina, umur dan masa bekerja di bilik pemeriksaan CT. Keputusan ujian menunjukkan bahawa kebarangkalian gangguan kelenjar tiroid meningkat untuk pekerja sinaran berbanding pekerja bukan sinaran. Kesan ini lebih teruk bagi pekerja sinaran dengan tempoh kerja yang lebih lama di dalam unit sinaran mengion. Oleh itu, pendedahan kepada sinaran mengion meningkatkan risiko gangguan kelenjar tiroid bagi pekerja di unit imbasan CT.

Kata kunci: Imbasan tomografi berkomputer (CT), dos sinaran terserak, gangguan kelenjar tiroid, triiodotironina, tiroksina, hormon rangsangan

1.0 INTRODUCTION

Medical radiation workers are always concerned with ionizing radiation exposure due to its health hazards. According to the International Commission on Radiological Protection (ICRP), the occupational exposure limit for radiation workers is an average effective dose of 20 millisieverts (mSv) per year, averaged over five consecutive years, with no single year exceeding 50 mSv [1]. With the exponential growth of medical technology development in both developing and developed countries, the use of ionizing radiation has become more frequent [2, 3].

Currently, computed tomography (CT) is widely recognized as one of the essential diagnostic methods. This is mainly due to their various advantages such as high sensitive image and specificity, fast diagnosis scan, and painless procedure [4]. During the CT scan examination, part of the radiation is scattered by the patient's body and the table of the device. This radiation are called scattered radiation. According to the standard operating procedure (SOP), only the patient is allowed to be present inside the CT room during the scanning period. However, there are certain circumstances in which medical staff, whether they are from radiological or non-radiological departments, must remain in the scanning room. These reasons may include calming an anxious patient, such as a toddler or child, or monitoring a patient who requires acute care to prevent involuntary movements during the scanning procedure. By being present in the CT room during the examination, radiation workers may experience an increase in cumulative dose (CD), which could lead to adverse health effects.

The sensitivity of human tissues and organs to ionizing radiation varies depending on the type of tissue or organ. The thyroid and reproductive organs are known to be more sensitive to radiation than nerve cells [5]. To date, studies have shown that prolonged exposure to low-level ionizing radiation from scattered sources has adverse effects on thyroid gland function [6] due to its high ability to absorb radiation [7]. Exterior radiations can expose thyroid antigen to human immune system, causing auto-immunity through dendritic cell activation [8] or direct death of the thyroid gland [9]. Some studies also acknowledged that human organs like the thyroid are likely a target for radiation-linked injuries due to their high sensitivity towards ionizing radiation [7].

In this paper, the amount of scattered radiation from a CT scan device at 18 different locations, both inside and outside of a CT examination room at Al-Zahraa Hospital, Diyala, Iraq, was quantified during four different examinations. Based on the measured amounts, the safe standing position for radiation workers in the CT examination room was found to be on both sides of the CT scan device, due to the protection provided by the gantry head and detectors. Furthermore, the impact of scattered radiation on the thyroid gland was evaluated by testing the secretion levels of triiodothyronine (T3) hormone, thyroxine (T4) hormone, and thyroid-stimulating hormone (TSH) in the blood of radiation workers. The results indicated that the probability of developing thyroid gland disorders increases significantly for radiation workers in comparison to non-radiation workers, with more severe effects observed in those with longer durations of work in ionizing radiation units. Significantly, this study contributes to expanding knowledge on scattered radiation from CT device, highlights the risks associated with ionizing radiation, and raises awareness on its impact to the thyroid gland.

2.0 METHODOLOGY

2.1 Scattered Radiation Measurement

Figure 1(a) shows the schematics of CT examination room with a CT device of Activion-16 (Toshiba) at Al-Zahraa Hospital. The scattered radiation measurements were performed at 18 locations, of which 15 were inside the CT examination room and 3 were outside of the examination room, as shown in Figure 1(a). All measurements were performed under standard room conditions with minimal background radiation. The CT examination room's lead shielding and the selected placement of the measurement points minimized the impact of external radiation interference to the measurements. To obtain the best result, the scattered radiation measurement was repeated three times subsequently for each location in four different examinations of abdomen and back, chest, neck, and head, and the average value was recorded. An electronic dosimeter (MiniTRACE-γ) was used to perform these measurements. The dosimeter detection range was 0.001 - 100 mSv/h and the device was calibrated periodically using a certified radiation source to ensure accuracy and consistency in dose measurement.

(a)

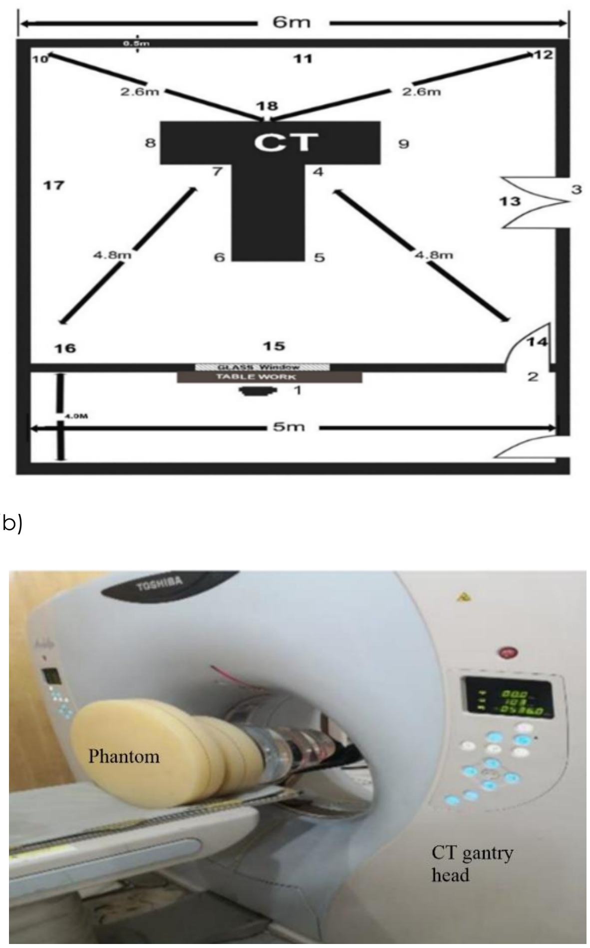

Figure 1 (a) Radiation measurement locations inside and outside of the CT examination room. (b) An image of a phantom model used in this work

Furthermore, during the examinations, a phantom was used to simulate the human body and replicate real irradiation conditions (Figure 1(b)). The phantom was made from solid acrylic and was designed according to the Food and Drug Administration America (FDA) performance standard for diagnostic X-ray systems to resemble the properties of human tissue and is used to study and calibrate medical imaging devices to evaluate their effectiveness. Notably, the CT scan device parameters including scan time, tube potential (120 kV), and tube current (mAs) were adjusted in accordance with the manufacturer's recommended values for each examination.

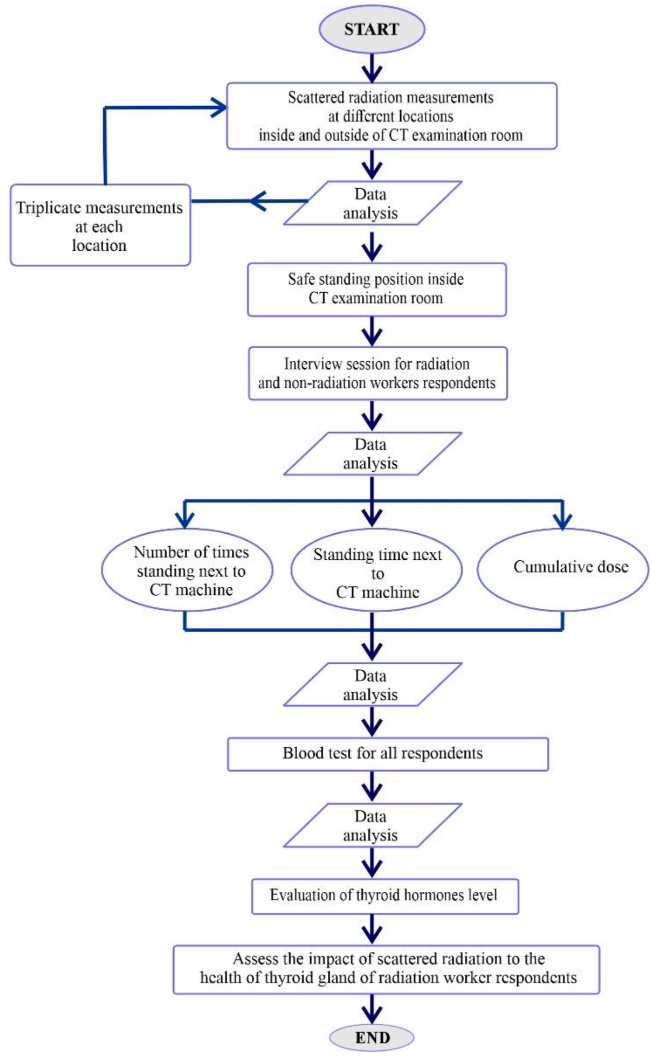

Figure 2 Flow chart of the study

2.2 Study Population and Design

The present study was comprised of 50 individuals, both male and female with no symptoms of thyroid disease. From this study population, 30 respondents were radiation workers who work to execute the CT examination in the diagnostic radiology unit and 20 respondents were non-radiation workers who work in the same hospital. The information such as age, health status and years of working at Al-Zahraa Hospital were obtained from interview session and by reviewing respondent's health record. For radiation worker respondents, information on the duration of work in the CT control room and the time spent standing beside the CT device during examinations between May and June 2022 was obtained from the radiology unit's records.

Furthermore, film batches were used to determine the CD received by radiation worker respondents during the 6 months. To estimate the amount of the monthly CD, an additional batch film was used during the study period, and it was worn on the upper chest area near the neck (close to the thyroid gland). These two film batches were sent to the laboratory after the study period to conduct the CD analysis. By using a special automatic densitometer, the CD was calculated for the respondents. Figure 2 shows a flow chart of a series of steps taken in this study, starting from measurements of scattered radiation doses until accessing the health of thyroid gland from the respondents.

2.3 Thyroid Hormones Measurements

To elucidate the thyroid gland function, a blood sample was collected from all the respondents. A 5 mL of blood sample was drawn by a needle via venipuncture process and the sample was divided into two aliquots. The first aliquot with 3 mL volume was placed in a gel tube (serum) and the second aliquot of 2 mL in volume was placed in an anti-coagulation tube (plasma). The first aliquot of serum in the gel tube was allowed to coagulate in room temperature for 10 minutes and later underwent centrifugation at 3000 rpm for a period of 10 minutes. Next, the resultant serum and plasma were transferred into other tube using sterilized micropipette. Generally, the tests were carried out within 48 hours and the samples were preserved in the temperature range 2 to 8 °C. The tubes were frozen and preserved at -20 °C or lower for a longer storage before further analysis (if needed).

The levels of thyroid hormones, which are T3, T4, and TSH in the blood samples were analyzed at the hospital laboratory to assess thyroid gland activity in all respondents. Depending on the type of tests, which were for T3, T4 or TSH, a little quantity of serum, i.e., in a range of few hundreds of µL, was taken from the gel tube (serum) by using a sterilized micropipette and placed in a disposable pipette tip. After that, the blood samples were analyzed using the MINI VIDAS® immunoassay system, which operates under the enzyme-linked fluorescent assay (ELFA) principle. Quality control measures, including internal calibration of the analyzer and the use of manufacturer-recommended control kits, were employed for each batch of tests. The testing was performed automatically for 20 minutes. When the test was completed, a report from the blood test was printed out for each blood sample.

2.4 Statistical Analysis on Cumulative Doses and Thyroid Hormone Levels

Descriptive statistical methods, specifically the calculation of mean and standard deviation (SD) was employed to analyze CDs and thyroid hormone levels (T3, T4, and TSH) within the same groups, such as radiation workers grouped by age and gender, or non-radiation workers grouped similarly. This approach provides a straightforward way to summarize the trends and variations in radiation exposure and its potential impact on thyroid hormone level.

In addition to descriptive statistics, an independent t-test was utilized to compare the mean thyroid hormone levels between the two main groups of respondents, which are radiation workers and non-radiation workers. The t-test allowed to assess whether the observed differences in thyroid hormone levels, such as TSH, T3, and T4, were statistically significant between these two distinct groups of respondents.

The combination of descriptive statistics and inferential analysis enhances the robustness of the study, providing both an overview of the data and a statistical comparison of key variables between radiation and non-radiation workers. Notably, in future studies with larger and more diverse datasets additional advanced methods such as ANOVA [10], correlation analyses (Pearson or Spearman) [11], or non-parametric tests (Mann-Whitney U test) [12], can be used to explore relationships and variations in thyroid hormone levels across multiple factors with larger sample size (respondents).

3.0 RESULTS AND DISCUSSION

3.1 Scattered Radiation

This section analyze the amount of scattered radiation from multiple measured points (locations) during the CT-scan examinations by using a phantom as a patient. Figure 3 shows the amount of scattered radiation from the CT device and the results were presented in unit of mSv. Figure 3(a-d) shows the average scattered radiation for abdomen and back, chest, neck, and head examinations, respectively. From all the figures, the highest amount of scattered radiation dose was in the abdomen and back examination. This is not unexpected as abdomen and back examination has the longest duration of exposure. Furthermore, the study presented by Ref. [13] proved that the amount of scattered radiation increases linearly with exposure time.

In all examinations, site number 18 had the highest amount of scattered radiation, followed by sites 7 and 4. To be more specific, site number 18 showed values of 18.55 mSv, 16.43 mSv, 12.77 mSv and 12.61 mSv, corresponding to the abdomen and back, chest, neck, and head examinations, respectively. Site number 7 showed the values of 18.22 mSv, 15.30 mSv, 11.93 mSV nd 11.94 mSv for each of the examinations. Whereas, site number 4 showed the values of 18.21 mSv, 15.32 mSv, 11.92 mSv and 11.93 mSv.

Furthermore, the results showed that the lowest amount of scattered radiation was measured on both sides of the device, which at sites 8 and 9 in all examinations due to protection (shielding) from gantry head and detectors. Site number 8 showed the values of 0.28 mSv, 0.17 mSv, 0.13 mSv and 0.15 mSv, and site number 9 showed the values of 0.27 mSv, 0.16 mSv, 0.13 mSv and 0.14 mSv, for each of the examinations, respectively.

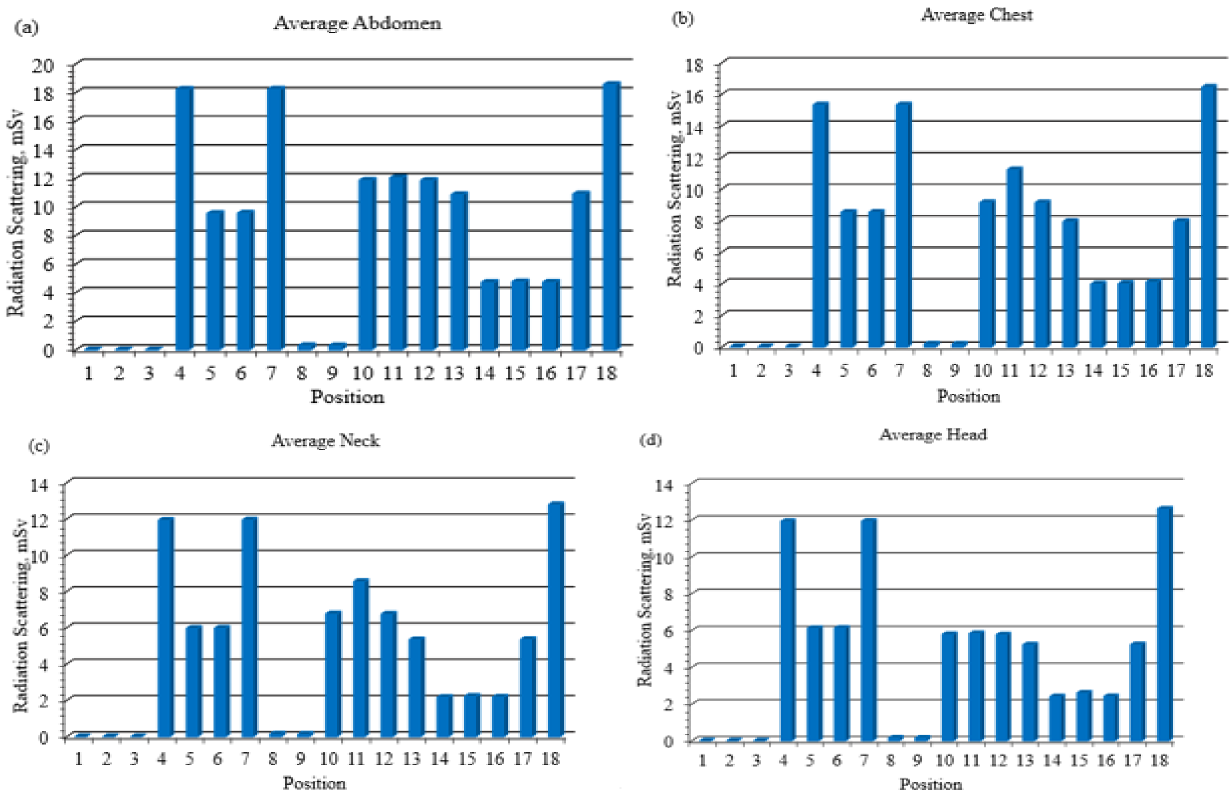

Figure 3 Average amount of scattered radiations for (a) abdomen and back, (b) chest, (c) neck and (d) head examinations

The measurements that were performed outside the CT room in positions 1, 2, and 3, resulted zero reading of scattered dose for all examinations due to the thickness of the wall that separated the examination room to the control room. In addition, the presence of lead shield in the wall also protect the staff from radiation in the control room.

The results in Figure 3 also indicate that it is impossible to completely avoid exposure to scattered radiation within the CT examination room. Therefore, the best way to avoid receiving a significant radiation dose in an emergency situation that requires the presence of workers is to avoid standing in site numbers 4, 7, and 18 and stand on both sides of the gantry (sites 8 and 9) to the greatest extend feasible to lessen the amount of received scattered radiation exposure in a CT examination room. Additionally, the radiation workers can also opt to wear personal protective equipment (PPE) such as lead aprons, thyroid shields and lead gloves to further reduce exposure, and adhire to safety protocols for effective PPE use in CT examination room.

3.2 Cumulative Doses for Radiation Workers

The results for CDs for male and female radiation workers are presented in Tables 1 and 2, respectively. The average number of times for both the male and female workers stood next to the CT device was about 3 times during the study period. The longest duration of standing next to the CT device were 158 second (s) for male respondents and 198s for female respondents.

The results also found that the CD received by male and female radiation workers, along with their monthly average exposures over the six months study period was 1.81 ± 0.36 mSv for male workers and 1.78 ± 0.34 mSv for female workers. Despite these doses being below the annual limit of 20 mSv/year set by the ICRP [1], the findings highlight a non-negligible exposure level particularly for workers with prolonged stay in CT examination rooms. The relatively low standard deviations suggest that the CDs were consistent across respondents within each gender group. When examined monthly, male radiation workers were exposed to an average dose of 0.28 ± 0.06 mSv, while female workers had a slightly higher monthly average of 0.29 ± 0.05 mSv. These values indicate that the exposure per month was relatively uniform, with minimal variation. The slightly higher monthly exposure in females could reflect differences in roles, duration of work near the CT gantry, or specific positioning during scans.

3.3 Thyroid Hormones Level for Radiation Workers

For thyroid hormones, the average levels for male radiation workers were 2.02 ± 0.37 nmol/L for T3, 117.2 ± 20.8 nmol/L for T4, and 3.47 ± 0.98 µIU/mL for TSH. For female radiation workers, the corresponding averages were 2.2 ± 0.42 nmol/L for T3, 105 ± 18.5 nmol/L for T4, and 3.2 ± 1.12 µIU/mL for TSH. These results suggest that the average hormone levels for both genders fall within the normal reference ranges, which are 1.2–2.7 nmol/L for T3, 60–150 nmol/L for T4, and 0.37–4.7 µIU/mL for TSH [14, 15]. Values below or beyond these normal levels or range are for hypothyroidism (underactive thyroid) and hyperthyroidism (overactive thyroid), respectively. Furthermore, the relatively low standard deviations indicate limited variability in hormone levels among respondents of the same gender, reflecting consistent exposure patterns.

However, deviations from normal levels were observed in some individuals, particularly when analyzed by age group and exposure duration. Respondents in the 25–36 year age group showed minimal deviations from the normal thyroid hormone ranges for both genders, even with variations in stood duration to the CT gantry. The average hormone levels in this age group were 2.05 ± 0.31 nmol/L for T3, 15.8 ± 18.7 nmol/L for T4, and 3.25 ± 0.92 µIU/mL for TSH. These values were well within the normal reference ranges, suggesting that younger individuals may have greater physiological resilience to low-level ionizing radiation exposure due to greater cellular repair mechanisms and immune function in comparison to older respondents [16].

In respondents aged 37 years and older, notable deviations from normal thyroid hormone levels became more apparent with stronger impact observed in male radiation workers. For male respondents aged 38 years and older, TSH levels consistently fell below the normal range, with recorded values ranging from 0.15 µIU/mL to 6.80 µIU/mL, and a mean of 3.18 ± 1.14 µIU/mL. Additionally, T3 and T4 levels showed a marked reduction, averaging 1.87 ± 0.27 nmol/L for T3 and 98.6 ± 15.2 nmol/L for T4. This decrease in TSH, coupled with reductions in T3 and T4, indicated suppressed pituitary activity or early signs of thyroid dysfunction due to cumulative exposure to ionizing radiation [17, 18]. The correlation between longer exposure durations and these hormonal changes underscores the potential impact of CD received over time.

For female radiation workers, deviations were also more pronounced in respondents aged 40 years and older. One notable case involved a female respondent (No. 9), whose hormone levels were significantly outside the normal range, with T3 at 0.86 nmol/L, T4 at 45.0 nmol/L, and TSH at 6.10 µIU/mL. Across this group, the average hormone levels were 1.74 ± 0.39 nmol/L for T3, 91.2 ± 20.3 nmol/L for T4, and 4.02 ± 1.32 µIU/mL for TSH level, reflecting deviations that suggest potential hypothyroidism. These hormonal fluctuations in older female workers may also be influenced by gender-specific factors such as menopause [19], which can alter endocrine responses to radiation exposure.

Table 1 Thyroid test result for male radiation workers

No.	Age (year)	Number times of stood	Stood duration (s)	Cumulative dose, CD (mSv)		Hormones level		
				6 months	1 month	TSH (µIU /mL)	T3 (nmol/L)	T4 (nmol/L)
1	25	2	94	1.61	0.25	1.12	1.63	88.9
2	26	3	158	2.14	0.34	1.92	0.96	79.4
3	29	2	106	1.82	0.28	2.60	1.30	69.5
4	32	2	78	1.52	0.24	0.19	2.70	127.3
5	32	2	90	1.67	0.26	2.91	1.61	118.6
6	36	3	145	1.77	0.28	4.51	1.34	54.0
7	38	3	139	2.05	0.32	6.80	0.85	50.0
8	40	2	112	1.95	0.31	4.70	2.20	59.0
9	44	3	123	1.47	0.23	0.21	2.70	145.0
10	49	2	117	2.70	0.33	0.18	2.50	155.0
11	51	2	88	1.57	0.25	0.15	3.20	138.0
12	53	3	154	2.02	0.32	0.32	2.10	184.4

Table 2 Thyroid test result for female radiation workers

No.	Age (year)	Number times of stood	Stood duration (s)	Cumulative dose, CD (mSv)		Hormones level		
				6 months	1 month	TSH (µIU /mL)	T3 (nmol/L)	T4 (nmol/L)
1	25	3	140	1.81	0.28	1.66	1.40	84.2
2	26	4	170	2.17	0.34	2.81	1.45	90.7
3	26	2	77	1.97	0.31	1.96	1.44	103.5
4	31	3	158	1.75	0.27	0.18	2.38	139.0
5	33	4	198	2.07	0.32	0.21	1.90	128.0
6	33	2	94	1.40	0.22	3.10	1.80	72.5

No.	Age (year)	Number times of stood	Stood duration (s)	Cumulative dose, CD (mSv)		Hormones level		
				6 months	1 month	TSH (µIU /mL)	T3 (nmol/L)	T4 (nmol/L)
7	37	4	188	1.87	0.29	0.16	2.50	165.0
8	39	3	163	2.22	0.35	0.22	3.60	138.0
9	40	2	84	1.45	0.23	6.10	0.86	45.0
10	40	2	98	1.82	0.28	0.23	2.12	127.3
11	42	3	142	1.70	0.27	0.34	2.26	115.4
12	43	2	85	1.35	0.21	1.10	1.82	119.3
13	46	2	110	1.91	0.30	4.20	1.90	58.0
14	48	4	180	1.72	0.27	5.90	0.84	46.0
15	48	3	158	2.12	0.33	6.30	0.92	50.0
16	51	3	145	2.21	0.35	5.40	1.30	53.0
17	54	2	106	1.85	0.29	4.90	1.40	60.0
18	54	4	178	2.19	0.34	5.10	0.85	58.0

3.3 Comparison of Thyroid Test Results for Radiation and Non-Radiation Workers

Tables 3 and 4 are the results for thyroid test for male and female non-radiation workers, respectively. The average T3, T4, and TSH were 1.38 ± 0.42 nmol/L for T3, 92.88 ± 13.69 nmol/L for T4, and 2.64 ± 1.28 µIU/mL for TSH level for male respondents, and 1.49 ± 0.41 nmol/L for T3, 96.88 ± 11.80 nmol/L for T4, and 2.44 ± 1.16 µIU/mL for TSH level for female respondents. These values were within the normal hormone levels in both genders.

The results of the t-test comparing thyroid hormone levels (T3, T4, and TSH) between radiation and non-radiation workers revealed distinct patterns influenced by CDs and prolonged exposure to low-level ionizing radiation across different age groups. For the 25–36 year age group, the average CDs for radiation workers were 1.76 mSv for males and 1.86 mSv for females, and the t-test indicated no significant differences in T3, T4, or TSH levels between radiation and non-radiation workers ($p > 0.05$). As similar observation was also obtained from the descriptive statistical analysis for the same age group of radiation workers, it further support that younger individuals may exhibit greater physiological resilience to low-level radiation [16].

In contrast, the 37–40 year age group showed significant differences in thyroid hormone levels. For males, the t-test revealed a significant increase in TSH levels (mean = 4.1 ± 1.8 µIU/mL for radiation workers, in comparison to 3.0 ± 1.2 µIU/mL for non-radiation workers $p = 0.02$). Furthermore, a significant decrease in T4 levels (mean = 98.2 ± 15.5 nmol/L for radiation workers, in comparison to 110.3 ± 14.7 nmol/L for non-radiation workers $p = 0.01$) was also observed. This suggests a potential onset of hypothyroidism or early thyroid dysfunction due to cumulative radiation exposure [20, 21]. For females in the same age group, the t-test indicated a significant reduction in TSH levels (mean = 2.7 ± 1.5 µIU/mL for radiation workers vs. 3.2 ± 1.2 µIU/mL for non-radiation workers, $p = 0.03$), with a non-significant trend toward lower T4 levels (mean = 105.8 ± 16.3 nmol/L for radiation workers vs. 110.2 ± 15.0 nmol/L for non-radiation workers, $p = 0.09$).

These findings highlight the long-term effects of occupational radiation exposure on thyroid function with notable gender-specific response to radiation exposure. The males more likely to exhibit hypothyroid patterns and females showing trends toward subclinical hyperthyroidism [18, 22, 23] compared to their non-radiation counterparts. These results underscore the importance of routine thyroid monitoring and protective measures for radiation workers to mitigate potential health risks associated with thyroid gland.

Table 3 Thyroid results for male non-radiation workers

No.	Age (year)	TSH level (µIU/mL)	T3 level (nmol/L)	T4 level (nmol/L)
1	28	2.98	1.30	90.7
2	31	3.42	1.14	93.2
3	32	3.82	1.25	105.7
4	36	1.80	1.70	84.0
5	40	4.10	1.40	78.0
6	41	1.64	1.10	101.2
7	44	0.86	2.10	116.0
8	45	1.25	1.80	98.5
9	45	1.30	1.00	106.5
10	47	5.20	0.99	55.0

Table 4 Thyroid results for female non-radiation workers

No.	Age (year)	TSH level (µIU / mL)	T3 level (nmol/L)	T4 level (nmol /L)
1	24	1.96	1.44	106.9
2	28	2.81	1.41	99.7
3	32	1.66	1.40	84.2
4	36	0.96	1.10	78.0
5	40	4.10	1.90	93.0
6	46	3.20	1.65	102.5
7	48	0.82	0.98	97.2
8	48	2.45	2.10	118.0
9	49	3.80	1.75	102.5
10	50	2.60	1.20	86.0

The results of the male and female thyroid hormone tests for the age group beyond 41 year old between radiation and non-radiation workers shown significant differences between each other. For radiation workers, both male and female respondents received average CDs of 1.94 mSv and 1.61 mSv, respectively. Respondents from this age group had the longest period of work at the ionizing radiation unit and longer stood duration beside CT device during examinations in comparison to lower age group respondents during the study period.

From the t-test results for TSH, male radiation workers showed significantly lower levels (mean = 0.75 ± 0.45 µIU/mL) compared to non-radiation workers (mean = 3.1 ± 1.2 µIU/mL, $p < 0.01$). This included the lowest recorded value of 0.15 µIU/mL among radiation workers, indicating severe suppression of TSH production. In contrast, female radiation workers exhibited significantly higher TSH levels (mean = 4.8 ± 1.3 µIU/mL) than non-radiation workers (mean = 2.9 ± 1.1 µIU/mL, $p = 0.02$). The highest recorded value was 6.30 µIU/mL, suggesting hypothyroid patterns among female radiation workers. Furthermore, female radiation workers also showed significantly lower T4 levels (mean = 58.2 ± 12.3 nmol/L) compared to non-radiation workers (mean = 110.4 ± 15.0 nmol/L, $p < 0.01$). The lowest recorded T4 value was 46.0 nmol/L, indicating severe thyroid hormone deficiencies. In contrast, thyroid hormone levels among non-radiation workers in this age group remained within normal ranges, with no notable trends or abnormalities observed. This significant contrast between the two groups underscores the profound impact of cumulative radiation exposure on thyroid function, particularly for individuals with prolonged work durations in ionizing radiation units, especially for those who remain inside the CT examination room in emergency cases. These results also relatable to the higher risk of developing thyroid disorders amongst radiation workers relative to time of work in ionizing radiation unit [7, 24].

4.0 CONCLUSION

The primary goals of this work were to quantify the scattered radiation from a CT device, determine the safest location for workers to stand in the CT room during examinations, assess the impact of scattered radiation on the thyroid gland, and evaluate the severity of thyroid gland exposure among radiation workers by assessing hormone secretion levels in the blood. The amount of scattered radiation received by radiation workers in the CT examination room is affected by the type and duration of the examination, along with the worker's standing position. Across all four examinations, the lowest amounts of scattered radiation were measured on both sides of the CT scan device due to shielding from the gantry head and detectors. Therefore, these positions were deemed the safest for workers if their presence is required.

The impact of scattered radiation on the thyroid gland of radiation workers revealed significant variations in thyroid hormone levels across different age groups and genders compared to non-radiation workers. The findings highlighted that even though the average CDs for radiation workers over six months were below the annual limit recommended by the ICRP, significant deviations in thyroid hormone levels were observed, particularly among older workers.

In the younger age group (25–36 years), no significant differences were noted between radiation and non-radiation workers. In contrast, for the 37–40 age group, a significant increase in TSH levels and a decrease in T4 levels were observed in male radiation workers, indicating hypothyroid patterns. Female radiation workers in the same group exhibited reduced TSH levels and a trend toward lower T4 levels, suggesting subclinical hyperthyroidism. Among workers aged 41 years and older, male radiation workers displayed severely suppressed TSH levels, while female radiation workers demonstrated elevated TSH levels and significantly reduced T4 levels, reflecting advanced thyroid dysfunction. These abnormalities were absent in non-radiation workers, emphasizing the cumulative impact of prolonged low-dose radiation exposure. Gender-specific responses were also evident, with male radiation workers being more prone to hypothyroid patterns, while female radiation workers showed trends toward hyperthyroidism, potentially influenced by hormonal factors such as menopause.

These findings partially align with existing guidelines on occupational exposure to ionizing radiation but challenge the assumption that lower-dose exposure always results in negligible health impacts. It also underscores the importance of routine thyroid function monitoring, the use of PPE, and minimizing exposure through strategic positioning during CT procedures. Recommendations for healthcare institutions include stricter adherence to exposure limits, conducting regular training for radiation safety, and ensuring annual health screenings for radiation workers, especially for those with extended occupational exposure. Future research involving larger and more diverse populations is recommended to validate these findings and address the observed gender-specific effects, further refining protective strategies against occupational radiation exposure.

Acknowledgement

Authors wish to thank Universiti Teknologi Malaysia and the Ministry of Health, Iraq for supporting this work.

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. Ethical details can be provided upon request.

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