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The Impact of Long-Term Occupational Radiation Exposure on Thyroid Health Among Radiographers in Oman

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ABSTRACT

The accumulative long occupational radiation exposure experienced by radiographers and the following consequential adverse effects have been an alarm for years. Health concerns included radiation induced skin injury, cataract development, cardiovascular and thyroid disorders. Thyroid and bone marrow are particularly sensitive to ionizing radiation. Long-term exposure to radiation can significantly impact thyroid functions, leading to various thyroid disorders over time.

This study aimed to evaluate the relation between long term exposures to ionizing radiation and the increased risk of thyroid dysfunction over time among radiographers in Oman. This was confirmed by analysis of thyroid hormones measurement; mean serum levels of T3 (triiodothyronine) (2.5 ± 0.9 pmol/L, $p<0.05$) and T4 (thyroxine) (5.1 ± 1.22 pmol/L, $p<0.01$) which showed significant drops as compared to normal level range. A significant increase in the mean serum TSH (thyroid stimulating hormone) levels of the subjects of the study (16.50 ±1.22 m(IU)/L, $p<0.001$) as compared to the normal level range.

Our results suggest prolonged exposure can lead to damaging effects of the thyroid gland and this could be explained by structural and functional changes in the thyroid tissue. Understanding the pathogenesis of these disorders is crucial for developing strict protective guideline measures for radiographers.

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Introduction

Ionizing radiation (IR) is considered as one of the main diagnostic and intervention procedures used in medicine. Humans are exposed to radiation rays through the environment, occupation, medical use, or other sources. Radiation exposure, particularly long-term cumulative exposure, can have injurious effects on human health leading to cellular [1].

Each organ has different sensitivity to IR. Bone marrow and thyroid gland are the most sensitive and susceptible tissues to radiation induce cellular dysfunction. Leukemia and thyroid dysfunction are common clinical abnormalities reported in individuals exposed to IR (International Agency for Research on Cancer, 2022).

Radiological technicians are at high risk of low-dose occupational radiation exposure with average annual doses of more than three times than of the general population.

This was explained due to their proximity to ionizing radiation used in medical imaging practices and radiotherapy [2]. Repeated exposure to low-dose radiation over many years has been linked to increased morbidity including malignancy risks as; leukemia, breast, and thyroid cancers among radio-technicians (International Agency for Research on Cancer, 2022).

Studies have shown that radio-technicians have elevated incidence of thyroid dysfunction compared to the general population and other healthcare workers and that thyroid gland is susceptible to radiation-induced damage [3, 4]. However, the precise effects of prolonged low-dose occupational radiation on thyroid remain uncertain, especially given the advanced technologies and safety protocols.

Method and Material

In this retrospective cohort study, 100 radiographers from several governmental health providing institutes in Oman were enrolled in this study. The study was approved by the research committee and the participants were approached through direct contact and they were consented to be enrolled in the study. Their medical records were accessed through the AL SHIFA system. The inclusion criteria for the study was enrolling radiographers (either male or female) who were more than 6 years in-service, they were working 7 hours per day for 5 days per week. The exclusion criteria were any

radiographer who has previous thyroid disorder: hypothyroidism, hyperthyroidism, thyroid cancer, or thyroid parenchymal disease nor thyroid surgery before starting the service. Pregnant female and any participant who has taken any medication which interferes with thyroid function.

The participants filled a survey to identify if they have any known thyroid disorder development after starting the service. Demographic data were collected from Al SHIFA system which were: sex, age, previous medical or surgical history, any concomitant medications, duration of radiation exposure.

Venous blood samples results for thyroid function tests (TSH, T3 and T4) and thyroid gland ultrasound of the included subjects for thyroid parenchymal structure, thyroid volume and presence of nodules were retrieved from Al Shifa system for participants who had thyroid dysfunction.

Statistical Analysis

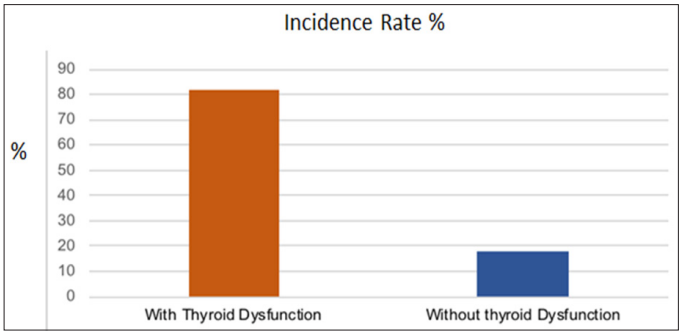
Statistical SPSS program (version 30.0) was used for all the analysis. The data were analyzed by one-way ANOVA and two-way ANOVA. All the results are expressed as mean ± standard error of the mean (SEM), and with the level of significance set at $p < 0.05$.

Results

A total of 100 subjects took part in this study from different hospitals and health centres in Oman working in the radiology departments. Pearson correlation coefficient was conducted and showed a significant positive correlation between number of years of radiation exposure and thyroid dysfunction, especially hypothyroidism ($r = 1$).

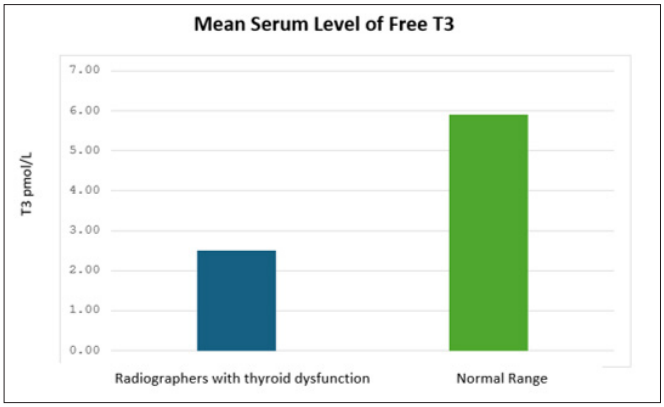
Exposure to Radiation (Years)	Correlation with thyroid dysfunction (coefficient, r)
1-2 years	0
3-4 years	0
5-6 years	0.5
6-10 years	1

Moreover, this study also showed that the Incidence rate (%) for the subject that reported thyroid dysfunction was significantly higher (82%) as compared to those who reported no medical issues in thyroid gland (18%) ($p<0.001$) as shown in graph 1.



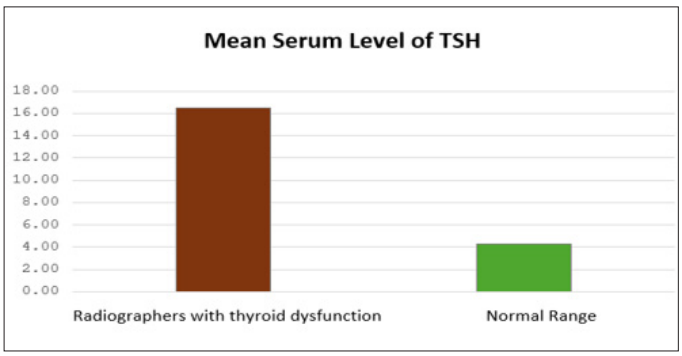
Graph 1: The Incidence rate % of Subject with or without Thyroid Dysfunction

Moreover the mean serum Levels of Free T3 was measured for the subjects that reported thyroid dysfunction, it was significantly decreased (2.5 ± 0.9 pmol/L) than normal range (3- 5.9 pmol/L) ($p<0.05$) as shown in graph 2.



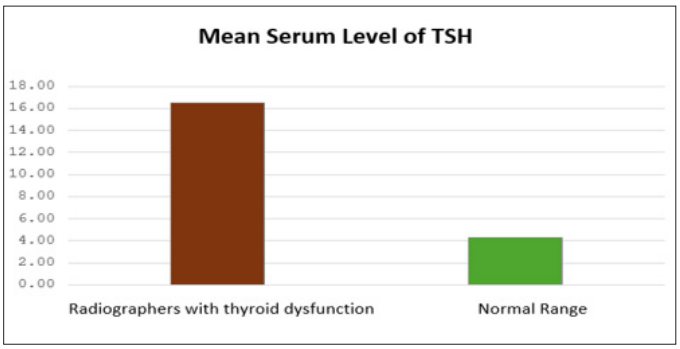
Graph 2: The Mean Serum Levels of Free T3

Also, the mean serum levels of free T4 was measured for the subjects that reported thyroid dysfunction, it was significantly decreased (5.1 ± 2.80 pmol/L) than normal range (8.5-22.5 pmol/L ($p<0.01$) as shown in graph 3



Graph 3: The Mean Serum Levels of Free T4

In addition the data of this study showed that the mean serum levels of TSH was significantly higher (16.5 ±2.80 m(IU)/L) as compared to the normal level (0.03-4.29 m(IU)/L) ($p<0.001$) as shown in graph 4.



Graph 4: Mean Serum Levels of TSH

Discussion

The current study hypothesised that prolonged exposure of ionizing radiation to thyroid gland can lead to structural and functional damage. Therefore in this study we aimed to examine the relation between long term exposure to radiation and thyroid

dysfunction among Omani and non - Omani radiographers within governmental health providing institutes in Oman.

The study examined the relation between periods of several years exposed to ionizing radiation and thyroid dysfunction. The results revealed that there is a strong positive correlation between long term exposure (after 5-6 years work service) and thyroid dysfunction (r =1).

Multiple large-scale epidemiological studies have reported increased rates of thyroid nodules, cysts, and malignancies among radio-technicians compared to both the general population and other healthcare professionals with less radiation exposure [5-7]. In a cohort of over 27,000 Chinese radiologic technicians, the prevalence of thyroid microadenomas doubled for those with over 10 years of radiation exposure [8].

While structural changes are well-documented, the evidence for radiation effects on thyroid functioning is still under investigation. Some studies revealed no significant difference in thyroid stimulating hormone (TSH), thyroxine (T3 and T4), or antithyroid antibody levels between radiology workers and controls . However, reported a higher rate of hypothyroidism among radio-technicians versus unexposed groups [9, 10].

In this study, thyroid hormones including measurement of serum level of T3 (triiodothyronine) and T4 (thyroxine) which showed significant reduction as compared to normal level range ($p<0.05$), ($p<0.01$) respectively; whereas only 2 subjects showed an increase in these hormones and reported a strong family history of hyperthyroidism ($p>0.05$). Additionally this study showed a significant increase in TSH serum levels of the subjects with thyroid dysfunction as compared to normal level range ($p<0.001$). The diagnosis was confirmed by thyroid ultrasound which revealed changes in thyroid echogenicity.

Proposed mechanisms for radiation-induced thyroid damage include: direct DNA damage causing gene mutations, oxidative stress, and autoimmune reactions that disrupt thyroid hormone regulation [11, 12]. These effects can result in hypothyroidism, hyperthyroidism or thyroid nodules. The radio-sensitivity of thyroid follicular cells likely also plays a role [13].

IR can cause double-strand DNA breaks and mutations in thyroid follicular cells. These mutations may lead to impaired cell function, apoptosis (programmed cell death), or uncontrolled proliferation, increasing the risk of thyroid cancer . High doses of radiation can lead to follicular cell atrophy and fibrosis, reducing the gland's ability to produce thyroid hormones [14].

Previously stated damage to follicular cells reduces their ability to produce thyroxine (T4) and triiodothyronine (T3), potentially causing hypothyroidism and that in some cases, thyroid tissue compensates by forming nodules or hyperplastic regions, which can lead to hyperthyroidism or an increased risk of thyroid cancer [15].

In Su stated that radiation exposure generates reactive oxygen species (ROS), leading to oxidative stress and lipid peroxidation in thyroid cells. This oxidative damage can activate inflammatory pathways, triggering apoptosis or fibrosis in thyroid tissue. The increased oxidative stress caused by ionizing radiation is more harmful to macromolecules, possibly leading to thyroid disorders. Other findings revealed that workers occupationally exposed to low doses of IR showed higher incidence of all types of chromosomal aberrations and elevated levels of serum 8-OHdG (8-hydroxy-2'-deoxyguanosine):a vital marker for measuring the effect of endogenous oxidative damage to DNA. Furthermore, occupational exposure to IR alters circulating redox and inflammatory biomarkers. As radiation causes oxidative stress, that happens when there is an inequality between reactive oxygen species (ROS) and antioxidants. Cells increase the release of defensive enzymes and proteins to try to neutralise the oxidant property and redox balance [16].

Free radicals including hydrogen peroxide, nitric oxide, superoxide, and hydroxyl radicals are produced by IR and may cause morphological and physiological changes in the cells. In thyroid gland cells, these radicals have the potential to interact with other macromolecules in thyroid cells and alter their structure and function, leading to hypo- or hyperthyroid disorders.

Further more radiation exposure can disrupt immune system function, potentially leading to autoimmune reactions against thyroid tissues. This has been observed in populations exposed to nuclear radiation, where increased incidences of thyroid autoantibodies were detected. Radiation-induced changes in thyroid antigen expression may cause immune cells to mistakenly attack the thyroid gland, leading to autoimmune thyroid disorders [17-22].

Conclusion

The mechanisms of thyroid dysfunction due to radiation exposure involve a complex interplay of direct cellular damage, oxidative stress, immune dysregulation, and hormonal imbalances. Understanding these pathways is crucial for assessing the long-term health risks of radiation-exposed populations and for developing strong protective measures guidelines.

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