Assessment Of Radiation Protection Practices Among Exposed Health Care Workers In Tobruk Medical Centre

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Introduction: The use of ionizing radiation in medical imaging for diagnostic and interventional procedures has increased substantially, leading to higher exposure for both patients and healthcare workers (HCWs). Effective radiation protection measures are crucial to minimizing associated risks.
Objective: This study assesses radiation protection practices among personal health care workers, patients, and environment in diagnostic radiology departments in Tobruk Medical Center.
Methods: A cross-sectional study was conducted among 70 HCWs, including radiologists, nurses, and radiographers, from March to May 2022. Data were collected through a validated self-administered questionnaire covering demographic details, radiation protection practices, and compliance with safety measures. Statistical analysis was performed using SPSS version 25.0.
Result: The study revealed that none of the participants regularly wore dosimeters. Only 28.6% consistently wore a lead apron during fluoroscopic examinations, and 14.3% used protective devices such as lead gloves and goggles during radiography in surgical settings. Training participation was low, with 74% of HCWs never attending radiation safety courses. Adherence to radiation protection measures for patients was comparatively better, with 92.9% of radiographers asking female patients about pregnancy status before procedures. However, environmental protection practices were deficient, as 85.7% of HCWs never checked the radiation warning lights.
Conclusion: The study highlights significant deficiencies in radiation protection practices among healthcare workers, posing risks to both personnel and patients. The findings underscore the need for stricter enforcement of safety regulations, mandatory training programs, and improved access to protective equipment.
Keywords: Ionizing Radiation, Radiation Protection, Practices, HCWs.

INTRODUCTION

Radiation is a natural part of the physical environment and is generally categorized into ionizing and non-ionizing types. Ionizing radiation is the most powerful and has the greatest impact on public health. Under typical conditions, about 80% of our exposure to ionizing radiation comes from natural sources, with radon gas being the most significant contributor. The remaining 20% comes from human-made sources, mainly medical X-rays.

The use of ionizing radiation in medical imaging for both diagnostic and interventional procedures has significantly increased in recent years, leading to a corresponding rise in radiation exposure for patients and healthcare workers (Park, 2009; Charles, 2001; Adetokunbo & Herbert, 2003). Today, medical and dental X-rays are the primary sources of man-made radiation exposure. Studies have reported a sharp increase in the prevalence of adverse health effects associated with ionizing radiation exposure over the past two decades (NCRP, 2009; Bury, 2004). However, documented evidence highlights a concerning lack of radiation safety knowledge among various groups of healthcare professionals at risk of occupational exposure, underscoring the severity of the issue (Shiralkar et al., 2003; Lee et al., 2004). Even though the harmful health effects of ionizing radiation, such as cataracts, skin erythema, and cancer, depend on the dose and duration of exposure, it is generally believed that no level of ionizing radiation is entirely safe (NIRS/WISE, 2005). Based on this assumption, radiation safety is guided by the ALARA (As Low As Reasonably Achievable) principle, which emphasizes minimizing radiation exposure while ensuring it does not exceed the effective dose limits set by the International Commission on Radiological Protection (ICRP) (ICRP, 2007).

Studies suggest that approximately 20 to 30 percent of radiological examinations ordered by doctors do not contribute to patient management. Additionally, many healthcare professionals tend to underestimate the radiation doses associated with different imaging techniques (Society of Pediatric Radiology, 2002; Keiijeers & Britton, 2010). These findings reinforce the widely accepted view that radiation exposure risks can be reduced by adhering to essential radiation protection principles, specifically optimization and justification (Beninson, 2015).

Libya has experienced advancements in medical imaging technology over the past three decades, yet compliance with radiation safety protocols remains underexplored. The Libyan Regulation of Ionizing Radiation and Protection against its Hazards (Act No. 2) aligns with ICRP standards, setting occupational exposure limits at 20 mSv per year, with a maximum of 50 mSv annually for any single year. For trainees under 18 years, the limit is 6 mSv. Pregnant workers at risk of radiation exposure should not exceed 13 mSv over any three-month period during pregnancy. Additionally, the dose limit for individuals who are neither employees nor trainees, including those under 16 years, is set at 1 mSv (Kase, 2004). Despite these regulations, gaps in adherence to safety protocols persist due to limited training and inadequate availability of protective equipment.

Worldwide, there are many studies with different results assessing the knowledge and of HCWs in radiation environments about radiation hazards and radiation protection (Iyousef et al., 2023; Guena et al., 2017; Alavi et al., 2017). However, only a few studies have been conducted in this field in Libya (Abdalla et al., 2024; Abdelkader, 2018), particularly surveys related to the radiation protection procedures of radiation workers in Tobruk city.

Previous studies conducted in Libya have primarily focused on evaluating employees' knowledge of radiation protection and their exposure levels. However, little attention has been given to assessing their practice of ionizing radiation protection procedures, despite the country's underdeveloped occupational health services. In addition, lack of baseline health data may hinder an objective assessment of the long-term effects of occupational radiation exposure on employees. Furthermore, the absence of records raises significant professional and legal concerns regarding worker safety and regulatory compliance in the future.

Assessing the baseline radiation protection practices of at-risk groups is crucial for developing effective strategies to prevent unnecessary exposure to ionizing radiation. This is important not only for protecting healthcare workers but also for safeguarding their patients from potential harm. This study aims to evaluate the radiation protection practices of HCWs at Tobruk Medical Center, focusing on personal safety measures, patient protection, and environmental safeguards.

Material And Methods

cross-sectional study was conducted among 70 HCWs occupationally exposed to radiation in the diagnostic radiology department of Tobruk Medical Center between March and May 2022. The target population consisted of 70 out of 100 HCWs with a response rate of 70%.

Inclusion Criteria:

- Radiologists, radiographers, and nurses with at least one year of experience in diagnostic radiology.
- HCWs involved in direct patient imaging procedures.

Exclusion Criteria:

- Senior administrative staff and personnel not directly handling radiation.
- Pregnant healthcare workers.

Data Collection and Ethical Approval

A structured questionnaire, validated through expert review and a pilot study, was distributed to participants. Ethical approval was obtained from the Ethical Committee of the Radiology Department, Tobruk Medical Center (Approval No: XYZ). Informed consent was secured from all participants.The study tool in this research included a self-administered and self-structured questionnaire designed and validated.

The questionnaire was translated into Arabic and revised by 2 experts; then a pilot study was conducted in 2 different random units on 5 specialists. The questionnaire contains four sections: A, B, C and D; Section A comprised questions regarding the demographic data of the participants including, gender, age, educational level, years of experience, occupation, and radiation protection training courses. Section B comprised 8 questions regarding the radiation protection measures and practices of personal HCWs. Section C comprised 9 questions regarding the radiation protection measures and practices of patients. Section D comprised 3 questions regarding environment protection. The four-point Likert scale was used to score the answers to the questions in section B,C, and D, 3 = Always, 2 = Most of the time, 1 = Sometimes and 0 = Never. The higher the score is, the better the radiographer's practice. The score was converted into percentages by dividing the total score by the maximum possible score multiplied by 100.

Statistical Analysis

Data were analyzed using SPSS version 25.0. Descriptive statistics were applied to evaluate adherence to radiation safety protocols. The questionnaire responses were scored using a four-point Likert scale: (3 = Always, 2 = Most of the time, 1 = Sometimes, 0 =

Never). The number of respondents (n) and percentages (%) were reported for each demographic characteristics and each questionnaire item.

Result

Socio-Demographic Characteristic Data

A total of 70 contributors completed the questionnaire. 57.1% of them were males, with 42.9% between the age group of 31–40 years. The majority of them (74.2%) had bachelor`s degrees while 17.1% had diplomas and the minority, 8.6%, had higher educational degrees. Table 1 shows a summary of the socio-demographic characteristics of the participants.

The years of experience were from 11-20 years among 47.1. % of HCWs, 27.1% of participants had experience levels more than 20 years old, and 14.2% had 6-10 years of experience.Despite the fact that, 26% of participants attended training courses on a regular basis, the majority of them (74%) had no training courses on radiation safety.

Table 1. Socio-Demographic Characteristics of the Participants

Parameters	No	%
Gender		
Male	40	**57.1%**
Female	30	**42.8%**
Age(years)		
20-30	20	**28.6%**
31-40	30	**42.9%**
>40	20	**28.6%**
Educational level		
Diploma	12	**17.1%**
Bachelor	52	**74.2%**
Higher educational degree	6	**8.6%**
Occupation		
Radiographer	55	**78.6%**
Nurse	7	**10.0%**
Radiologist	8	**11.4%**
Years of experience		
Less then 5 years	8	**11.4%**
6-10 years	10	**14.2%**
11-20 years	33	**47.1%**
More than 20 years	19	**27.1%**

Personal Radiation protection practices among HCWs

Healthcare workers' compliance with radiation protection measures and practices, as presented in Table 2, was evaluated in terms of personal protection during radiological examinations. Encouragingly, 100% of workers reported wearing thermoluminescent dosimeter (TLD) badges, reflecting strong adherence to radiation monitoring protocols.

However, several critical protective measures were notably underutilized. Only 28.6% of healthcare workers (HCWs) wore lead aprons and other protective devices during fluoroscopic examinations, while just 14.3% used lead gloves, goggles, and thyroid collars during theater radiography. Additionally, adherence to safe practices such as maintaining an adequate distance from the radiation source (42.9%) and minimizing procedure time (57.1%) was moderate.

Despite these efforts, the use of lead aprons remained low, with only 28.6% of HCWs wearing them during fluoroscopic procedures and 21.4% during portable radiography. These findings highlight gaps in compliance with essential radiation safety measures, underscoring the need for improved adherence to personal protective practices.

Table 2. Personal Radiation Protection Practices among HCWs

Question Number	Research Question	Never	Sometimes	Most of the time	Always
Q1	Do you wear the personal dosimeter during work?	70 (100%)	0 (0%)	0 (0%)	0 (0%)
Q2	Do you read your thermoluminescent dosimeter badge?	70 (100%)	0 (0%)	0 (0%)	0 (0%)
Q3	Do you wear a lead apron and other protective devices during fluoroscopic examinations?	10 (14.2%)	10 (14.2%)	30 (42.9%)	20 (28.6%)
Q4	Do you wear a lead apron and other protective devices during portable radiography?	5 (7.1%)	15 (21.4%)	35 (50%)	15 (21.4%)
Q5	Do you wear lead gloves, goggles, and thyroid collar during theatre radiography?	40 (57.1%)	10 (14.3%)	10 (14.3%)	10 (14.3%)
Q6	Do you use minimal exposure time?	5 (7.1%)	10 (14.3%)	15 (21.4%)	40 (57.1%)
Q7	Do you keep enough distance from the radiation source?	5 (7.1%)	10 (14.3%)	25 (35.7%)	30 (42.9%)

Radiation Protection Practices Among HCWs toward Patients

Healthcare workers' adherence to radiation protection practices, as presented in Table 2, demonstrated positive compliance in several key areas. Notably, 57.1% of participants ensured proper collimation and effectively utilized the light beam diaphragm. Additionally, 80% maintained the appropriate source-to-image distance (SID). Encouragingly, 92.9% of radiographers consistently inquired about female patients' pregnancy status before conducting radiological examinations, while 7.1% did so most of the time. These findings highlight a generally good adherence to radiation protection protocols concerning patient safety.

Table 3. Radiation Protection Practices Among HCWs toward Patients

Question Number	Research Question	Never	Sometimes	Most of the time	Always
Q1	Do you make use of a light beam diaphragm?	3 (4.3%)	7 (10%)	20 (28.6%)	40 (57.1%)
Q2	Do you make use of a cone when needed?	65 (92.9%)	5 (7.1%)	0 (0%)	0 (0%)
Q3	Do you ensure proper collimation?	3 (4.3%)	7 (10%)	20 (28.6%)	40 (57.1%)
Q4	Do you make use of markers?	1 (1.4%)	4 (5.7%)	15 (21.4%)	50 (71.4%)
Q5	Do you ensure proper source to image distance (SID)?	2 (2.9%)	3 (4.3%)	14 (20%)	56 (80%)
Q6	Do you ask female patients whether they are pregnant before the examination?	0 (0%)	0 (0%)	5 (7.1%)	65 (92.9%)
Q7	Do you make use of gonad shield?	60 (85.7%)	7 (10%)	3 (4.3%)	0 (0%)
Q8	Do you use minimal exposure time and correct exposure factors?	2 (2.9%)	3 (4.3%)	15 (21.4%)	50 (71.4%)
Q9	Do you normally repeat exposures and radiographs?	60 (85.7%)	5 (7.1%)	4 (5.7%)	1 (1.4%)

Radiation Protection Practices Among HCWs toward Environment

The data presented in Table 4 highlights a concerning trend in compliance with environmental safety measures. Notably, 85.7% of respondents reported that lead aprons were never provided for all co-patients and staff. Furthermore, only 57.1% ensured that doors were closed before making an exposure. Additionally, a significant 85.7% failed to check whether the radiation symbol light was functioning properly, indicating a substantial gap in adherence to radiation safety protocols.

Table 4. ***Radiation Protection Practices Among HCWs Toward Environment***

Question Number	Research Question	Never	Sometimes	Most of the time	Always
Q1	Do you provide lead aprons for all co-patients or staff?	60 (85.7%)	5 (7.1%)	3 (4.3%)	2 (2.9%)
Q2	Do you ensure the room door is closed before making exposure?	5 (7.1%)	10 (14.3%)	15 (21.4%)	40 (57.1%)
Q3	Do you have the radiation symbol light working?	60 (85.7%)	8 (11.4%)	2 (2.9%)	0 (0%)

Discussion

The primary objective of radiation protection is to establish precise guidelines for the safe use of ionizing radiation, ensuring the well-being of healthcare workers (HCWs), patients, and the public while preventing radiation-related complications (Sharma et al., 2016; Lopez et al., 2018). Adherence to safety standards is essential to minimize occupational and patient exposure. Each practitioner must possess a fundamental understanding of radiation protection principles, which include the use of appropriate protective devices, compliance with safety protocols, and optimization strategies (Maina, Motto, & Hazell, 2019). following these guidelines can significantly reduce radiation risks (Lakhwani et al., 2019).

A study conducted in Egypt found that 51.3% of radiology department staff were aware of radiation protection procedures, but only 18% of nursing and support staff demonstrated practical knowledge of radiation safety, increasing risks associated with ionizing radiation (Alavi et al., 2017). Similarly, Maina et al. assessed radiation protection practices in public hospitals and reported that compliance was inadequate, with only 21.4% of participants wearing lead aprons or other protective devices during portable radiography (Maina, Motto, & Hazell, 2019). The study revealed that none of the medical imaging professionals surveyed owned radiation dosimeters. Alarmingly, only 21.4% of participants wear lead aprons or other protective devices during portable radiography. it also highlighted a significant lack of appropriate radiation protective equipment. Additionally, concerns were raised about the training and experience of many HCWs, suggesting that their certifications and qualifications require thorough review.

A similar study by Abuzaid et al. assessed radiation protection compliance in radiology departments and found that 75.1% of HCWs followed environmental protection protocols, 60.4% adhered to patient protection measures, and 45.7% practiced self-protection. While compliance levels were relatively high in some areas, the study emphasized the need for increased knowledge and awareness to further enhance radiation safety practices (Abuzaid et al., 2019).

Since HCWs are exposed to ionizing radiation daily, they receive significantly higher doses than the general public, putting them at a greater risk of radiation-related complications. This makes knowledge of radiation protection critically important. Additionally, the general population remains largely unaware of the risks associated with ionizing radiation exposure. Therefore, it is essential for radiology staff to implement proper radiation protection measures to safeguard not only themselves but also the public and the environment (Zervides et al., 2020; Faggioni et al., 2017)

The study revealed a significant concern, as none of the participants utilized thermo-luminescent dosimeter badges. These dosimeters are essential for recording occupational radiation exposure among healthcare workers, ensuring proper monitoring and adherence to safety standards. The absence of dosimeter usage indicates a critical lapse in radiation protection, potentially leading to unmonitored exposure and increased health risks. This finding underscores the urgent need for strict compliance with radiation safety regulations and the implementation of mandatory dosimetry monitoring to safeguard the well-being of personnel in radiology departments.

Additionally, essential personal protective practices, such as wearing lead gloves, thyroid collars, lead caps, and goggles, were not consistently followed and were often neglected. A significant 57.1% of participants reported never using this protective devises during theater radiography, while 28.6% admitted to neglecting it during fluoroscopic procedures. This lack of compliance may be due to the unavailability of protective equipment in radiology departments. This result is similar to that obtained (Abuzaid et al., 2019).In terms of patient protection, most participants demonstrated good adherence to radiation safety practices, with 57.1% ensuring proper collimation. However, nearly 5% reported frequently repeating radiographs, which can increase unnecessary radiation exposure. The use of gonadal shielding is crucial in minimizing the harmful effects of ionizing radiation, yet 85.7% of HCWs never used gonad shields during examinations, while 7% used them occasionally. This may be influenced by recent findings suggesting that gonad shields could inadvertently increase patient radiation exposure (Kaplan et al., 2018).

Encouragingly, 92.9% of HCWs consistently asked female patients about pregnancy status before conducting radiological examinations, compared to 5% who did so most of the time. This is crucial, given the carcinogenic and genetic mutation risks associated with radiation exposure (Kaplan et al., 2018). However, stricter measures are needed to ensure full compliance with standard safety protocols.

Regarding radiation protection of environment, a substantial 85.7% of participants reported never providing lead aprons for all co-patients or staff. This indicates a severe gap in the adherence to basic protective measures, which can expose individuals to unnecessary radiation. Only a small percentage (7.1%) provides lead aprons sometimes, and even fewer do so regularly. This suggests a lack of consistent protective measures in place. 57.1% of participants always ensure that the room door is closed before making an exposure, which is a positive safety practice to protect those outside the room from unnecessary radiation exposure. However, 7.1% never ensure the door is closed, and 14.3% sometimes do, indicating a need for greater consistency and adherence to this simple safety measure. The data indicates a critical issue with the 85.7% of participants who report that the radiation symbol light is never working. The absence of a functioning symbol light is a serious safety concern as it prevents others in the area from being alerted to the presence of radiation. Only 11.4% report that the light sometimes works, with no participants indicating that it is always functional. This suggests a significant lack of attention to important environmental safety protocols.

Implications and Recommendations

To address these issues, several critical measures should be implemented:

- Mandatory Radiation Safety Training: Regular training workshops must be established to educate HCWs on radiation hazards and protective measures.
- Provision of Essential Protective Equipment: Hospitals must be adequately stocked with lead aprons, thyroid collars, and dosimeters to ensure compliance.
- Regulatory Enforcement and Compliance Audits: The Ministry of Health and the Atomic Energy Authority should conduct frequent inspections and enforce penalties for non-compliance.
- Incorporating Radiation Safety into Medical Curricula: Medical and radiology training programs should integrate radiation protection education into their coursework to ensure early awareness.
- Improved Monitoring of Occupational Radiation Exposure: Regular dosimetry monitoring should be introduced to assess exposure levels and prevent long-term health risks.

Conclusion

The study identified a major shortfall in radiation protection practices among the participants, impacting their own safety, as well as that of patients and those nearby. It revealed a severe shortage of radiation protection equipment and tools including all personal monitoring devices, apron, lead gloves, goggles, and thyroid collar, which require Immediate and urgent intervention from the Ministry of Health and the Atomic Energy Authority in Libya. Systematic implementation of rules to check and ensure that the recommended safety guidelines of practice are strictly followed would help and improve the safe practice of using ionizing radiations to produce optimum radiological images for correct diagnosis with lower doses for personnel, patients, and the general public.

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References

Abdalla, A., Alarefee, H., Alwerfaley, M., Kribat, E., & Yosif, N. (2024). Evaluation of the safety rate in the diagnostic radiology departments in Alkhoms City, Libya. Khalij-Libya Journal of Dental & Medical Research, 8(2), 4–7.

Abdelkader, S. (2018). Assessment of knowledge and awareness towards radiation among medical staff. Journal of Medical Sciences, 13(1), 254–259.

Abuzaid, M. M., Elshami, W., Shawki, M., & others. (2019). Assessment of compliance to radiation safety and protection at the radiology department. International Journal of Radiation Research, 17(3), 439–446.

Adetokunbo, O. L., & Herbert, M. G. (2003). Short textbook of public health medicine in the tropics (4th ed.). Arnold.

Alavi, S. S., Dabbagh, S. T., Abbasi, M., & Mehrdad, R. (2017). Medical radiation workers' knowledge, attitude, and practice to protect themselves against ionizing radiation in Tehran Province, Iran. Journal of Education and Health Promotion, 6, 58.

Alotaibi, M., Bakir, Y. Y., Al-Abdulsalam, A., & Mohammed, A. M. (2015). Radiation awareness among nurses in nuclear medicine departments. Australian Journal of Advanced Nursing, 32(3), 25-33.

Beninson, D. (n.d.). Justification and optimization in radiation protection. International Radiation Protection Association. Retrieved from http://www.irpa.net/irpa5/cdrum/VOL.3/J3-1.

Booshehri, M., Ezoddini-Arkakani, F., & Nozari, H. (2012). Evaluation of dentists' awareness about personnel and patients' national protection in Yadz dental offices. Health, 4, 490-492.

Bury, B. (2004). X-ray dose training: Are we exposed to enough? Clinical Radiology, 59, 926.

Charles, M. (2001). Sources and effects of ionizing radiation. Journal of Radiological Protection, 21, 83-85.

Clark, K. C. (1957). Positioning in radiography. American Journal of Medical Sciences, 233(1), 491. https://doi.org/10.1097/00000441-195710000-00024.

El-Feky, A. A., El-Sallamy, R. M., El-Sherbeni, A. A., & Hagras, H. E. (2017). Safety measures among workers occupationally exposed to ionizing radiation in Tanta University Hospitals. Tanta Medical Journal, 45, 166–174.

Faggioni, L., Paolicchi, F., Bastiani, L., & others. (2017). Awareness of radiation protection and dose levels of imaging procedures among medical students, and radiology residents at an academic hospital: Results of a comprehensive survey. European Journal of Radiology, 86, 135–142. https://doi.org/10.1016/j.ejrad.2016.10.033.

Guena, M. N., Nguemeleu, D. N., Ndah, T. N., & Moifo, B. (2017). An assessment of both patients and medical staff awareness of the risks of ionizing radiation from CT scans in Cameroon. Open Journal of Radiology, 7, 199-208.

International Commission on Radiological Protection (ICRP). (2007). Recommendations of the ICRP: ICRP Publication 103. Annals of the ICRP, 37(2-4).

Kaplan, S. L., Magill, D., Felice, M. A., & others. (2018). Female gonadal shielding with automatic exposure control increases radiation risks. Pediatric Radiology, 48, 227–234. https://doi.org/10.1007/s00247-017-3996-5.

Kase, K. R. (2004). Radiation protection principles of NCRP. Health Physics, 87(3), 251-257.

Keijeers, G. B., & Britton, C. J. (2010). Doctors' knowledge of patient radiation exposure from diagnostic imaging requested in the emergency department. Medical Journal of Australia, 193(8), 450-453.

Lakhwani, O. P., Dalal, V., Jindal, M., & others. (2019). Radiation protection and standardization. Journal of Clinical Orthopaedics and Trauma, 10(4), 738–743. https://doi.org/10.1016/j.jcot.2018.08.010.

Lee, C. I., Haims, A. H., Monico, E. P., Brink, J. A., & Forman, H. P. (2004). Diagnostic CT scans, assessment of patients, physicians and radiologist awareness of radiation dose and possible risks. Radiology, 231, 393-398.

Lopez, P. O., Dauer, L. T., Loose, R., & others. (2018). ICRP Publication 139: Occupational radiological protection in interventional procedures. Annals of the ICRP, 47(2), 1–118. https://doi.org/10.1177/0146645317750356.

Iyousef, K., Assiri, A., Almutairi, S., Aldalham, T., & Felimban, G. (2023). Awareness of radiation protection and common radiation dose levels among healthcare workers. Global Journal of Quality & Safety in Healthcare, 6(1), 1-5.

McCollough, C. H., Schueler, B. A., Atwell, T. D., Braun, N. N., Regner, D. M., Brown, D. L., & LeRoy, A. J. (2007). Radiation exposure and pregnancy: When should we be concerned? Radiographics, 27(4), 909-917.

National Council on Radiation Protection and Measurement (NCRP). (2009). Ionizing radiation exposure of the population of the United States: Recommendations of the

National Council on Radiation Protection and Measurements (Report No. 160). Bethesda, MD.

Nuclear Information and Resource Service/World Information Service in Energy (NIRS/WISE). (2005). US radiation panel recognizes no safe radiation dose. Biological Effects of Ionizing Radiation Report VII (BEIR VII). Washington, DC. Retrieved from https://www.nirs.org/radiation/radtech/nosafedose.

Park, K. (2009). Park's textbook of preventive and social medicine (20th ed.). M/s Barnasidas Bhanot.

Salah Eldeen, N. G., & Farouk, S. A. (2020). Assessment of awareness and practice of ionizing radiation protection procedures among exposed healthcare workers. Egyptian Journal of Occupational Medicine, 44(1), 529–544.

Sarman, I., & Hassan, D. H. C. (2016). Factors affecting radiographers' compliance with radiation protection on all areas of hospital settings worldwide: A meta-analysis. IJIRST International Journal of Innovative Research in Science & Technology, 3, 433–438.

Sharma, M., Singh, A., Goel, S., & others. (2016). An evaluation of knowledge and practice towards radiation protection among radiographers of Agra city. Scholars Journal of Applied Medical Sciences, 4(6), 2207–2210. https://doi.org/10.21276/sjams.2016.4.6.70.