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Assessment of Occupational Exposure Among Diagnostic Radiology Workers in King Faisal Medical Complex in Taif City - Saudi Arabia

Emad Alamri[1], Mahmood Abd-Alalim[1], Osama Albedaiwi[2], Abdulaziz Alamri[3], Mohammed Alnafea[4*]

1.Nuclear Medicine, King Faisal Medical Complex, Taif, Saudi Arabia
2.Riyadh Specialized Dental Center, Riyadh, Saudi Arabia
3.Radiological Department, Prince Faisal bin Khalid Cardiac Center, Abha, Saudi Arabia
4. Department of Radiological Sciences, College of Applied Medical Sciences, King Saud University, Riyadh, Saudi Arabia

ABSTRACT

Radiographic imaging is extremely valuable as a diagnostic tool in medicine, but ionizing radiation poses hazards for health-care providers as well as patients in health-care facilities (HCFs). Occupational radiation exposure can occur due to various human activities, including the use of radiation in medicine. Radiation exposure from diagnostic X-ray and computed tomography (CT) scan carry well-known potential risks. Personnel and radiation safety monitoring is an important safety precaution in the practice of radiography. The study aimed to assess the occupational radiation exposure and safety protection among medical staff in HCFs in the Eastern Province, Kingdom of Saudi Arabia (KSA). This study compares the occupational radiation dose levels for all radiation workers in King Faisal Medical Complex in Taif City of the kingdom of Saudi Arabia over four years. The occupational exposure was quantified using thermoluminescence dosimeters. The study results concludes that the occupational radiation doses to all workers during the four years period were below the limits set by the ICRP recommendations. The measured annual effective doses for workers were found to be 0.39 mSv.

Keywords: Radiation Dose; Dose limits; Occupational exposure; Personal dosimetry; Radiology; TLD.

*Corresponding Author Email: alnafea@ksu.edu.sa
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INTRODUCTION

Ionizing radiation have been used in many applications, such as medicine, research, education, industry, and agriculture, for a wide variety of beneficial purposes [1]. Medical imaging is a primary constituent of the entire healthcare system, from health and screening to early diagnosis, treatment options and follow-up [2]. It is widely known by both the patients and physicians that the medical imaging plays an important role in disease diagnosis [3]. The advances in technologies in radiological imaging and radiotherapy have helped to increase the accuracy of the medical diagnosis and treatment [4]. Medical diagnostic imaging technologies use ionization radiation for diagnosis and therapy process, which results in radiation exposure to diagnostic radiology (DR) workers and patients [5]. The DR workers can be exposed to low-level radiation over a long time, which can be related to biological effects [6]. An occupationally exposed worker is a term that refers to a personal who is exposed to the ionization radiation from their work environment [7]. To monitor occupational radiation exposure, all workers were wearing a small device known as a personal dosimeter. Multiple types of dosimeters can be used such optically stimulated luminescence (OSL), Thermoluminescent dosimeter (TLDs) and metal-oxide semiconductor field effect transistor [8]. The system of radiation protection across worldwide is based on the recommendations of the International Commission for Radiation Protection (ICRP). The ICRP recommendations include dose limits for radiation field workers, which is the major principle for radiation protection [9]. The latest report published by the United Nations Scientific Committee on Effects of Atomic Radiations (UNSCEAR) estimates that worldwide, there are about 4 to 5 billion medical radiological examinations per year, up from 3.6 billion in 2008 [10]. In Saudi Arabia, the radiology patients in the ministry of health (MOH) hospitals increased by 50% from 2009 to 2019. In Taif, 105% increase in number of radiology patients (156,200 to 320,000) have been reported from 2017 up to 2020 [10] as demonstrated in Figure 1. In the last five years, the radiological examination in King Faisal Medical Complex (KFMC) increased by 31% from 2017 to 2021 (131,000 to 172,000 examinations) according to the MOH, 2022 systematic statistic [11] as shown in Figure 2. Increased patients and their examinations may lead to an increased radiation exposure to radiographers, nurses, and radiologists, which can pose health risks such as cancer and cataract[11]. Therefore, the radiation received by the worker should be reviewed and evaluated. Also, the impact of the workload on radiation exposure for DR workers must be investigated. The main objective of this study is to identify the radiation doses for DR workers in KFMC and to compare the dose received with the limit of ICRP. The main objectives of this study were to investigate the radiation dose among DR workers in KFMC in last four years. As well as to comparing workers annual effective doses to

ICRP annual limit of 20 mSv/year and UNSCEAR values, to investigate reasons for high and low exposure to the workers.

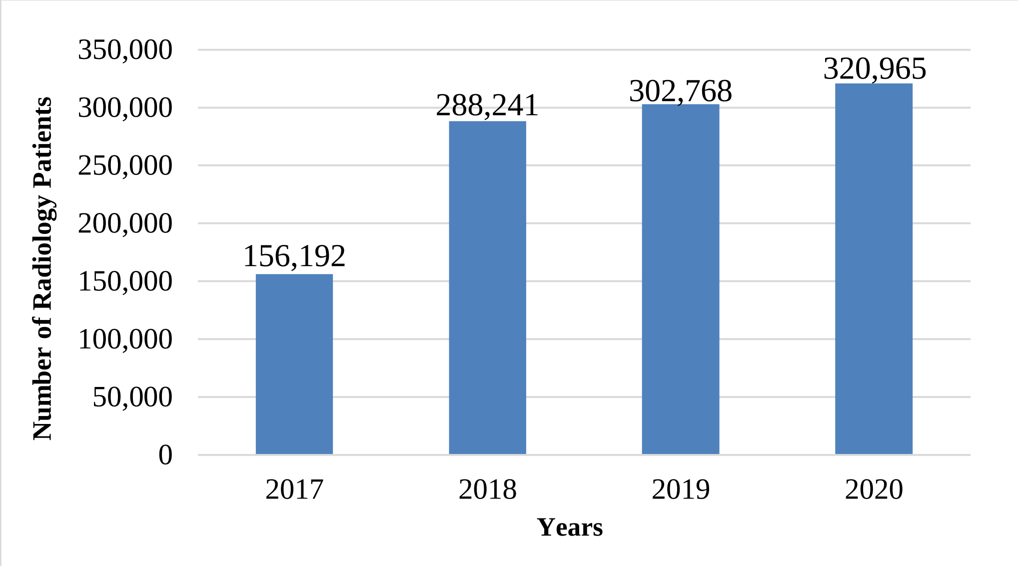

Figure 1: This represent the number of patients obtained a diagnostic radiography scan on the Taif city between 2017 up to 2020.

THEORETICAL BACKGROUND

Ionization Radiation

Radiation is the emission of energy through space with a variety level as waves or particles including electromagnetic, acoustic or gravitational. When the energy level enough to eject an electron from an atom, thereby ionizing the atom, it is considered ionizing radiation, such as photon (X-rays and gamma rays) or beta and alpha particles. Because of this effect, ionizing radiation is more biologically relevant, having the effect to cell function, mutate cells and even cause cell death [12].

Radiation Quantity and Units:

The three common quantities used to measure ionizing radiation are exposure, (X), absorbed dose, (D), and dose equivalent, (H). These quantities are defined differently, have different applications and uses, and should not be used interchangeably by the radiation protection professional. Exposure describes the amount of radiation traveling through the air. Many radiation monitors measure exposure. The units for exposure are the roentgen (R) and coulomb/kilogram (C/kg). Dose equivalent (or effective dose) combines the amount of radiation absorbed and the medical effects of that type of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Units for dose equivalent are the roentgen equivalent man (rem) and Sievert (Sv), and biological dose equivalents are commonly measured in 1/1000th of a rem (known as a millirems or mrem).The following subsection briefly the radiation quantity that contribute to the radiation dose to the patient.

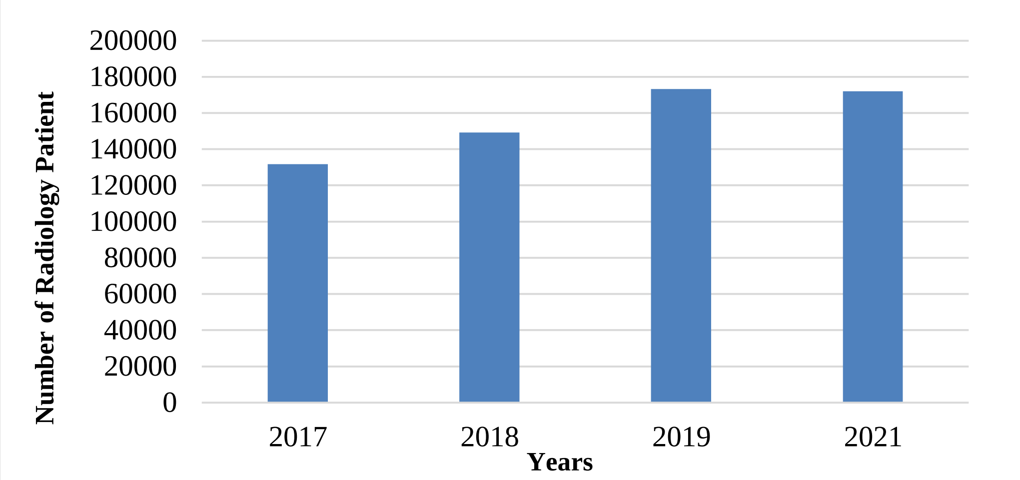

Figure 2: This demonstrate the number of patients having radiological examination at King Faisal Medical Complex during 2017-2021.

Absorbed Dose

Describing the amount of energy of ionizing radiation deposited per unit mass, measured, and reported in grays (Gy), where one Gy equals one Joule of energy deposition per Kilogram of tissue. The absorbed dose does not consider the different types of radiation and organs [13].

Equivalent Dose

Each type of ionizing radiation deposit different amounts of energy, therefore, can cause different biological effects, this is the concept of radiation biological effectiveness. Due to this, a radiation weighting factor for each radiation type is applied to the absorbed dose to create the equivalent dose and measured in Sievert (Sv) [13].

Where, are radiation weighting factor and absorbed dose, respectively.

Effective Dose (*E*)

Some organs in the body are more radiosensitive than others, so the radiation effect on each organ in the body is different. Tissues such as skin is less radiosensitive than bone marrow, so the marrow is more liable for radiation effects. Therefore, the tissue weighting factor for organs is applied to the equivalent dose to create the effective dose, also measured in Sievert [13]. The relation between absorbed, equivalent, and effective dose can be visualized in Figure 3.

Where, are tissue weighting factor and equivalent dose, respectively.

Diagnostic Modalities Using Ionizing Radiation

X-rays, computed tomography (CT), fluoroscopy and nuclear medicine are all forms of ionizing radiation. X-ray radiography is non-invasive technique provides a useful visualization of the body internal tissues and structures. X-rays can be used for diagnostic assessment and monitoring [14]. CT is a combination of many X-rays taken from various angles to produce a cross sectional images. CT defined as a high dose technique due to its slice by slice, axial imaging. Currently, a CT scan can compile a three-dimensional reconstruction of the body within a few seconds, thereby significantly decreasing the dose. Fluoroscopy uses a continuous X-ray and provides real-time visualization of tissue or contrast movements throughout the body [14].

Dose Limitations

The purpose of the International Basic Safety Standards (BSS) is to establish basic requirements for protection against the risks associated with exposure to ionizing radiation and for the safety of radiation sources. The standards have been developed from widely accepted radiation protection and safety principles, such as those published in the Annals of the ICRP [15]. The objective of the ICRP is to provide a system and useful standards for medical, occupational, and environmental radiation protection without restricting beneficial practices giving rise to undue exposure to radiation. It was recommended for workers exposed to radiation sources to apply all the requirements established in the BSS for protection against ionizing radiation and the safety of radiation sources. The personal dose equivalent (H_p 10) is the dose received by tissue at a 10-mm depth from the surface of the skin, which is considered the dose to the whole body (effective dose). The ICRP dose limit was established as the annual effective dose. An effective dose limit of 20 mSv has been set for DR workers each year. Table 1 [15, 16].

Table 1: Occupational dose limits from ICRP 2007, 2012.

Type of limit	Occupational limit
Effective dose	20 mSv/year, averaged over a defined 5-year period
Annual equivalent dose in:	
Lens of the eye	20 mSv
Skin	500 mSv
Hands and feet	500 mSv

Personal Monitoring Dosimeters

Monitoring dosimetry is a device that measures and record personal dose from external ionizing radiation. There are multiple types of personal dosimeters, in between the TLDs are the most appropriate [17, 18], which are used to estimate workers effective doses at KFMC.

Thermoluminescent dosimeter (TLD)

Specific crystalline materials are used in TLDs. Activators are added to the crystal to keep energy trapped within the conductance and valance band. When these crystals are irradiated, the absorbed energy is stored inside the crystal lattice; the bound electrons in the valance band are then excited and produce free electrons. These electrons receive energy and move to the conduction band, where they are trapped in energy gaps until they obtain sufficient energy to escape. When the crystal is heated, the crystal lattice vibrates, and the trapped electrons release the stored energy as visible light. Then, the photo multiplier tube (PMT) converts the emitted light to electric currents. Dose measurements are calculated by detecting the amount of emitted light. There are multiple types of crystals, the most commonly type used in TLDs in medical field is lithium fluoride (LiF) as it is tissue equivalent. Thermo-luminescent crystals can be used in the form of powder, chips, rods, and cards.

TLD Readout

The Radiation Protection Program (RPP) of MOH acts as a national register and regulator of occupational radiation doses for MOH hospitals. TLD badges were collected and read using a Harshaw 6600 plus an automated TLD reader (Thermo Electron Corporation, Ohio, USA), and WinREMS software [19]. For TLD reader calibration and quality control, it was calibrated under reference situation using an irradiator a Strontium-90 / Yttrium-90, with a radiation activity of 0.50 mCi and the sensitivity of reader has a range from 10 μGy to 1 Gy, with a linearity of about 5%. The time temperature profile had a 120^{o} C preheated temperature and an acquisition temperature rate of 20^{o} C/s up to 390^{o} C. The ideal flow rate mode of the reader is 28 l/h 20.

Research Methodology

A retrospective cross-sectional study including 107 DR workers in KFMC, analyzing their occupational radiation exposure in last four years. All workers were wearing whole-body TLDs for monitoring their radiation exposure. The study sample included radiographers (technician, technologists), radiologists, nurses, and medical physicists. The exclusion criteria included part-time workers and radiography trainers. Each radiation worker has a dose record that includes the worker's name, identification number, and quarterly radiation dose. Worker's radiation dose readout is recorded quarterly in the RPP. Collection of TLDs was the responsibility of the radiation safety officer (RSO) in the hospital. Radiation dose records were retrieved from the RPP and maintained at the RSO office. The RPP adopted three investigation levels, which are: operational level (minimum detectable limit (MDL) – 1.25 mSv), level I (1.25–3.75 mSv), and level II (>3.75 mSv) per quarter, using these levels as trigger points to determine when a certain decision should be taken. The RPP policy states that no action will be taken if workers exposed to doses below level I. All analyses used Statistical Package for Social Sciences (SPSS), and EXCEL program used for creating figures and chart.

Table 2: Annual average effective dose (mSv), minimum, maximum, standard deviation and annual collective effective dose (man-mSv) of the effective dose for all the occupationally exposed workers during 2018–2021.

Year	Number of workers	Annual average effective dose (mSv)	Standard deviation	Annual collective effective dose (man-mSv)
2018	80	0.29 mSv (0.09-1.06 mSv)	0.11	23.2
2019	93	0.33 mSv (0.08-0.87 mSv)	0.19	31.2
2020	99	0.47 mSv (0.12-1.49 mSv)	0.23	46.5
2021	105	0.49 mSv (0.18-1.48 mSv)	0.27	52.9
Average		0.39 mSv (0.08-1.49 mSv)		

RESULTS AND DISCUSSION

The study contained 107 diagnostic radiology workers, 53% were male and 47% were female, who worked at KFMC from 2018 to 2021. The percentage distribution of workers is as follows: radiographers (54%), radiologists (17%), nurses (10%), and medical physicists (3%). The number of occupationally exposed workers, their annual average effective dose (mSv), minimum, maximum, standard deviation, and the annual collective effective dose (man-mSv) are listed in Table 2. The four-years average of annual average effective dose was found to be 0.39 ± 0.01 mSv, with a standard deviation of 0.23 mSv. Also, the results showed that the lowest and highest annual average effective doses (0.08 mSv and 1.49 mSv) were reported in 2020. Table 3 shows the percentage of the DR workers within RPP level. All workers in KFMC during period of 2018 to 2021 were below level I (1.25-3.75 mSv). During the study period, the occupational radiation dose for all DR workers were below the international recommended dose limit (20 mSv). The annual average effective dose was in the range between (0.387-0.404 mSv) for all groups as shown in Figure 4. As shown in Figure 5 the annual average effective doses were between the range 0.29–0.49 mSv, 0.29-0.48 mSv, 0.28-0.57 mSv, 0.30 – 0.48 mSv, and 0.24-0.62 mSv for male radiographers, female radiographers, radiologists, nurses, and medical physicists respectively. The average annual effective doses for all radiographers less than 0.50 mSv. However, the lowest and highest average annual effective doses were 0.24 mSv and 0.62 mSv for medical physicists. Figure 6 shows the frequency of the effective doses for all workers with normal distribution curve, all workers' effective doses below 1.50 mSv. More than 99% received an annual effective dose less than 1.25 mSv, while less than 1% received an annual effective dose of more than 1.25 mSv, and not exceeded 1.49 mSv. In 2021, the DR workers were exposed to the highest annual effective dose compared to the previous years, due to an increase in the radiology procedures and the number of patients.

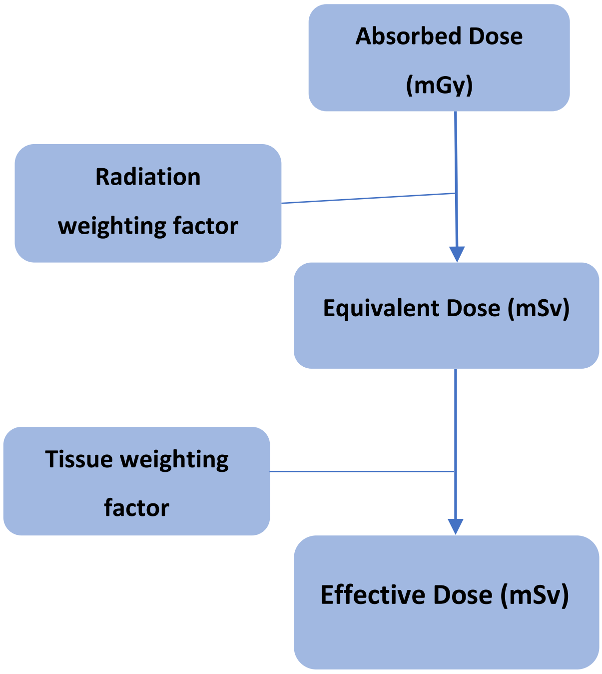

Figure 3: The relation between absorbed, equivalent, and effective dose

The comparative analysis of the annual average effective doses in diagnostic radiological departments for Saudi Arabia hospitals and for different countries is given in Table 4 [21]. Comparing the annual average effective doses reported in this study with previous literature illustrated in Figures7-8, current results recorded the lowest value among the previous studies. The lower annual average effective dose in literature studies was 0.52 mSv compared to 0.39 mSv in this study, with different percentage 28.6% as shown in Figure 7. This value indicates a proper implementation of radiation protection practices in compliance with ICRP recommendations, that necessitates to maintain the occupational radiation dose as low as reasonably achievable. These limits of proper radiation protection were achieved mainly due to many factors, such as: improving the effective radiation protection policies, using better manufacturing radiography machine, and raising workers awareness about the importance of applying adequate radiation protection equipment.

Table 3: Percentage of workers according to the RPP investigation levels.

Investigation Level	Operational	Level I	Level II
Dose interval	MDL - 1.25 mSv	1.25–3.75 mSv	> 3.75 mSv
Percentage of workers	99.3%	0.7%	0%

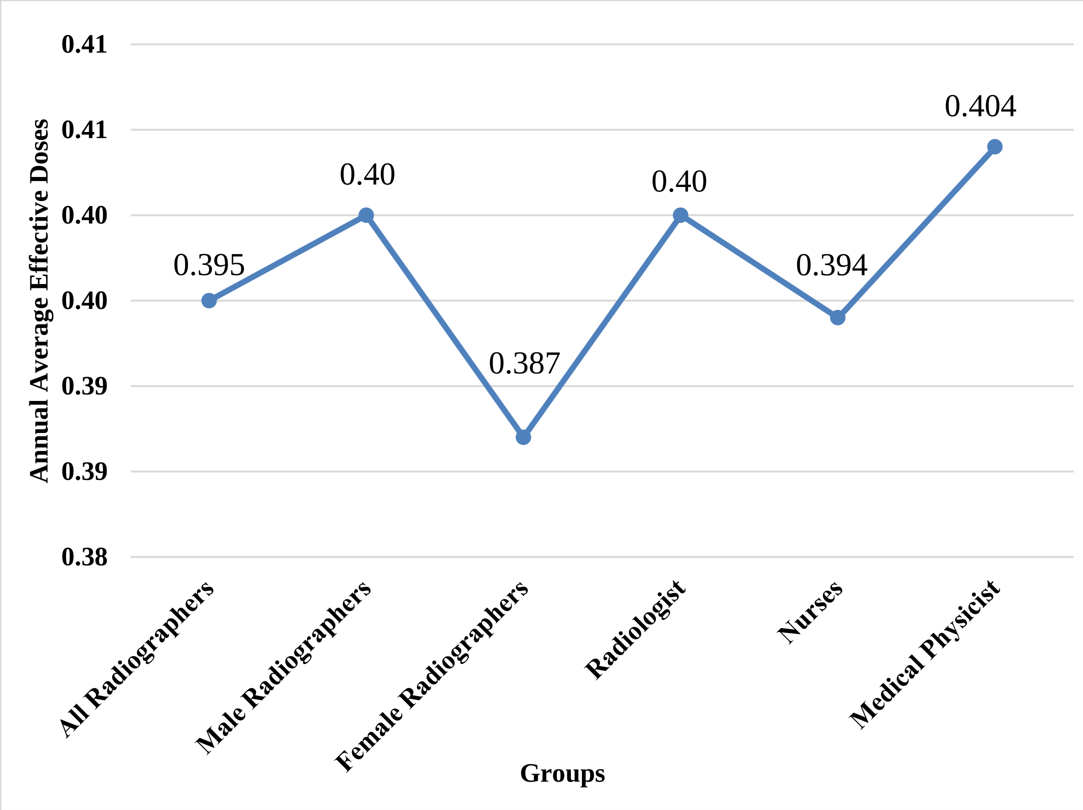

Figure 4: Annual average effective dose for each diagnostic radiology group.

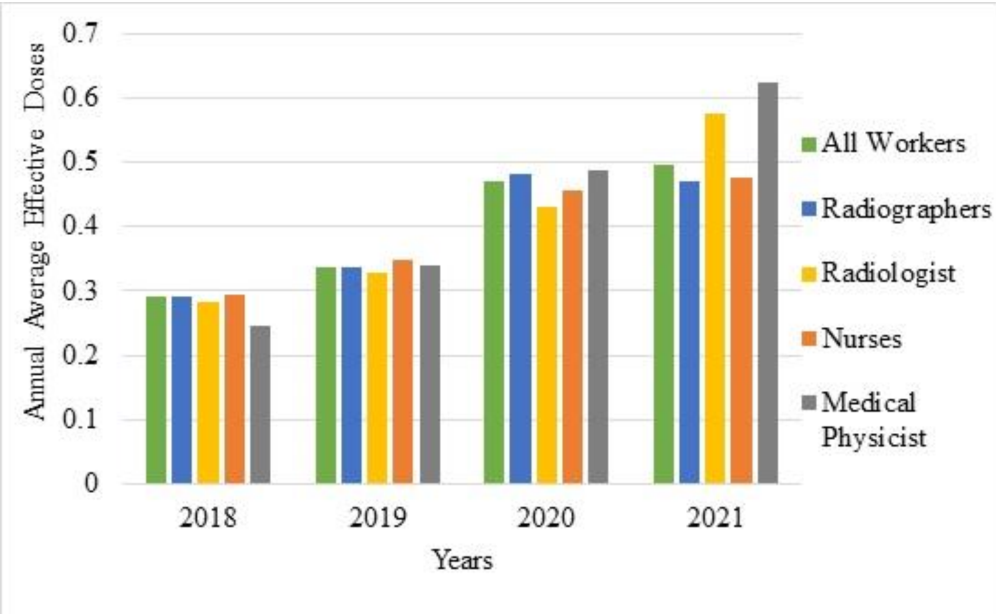

Figure 5: The annual average effective doses during study period 2018-2021 for each group.

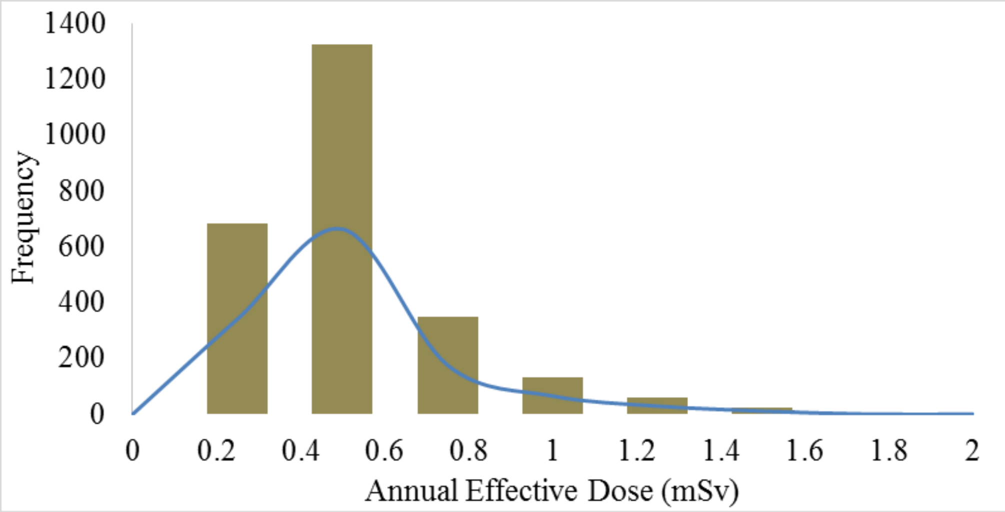

Figure 6: Frequency of the annual effective dose for all workers combined during 2018–2021 with the normal distribution curve.

Table 4: Comparative analysis of effective doses in diagnostic radiology different national hospitals and countries [1, 6, 19, 21-27].

Countries	Time period	Average effective dose (mSv)
South Korea	2012-2013	1.80
Pakistan	2003-2007	1.47
Ghana	2000-2009	1.05
Kuwait	2008-2009	1.05
United Arab Emirates	2002–2016	0.53
Pakistan	2007-2011	0.52
World UNSCEAR		1.34
National studies:		
Asser region, Saudi Arabia	2018-2019	1.4
MOH hospitals, Saudi Arabia	2015–2019	0.88
University hospital of KAU, KSA	2009-2010	0.66
King Fahad Medical City, KSA	2018–2019	0.53
Current study	2018-2021	0.39

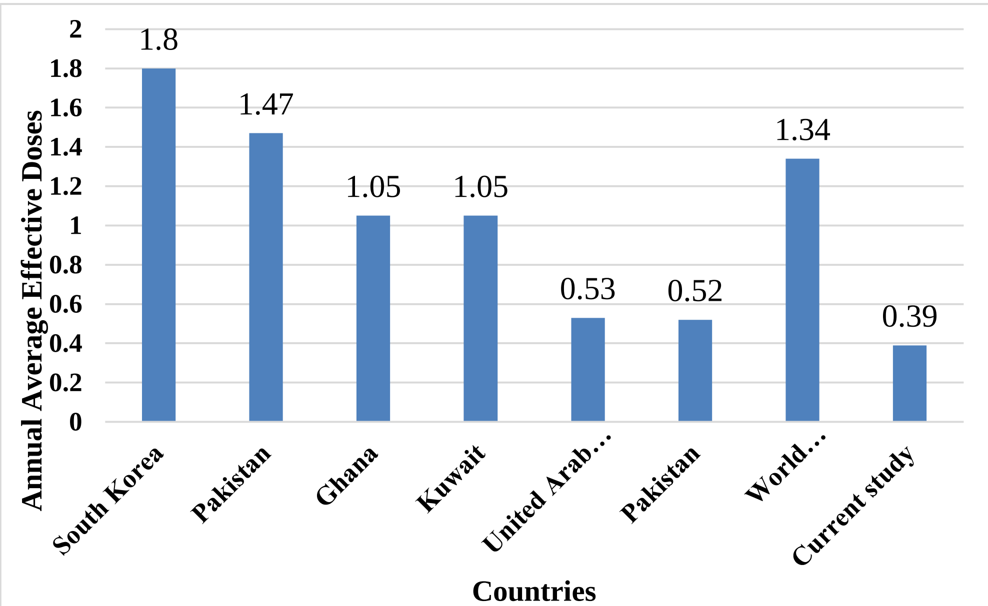

Figure 7: Comparing our study result with previous study in another countries.

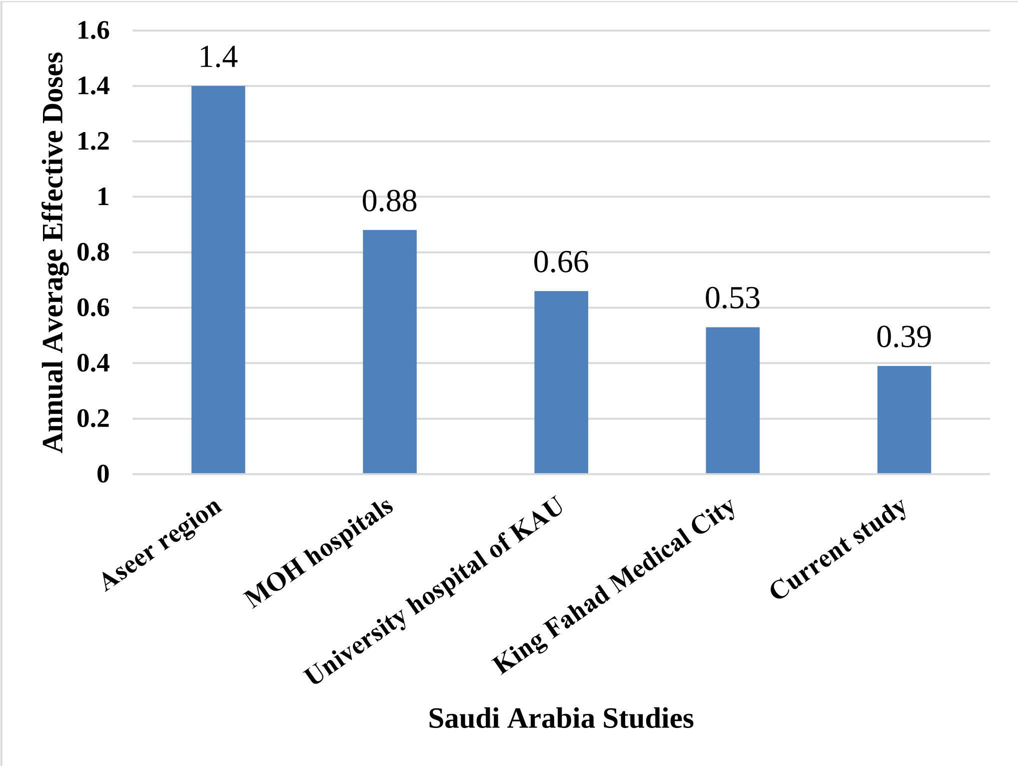

Figure 8: Comparing our study result with previous study in Saudi Arabia.

CONCLUSION

The radiation protection program carried out at KFMC was effective due to correctly applying the international recommended regulations. The study results concludes that the occupational radiation doses to all workers during the four years period were significantly below the limits set by the ICRP recommendations. The measured annual effective doses for workers were found to be 0.39 mSv. For future work, a study of the equivalent dose for the skin, hands, feet, and lens of the eye would offer a comprehensive overview for the radiation safety practices in KFMC.

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REFERENCE

1. Nassef, M. H., & Kinsara, A. A. (2017). Occupational radiation dose for medical workers at a university hospital. J Taibah University for Science, 11(6), 1259–1266.
2. Bercovich, E., & Javitt, M. C. (2018). Medical imaging: from roentgen to the digital revolution, and beyond. Rambam Maimonides Medical Journal, 9(4).
3. Mollura, D. J., Culp, M. P., & Lungren, M. P. (2019). Radiology in Global Health (D. J. Mollura, M. P. Culp, & M. P. Lungren, Eds.). Springer International Publishing. https://doi.org/10.1007/978-3-319-98485-8.
4. Beaton, L., Bandula, S., Gaze, M. N., & Sharma, R. A. (2019). How rapid advances in

imaging are defining the future of precision radiation oncology. British Journal of Cancer, 120(8), 779–790.

5. Lee, S.-K., Kim, J. S., Yoon, S.-W., & Kim, J. M. (2020). Development of CT Effective Dose Conversion Factors from Clinical CT Examinations in the Republic of Korea. Diagnostics, 10(9), 727.
6. Alashban, Y., Shubayr, N., Almalki, M., Albeshan, S., Aldawood, S., & Aldosari, A. (2021). Assessment of radiation dose for dental workers in Saudi Arabia (2015–2019). Journal of King Saud University - Science, 33(1), 101250. https://doi.org/https://doi.org/10.1016/j.jksus.2020.101250
7. Szewczak, K., Jednoróg, S., & Krajewski, P. (2013). Individual dose monitoring of the nuclear medicine departments staff controlled by Central Laboratory for Radiological Protection. Nuclear Medicine Review, 16(2), 62–65.
8. Izewska, J., & Rajan, G. (2005). Radiation dosimeters. Radiation Oncology Physics: A Handbook for Teachers and Students, 71–99.
9. Silver, E. H., Shulman, S. D., & Rehani, M. M. (2021). Innovative monochromatic X-ray source for high quality and low dose medical imaging. Medical Physics, 48(3), 1064–1078.
10. Yearbook, S. (2020). Available online: https://www. moh. gov. sa/en/Ministry/Statistics/book. Pages/Default. Aspx (Accessed on 6 November 2019).
11. Statistical system of the MOH. (2022). Statistical system of the ministry of health. https://systems.moh.gov.sa/
12. IAEA. (2014). IAEA Safety Standards Series No. GSR Part 3-Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. International Atomic Energy Agency Vienna.
13. McEvoy, J. H. (2020). Diagnostic Exposure of Ionizing Radiation and Its Long-Term Effects. https://macsphere.mcmaster.ca/handle/11375/25462
14. Valentin, J. (2008a). The 2007 recommendations of the international commission on radiological protection. Elsevier International Commission on Radiological Protection.
15. Valentin, J. (2008b). The 2007 recommendations of the international commission on radiological protection. Elsevier International Commission on Radiological Protection.
16. Covens, P., Berus, D., Buls, N., Clerinx, P., & Vanhavere, F. (2007). Personal dose monitoring in hospitals: global assessment, critical applications and future needs. Radiation Protection Dosimetry, 124(3), 250–259.

17. Vañó, E., González, L., Guibelalde, E., Fernández, J. M., & Ten, J. I. (1998). Radiation exposure to medical staff in interventional and cardiac radiology. The British Journal of Radiology, 71(849), 954–960. https://doi.org/10.1259/bjr.71.849.10195011.
18. Zorzetto, M., Bernardi, G., Morocutti, G., & Fontanelli, A. (1997). Radiation exposure to patients and operators during diagnostic catheterization and coronary angioplasty. Catheterization and Cardiovascular Diagnosis, 40(4), 348–351. https://doi.org/https://doi.org/10.1002/(SICI)1097-0304(199704)40:4<348::AID-CCD4>3.0.CO;2-9
19. Shubayr, N., Alashban, Y., Almalki, M., Aldawood, S., & Aldosari, A. (2021). Occupational radiation exposure among diagnostic radiology workers in the Saudi ministry of health hospitals and medical centers: a five-year national retrospective study. Journal of King Saud University-Science, 33(1), 101249.
20. Alashban, Y. (2021). An assessment of occupational effective dose in several medical departments in Saudi Arabia. Journal of King Saud University - Science, 33(3), 101402. https://doi.org/https://doi.org/10.1016/j.jksus.2021.101402
21. Radiation, U. N. S. C. on the E. of A. (2008). Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2006 Report, Volume I: Report to the General Assembly, Scientific Annexes A and B. United Nations.
22. Al-Abdulsalam, A., & Brindhaban, A. (2014). Occupational radiation exposure among the staff of departments of nuclear medicine and diagnostic radiology in Kuwait. Medical Principles and Practice, 23(2), 129–133.
23. Elshami, W., Abuzaid, M., Piersson, A. D., Mira, O., AbdelHamid, M., Zheng, X., & Kawooya, M. G. (2019). Occupational dose and radiation protection practice in UAE: a retrospective cross-sectional cohort study (2002–2016). Radiation Protection Dosimetry, 187(4), 426–437.
24. Hasford, F., Owusu-Banahene, J., Otoo, F., Adu, S., Sosu, E. K., Amoako, J. K., Darko, E. O., Emi-Reynolds, G., Nani, E. K., & Boadu, M. (2012). Assessment of annual whole-body occupational radiation exposure in education, research and industrial sectors in Ghana (2000–09). Radiation Protection Dosimetry, 150(3), 350–358.
25. Jabeen, A., Munir, M., Khalil, A., Masood, M., & Akhter, P. (2010). Occupational exposure from external radiation used in medical practices in Pakistan by film badge dosimetry. Radiation Protection Dosimetry, 140(4), 396–401.

26. Johary, Y. H., Aamry, A., Albarakati, S., AlSohaim, A., Aamri, H., Tamam, N., Sulieman, A., Omer, H., Babikir, E., Khandaker, M. U., & Bradley, D. (2022). Staff radiation exposure at four radiology departments in the Aseer region of Saudi Arabia. Radiation Physics and Chemistry, 110302. https://doi.org/https://doi.org/10.1016/j.radphyschem.2022.110302
27. Kim, J., Cha, E. S., Choi, Y., & Lee, W. J. (2018). Work procedures and radiation exposure among radiologic technologists in South Korea. Radiation Protection Dosimetry, 178(4), 345–353.
28. Masood, K., Ahmad, M., Zafar, J., Haq, M. ul, Ashfaq, A., & Zafar, H. (2012). Assessment of Occupational Exposure Among Pakistani Medical Staff During 2007–2011. Australasian Physical & Engineering Sciences in Medicine, 35(3), 297–300. https://doi.org/10.1007/s13246-012-0156-y