JKAU: Eng. Sci., Vol. **34** No. 1, pp: 33 – 42 (2024 A.D.)
DOI:10.4197/Eng.34-1.3

Occupational Dose Monitoring in Interventional Radiology Department at King Abdulaziz Medical City in Jeddah (KAMC-Jeddah)

Hind Alzahrani [1], Shouq Alqahtani [1], Afnan Alghamdi [1], Mohammed Allabban[2] , Khalid Almalki [3], Ahmad Subahi [4]

1 Radiological Sciences Department, College of Applied Medical Science, King Saud Bin Abdulaziz University for Health Sciences, National Guard Health Affairs, Jeddah, Saudi Arabia
2 Radiation Safety Officer & Qualified Expert, National Guard Health Affairs, Jeddah, Saudi Arabia
3 Interventional Radiology Department, King Abdulaziz Medical City, Ministry of National Guard Health Affairs, Jeddah, Saudi Arabia
4 Basic Science Department, College of Science and Health Professions, King Saud Bin Abdulaziz University for Health Sciences, National Guard Health Affairs, Jeddah, Saudi Arabia

Abstract. Interventional Radiology (IR) is a relatively new and increasingly significant field in healthcare, offering minimally invasive procedures with shorter recovery times. However, as interventions become more complex and longer in duration, there is an increased risk of radiation exposure for medical staff. To address this, substantial efforts have been made to develop radiation protection measures and guidelines to minimize doses and ensure the safety of IR staff. Therefore, the purpose of this study is to measure the doses for IR workers and determine which workers had received the most radiation exposure, as well as map the areas in the IR department. The data were measured in the form of Equivalent doses using Optically Stimulated Luminescence (OSL) dosimeters worn under the lead apron. The methodology for collecting the data of workers' radiation doses was based on the most common procedures during the two months of data collection, which included Peripherally Inserted Central Catheter (PICC) Line, Nephrostomy, Angioplasty, Inferior Vena Cava (IVC) Filter, Arteriovenous (Av) fistulagram, Embolization, Cerebral Angiogram, and Stent Placement. The study showed that the most significant amounts of OSL doses were recorded during two procedures: Embolization and Angioplasty. In Embolization, the median of Shallow Dose Equivalent (SDE) values in mSv for Radiologists, Technologists, and Nurses were recorded as (0.0040), (0.0026), and (0.0021) respectively. In Angioplasty, the median SDE values for Radiologists, Technologists, and Nurses were (0.0033), (0.0021), and (0.0017) respectively. This indicates that Radiologists received the highest radiation dose. Additionally, mapping the procedure room of the angiography suite revealed that areas No. 1 and 5 were the most exposed to radiation, while areas No. 6, 7, 8, and 9 showed no radiation exposure at all. A better understanding of the occupational dose in Interventional Radiology was made possible by myOSL dosimeter measurements. Furthermore, several recommendations have been suggested to lower the dose for workers and maximize radiation safety and protection in the IR department.

Keywords, Interventional Radiology, Radiation dose, Procedures, OSL, EqD.

1. INTRODUCTION

Medical imaging encompasses a wide variety of procedures used to view the human body in order to diagnose, monitor, or treat medical disorders. Medical imaging procedures come in a variety of forms or modalities, each with its own set of technology and techniques. Each type of technology provides different information on the anatomical part being investigated or treated, including sickness, injury, or the efficacy of medical treatment [1]. Ionizing radiation is used to create images of the body in Computed Tomography (CT), Fluoroscopy, and Radiography (Conventional X-ray), which also includes Mammography [2]. However, when this radiation interacts with body tissues in excessive amounts, it can have serious biological effects. Radiation can impair the functioning of tissues and/or organs above certain thresholds and can cause acute effects such as skin erythema, loss of hair, radiation burns, and acute radiation syndrome [3]. These effects are more severe with greater doses and higher dosage rates, and this level of harm can be assessed by measuring the effective dose [4]. This dosage can be predicted based on the organs' radiation sensitivity and the type of irradiation [5]. Furthermore, by estimating the effective dose, the probability of stochastic effects occurrence such as cancer can be roughly determined. The duration of the irradiation and the radiation's induced effects have a direct relationship. As a result, procedures performed under the guidance of dynamic fluoroscopic imaging expose patients and medical staff to a higher dose of radiation. Procedures performed in Interventional Radiology (IR), for example, are associated with a high occupational dose, particularly in Angiography [6].

Interventional Radiology (IR) is a fairly new field that has only been around for about a half-century. Despite this, it has risen in significance and is now an essential element of any major healthcare delivery system [7-9]. In fact, when compared to surgical treatments, interventional procedures are valuable and frequently more superior therapeutic options, most probably due to their minimally invasive techniques and short recovery time compared to surgical operations [10,11]. As the field has progressed, a wider range of interventions and complex procedures with longer dynamic imaging durations have become available [5,6]. It should come as no surprise that more advanced and longer procedures consistently result in a high radiation dose for medical staff. In light of this, significant efforts have been made in recent times to advance radiation protection and minimize administered doses during interventional procedures, not only through technical advancements but also through organizational measures and tightened guidelines [11,13]. Accordingly, radiation protection and dose evaluation are important for Interventional Radiology staff [14,15].

Different dosimeters can be used to determine the equivalent dose when it comes to dose control. One of these is Conventional Optically Stimulated Luminescence (OSL) badges, which are used to calculate the accumulated effective dose by monitoring the ionizing radiation absorbed by body tissue. Many research studies on occupational radiation dose have been conducted due to the sheer importance of dose monitoring in Interventional Radiology. In a study published in 2013, researchers used a Silver-activated phosphate glass dosimeter device beneath the lead apron and another one above it. This study was notable because it indicated that in Interventional Radiology, the Radiologist was the most vulnerable worker to radiation exposure. Most of the studies on occupational radiation doses in Interventional Radiology have focused primarily on the patient and physician. There is limited data on the exposure of other medical staff, such as Nurses and Radiologic Technologists [16]. Thus, this study describes the occupational radiation dose for Interventional Radiology workers during different procedures and identifies which of them received the highest exposure level or peak value, respectively, using an OSL dose.

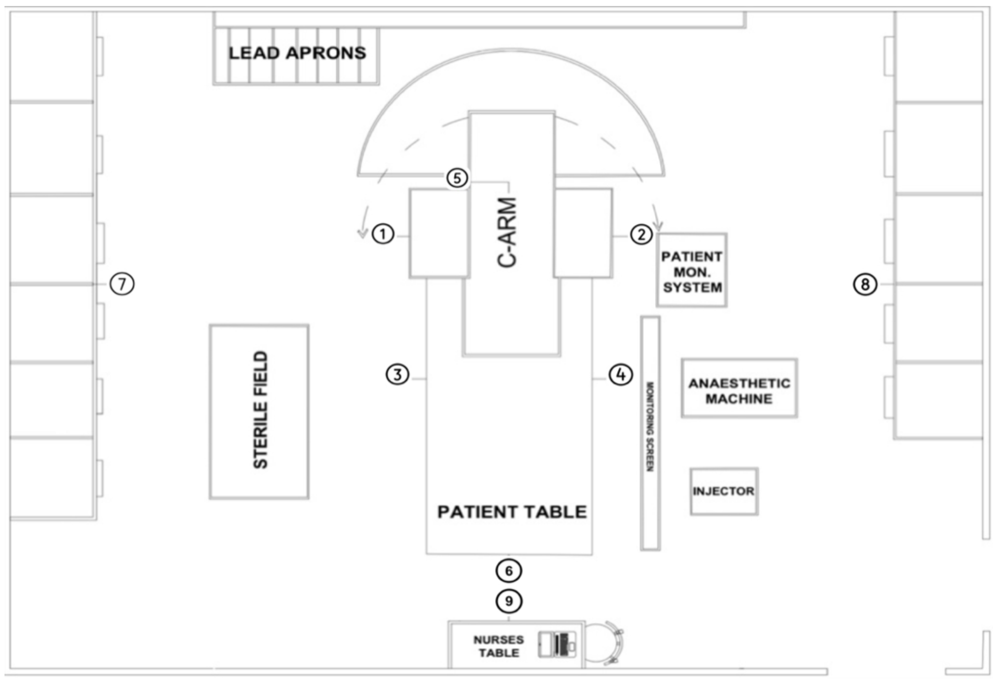

Figure.1 A sketch of the room setting in the Angiography suite in KAMC-Jeddah showing the location of OSL devices positioned to measure the radiation dose.

2. METHODOLOGY

This prospective cohort study took place in the Interventional Radiology department at KAMC, Jeddah, with a data collection period of two months. The study focused on personnel workers (Radiologists, Technologists, and Nurses) in an Angiography suite and excluded (Anesthesiologists and Interns) from participation in order to mitigate the potential for inconsistent presence during procedures, which could result in inaccurate data collection.

The study included consented healthcare workers who participated in 82 procedures, which were grouped into eight different Interventional Radiology procedures. These procedures consisted of Peripherally Inserted Central Catheter (PICC) Line, Nephrostomy, Angioplasty, Inferior Vena Cava (IVC) Filter, Arteriovenous (Av) Fistulogram, Embolization, Cerebral Angiogram, and Stent Placement procedures. The sampling technique used was non-probability convenience. Workers in the console room and patients were also excluded from the study.

In the current study, an Optically Stimulated Luminescence dosimeter (OSL) was used to measure the equivalent dose in

Interventional Radiology procedures. The OSL dosimeter has the advantage of being able to repeatedly read dose information without losing it. It is widely used by radiation workers, accounting for more than one-third of radiation workers [13]. Additionally, OSL dosimeters have high accuracy in photon detection and can measure a wide range of dosages [14].

OSL dosimeter was worn under the lead apron to measure potential occupational doses from ionizing radiation. It is important to note that the devices were worn by professionals, not by the employees themselves. For example, OSL dosimeters are to be worn by whoever is performing the procedure. Additionally, this study was conducted under the assumption that all workers followed proper radiation protection protocols by wearing a lead apron, thyroid shield, and eye lens shield.

A Kruskal-Wallis test, a non-parametric test, was used to compare two or more independent samples in order to differentiate between the Deep Dose Equivalent $H_p(10)$ (DDE) and Shallow Dose Equivalent $H_p(0.07)$ (SDE) received by workers. The test was also used to determine the difference in worker dose across different procedures. The Kruskal-Wallis test was chosen because the data were not normally distributed. A significance level of p-value <0.05 was considered. The unit of measurement used was Millie-Sievert. The median of all equivalent doses was analyzed and calculated using JMP software.

3. RESULTS

The occupational radiation dose for healthcare workers (Radiologists, Technologists, and Nurses) in 8 different procedures in the Interventional Radiology Department at KAMC-J were measured.

(Figure 2) shows that the most common IR procedures were the PICC line (26.8%) and Nephrostomy (14.6%). The frequencies of Angioplasty, IVC Filter Placement, AV Fistulogram, Embolization, Cerebral Angiogram, and Stent Placement ranged between 8.54% and 10.98% for each procedure out of a total of 82 procedures.

(Table 1) shows the Deep and Shallow Dose Equivalent results. The median DDE for Radiologists, Technologists, and Nurses was 0.0013 (IQR 0.0014), 0.0007 (IQR 0.0012), and 0.0002 (IQR 0.0007) mSv respectively. Where is the median SDE in mSv for Radiologists, Technologists, and Nurses was 0.0014 (IQR 0.0020), 0.0013 (IQR 0.0013), and 0.0009 (IQR 0.0011). Statistical analysis using the Kruskal-Wallisu test showed a significant difference between the DDE and SDE doses received by healthcare workers in different procedures (DDE p-value <0.0001*, SDE p-value 0.0015*).

(Table 2) shows that the highest OSL doses were recorded during Embolization and Angioplasty procedures, with median SDE values of (0.0040, 0.0026, 0.0021 mSv) (0.0033, 0.0021, 0.0017 mSv) for Radiologists, Technologists, and Nurses. This indicates that Radiologists received the highest radiation dose.

Table.1: A comparison of the Deep and Shallows Equivalent Doses obtained from the OSL dosimeter for the personnel working in the Angiographic suite in mSv.

Equivalent Dose	Radiologist	Technologist	Nurse	P value
	Median and IQR $x10^{-2}$			
DDE mSv	**(0.13, 0.14)**	**(0.07, 0.12)**	**(0.02, 0.07)**	**0.0001***
SDE mSv	**(0.14, 0.20)**	**(0.13, 0.13)**	**(0.09, 0.11)**	**0.0015***
Stent Placement	**0.18, 0.12**	**0.17, 0.04**	**0.11, 0.09**	**0.0530**

Statistical analysis revealed a significant difference in the highest dose received by those workers during different procedures, as determined by the Kruskal-Wallis test (p-value = 0.0102) for Angioplasty and Embolization procedures. However, there were no statistically significant differences observed for the other procedures. In the Angiography suite, nine OSL dosimeters were used with a height of 1.5 cm inside the room to create a map and identify hot spots for different procedures. (Figure 1) shows that area No. 5 was the hot spot for IVC Filter and Cerebral Angiogram procedures, while area No. 1 was the hot spot for Nephrostomy and PICC Line procedures. The remaining procedures were not mapped out.

Table.2 The doses received by workers in different procedures with OSL readings in mSv.

Procedures	Radiologist	Tech	Nurse	P value
	Median and IQR $x10^{-2}$			
PICC Line	**0.10, 0.07**	**0.05, 0.10**	**0.07, 0.07**	**0.0756**
Nephrostomy	**0.10, 0.11**	**0.08, 0.06**	**0.06, 0.11**	**0.3379**
Angioplasty	**0.33, 0.15**	**0.21, 0.20**	**0.17, 0.14**	**0.0102 ***
IVC Filter	**0.16, 0.03**	**0.15, 0.12**	**0.09, 0.09**	**0.4045**
Av Fistulogram	**0.12, 0.10**	**0.11, 0.10**	**0.07, 0.05**	**0.1713**
Embolization	**0.40, 0.06**	**0.26, 0.21**	**0.21, 0.11**	**0.0102 ***
Cerebral Angiogram	**0.29, 0.18**	**0.19, 0.12**	**0.12, 0.14**	**0.1357**

4. DISCUSSION

The results of this study showed that the highest exposure to radiation and duration time occurred during Angiography and Embolization procedures. It is important to note that the difficulty level of each procedure may contribute to the high radiation dose, and this is entirely dependent on the patient's condition. Furthermore, the readings indicated that the highest doses were received by the Radiologist, then the Technologist and the Nurse, respectively. Additionally, mapping the setting room of the angiography suite revealed that areas No. 1&5 were the most exposed to radiation, while areas No. 6, 7, 8, and 9 showed no radiation at all, making them the safest areas for the workers in the setting room.

After obtaining the measurements from the OSL devices, the readings indicated that the procedures with the highest recorded radiation dose were Angioplasty and Embolization. These are critical and complex operations that require a long time. The readings also showed that the Radiologists received the highest dose. The main reason for this is the high demand for their presence during procedures, as they are the leading operators for most procedures. Technologists received the second highest dose, and this may be due to a few reasons. First, Technologists are the Radiologists' main assistants during all procedures. Additionally, Technologists working in Angiography at KAMC are certified to perform PICC line procedures without the presence of a Radiologist. Moreover, KAMC is one of the largest Oncology centers in the western region, leading to a large number of PICC line procedures. Subsequent to mapping the room setting of the Angiography suite to determine hot spots for specific procedures using OSL dosimeters in different areas as defined in (figure 1), the readings showed that the hot spot for IVC Filter and Cerebral Angiogram procedures was area number five. This is due to the area of interest in these operations being focused on/or near the patient's head. Therefore, the hot spots for PICC Line and Nephrostomy procedures were in area number one, located right next to the C-arm detector. Most PICC Line procedures are done with right-sided insertion in the hand, which leads to fewer complications. The remaining areas, number 2, 3, and 4, received less radiation, mainly backscattered radiation. Finally, areas number 6, 7, 8, and 9 indicated that there was no radiation at all, making them the safest areas for the workers in the room.

In research published in 2013, the researchers used two OSL devices, one beneath the lead apron and one above it. That study was notable because it indicated that the Radiologist was the most prone worker to radiation exposure in Interventional Radiology, followed by the Nurse and then the Technologist [15].

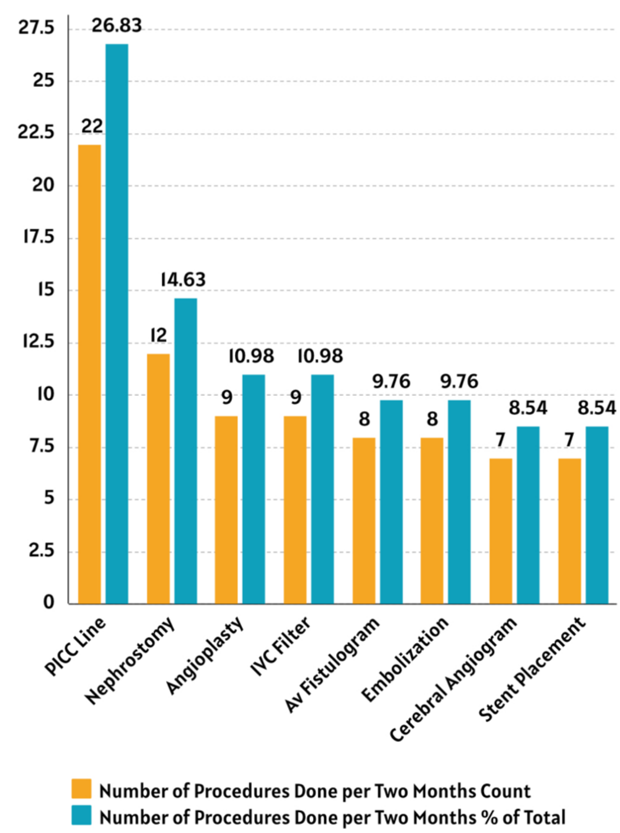

Figure.2 A frequency bar chart that indicates the most performed procedures in the Interventional Radiology department done per two months.

Similarly, in our study, after using one OSL device under the lead apron, the results showed that the Radiologist received the highest dose, respectively. However, in contrast, our findings state that the Technologist received a higher dose than the Nurse, respectively. In a research paper in 2016, the researchers used real-time devices that are worn by the Radiologist and Technologist. They obtained the data from the ten most performing procedures, and the result showed that the procedures that had the highest exposure were endovascular aortic repair (EVAR) procedures [16]. Another study published in 2018 utilized integrated dosimetry software. Transjugular Intrahepatic Portosystemic Shunt (TIPS) procedures were shown to have the highest exposure among the twelve frequently performed procedures, according to the data they collected. Contrarily, in this study, we used the OSL device worn by the Radiologist, Technologist, and Nurse to collect data from the eight most frequently performed procedures, and the results indicated that Angioplasty and Embolization procedures had higher radiation exposure [17].

The findings of this study have to be seen in light of some limitations, the first one is that our initial study compared Real-Time dosimeter to a Conventional dosimeter, but the reader of the devices was out of order and needed maintenance during the data collection period. We couldn’t wait for the dosimeter company to fix it due to the long time it would take, resulting in us changing our method to use only Conventional dosimeter. The second limitation is the insufficient sample size, especially for the mapping of the different procedures, because of time constraints. Finally, there is a lack of previous studies in this field of research, as it hasn’t progressed significantly since approximately 2013.

5. CONCLUSION

In conclusion, the measurements provided by the myOSL dosimeter offered a better understanding of the occupational dose in Angiography. According to the results, the Radiologist was the most prone worker to radiation exposure in Interventional Radiology, followed by the Technologist and then the Nurse. Therefore, we recommend changing the location of the sterile field to allow the Radiologist and Technologist performing the procedures more room for movement, as they will not be restricted to one area near the x-ray source.

Additionally, there were significant differences between the doses received by the workers in Embolization and Angioplasty procedures. We suggest that future studies compare Real-Time dosimeters to myOSL dosimeters to measure staff radiation exposure and also map the different procedures. Furthermore, to ensure greater statistical accuracy, we recommend collecting a larger sample size over a longer period of time.

6. ACKNOWLEDGMENT

Several people played an important role in accomplishing this paper. We thank Eng. Mohammed Hamdan for his assistance in providing the OSL devices. Also, we thank Dr. Alaa Althubaiti for her help through the data analysis process.

7. REFERENC1- Hussain, S., Mubeen, I., Ullah, N., Shah, S. S. U. D., Khan, B. A., Zahoor, M., Ullah, R., Khan, F. A., & Sultan, M. A., Modern Diagnostic Imaging Technique Applications and Risk Factors in the Medical Field: A Review, BioMed research international, (20222- Kasban, H., El-Bendary, M. A. M., and Salama, D. H., A comparative study of medical imaging techniques, International Journal of Information Science and Intelligent System, 4, 37-58, (2015)

3- World Health Organization, Ionizing radiation and health effects (2023), website: https://www.who.int/news-room/fact-sheets/detail/ionizing-radiation-health-effects-and-protective-measures

4- Ferrari, C., Manenti, G., & Malizia, A., Sievert or Gray: Dose Quantities and Protection Levels in Emergency Exposure, Sensors, 23, 1918, (2025- Jain, S., Radiation in medical practice & health effects of radiation: Rationale, risks, and rewards, Journal of family medicine and primary care, 10, 1520–1524, (2021)

6- Garg, T., & Shrigiriwar, A., Radiation Protection in Interventional Radiology, The Indian journal of radiology & imaging, 31, 939–945, (2022)

7- Doherty, M. G., Value of Interventional Radiology: Past, Present, and Future, Seminars in interventional radiology, 36, 26–28, (2019)

8- Baum, R. A., & Baum, S., Interventional radiology: a half century of innovation, Radiology, 273, S75–S91, (2014)

9- Charalel, R. A., McGinty, G., Brant-Zawadzki, M., Goodwin, S. C., Khilnani, N. M., Matsumoto, A. H., Min, R. J., Soares, G. M., & Cook, P. S., Interventional radiology delivers high-value health care and is an Imaging 3.0 vanguard, Journal of the American College of Radiology : JACR, 12, 501–506, (2015)

10- White, S. B., Value in Interventional Radiology: Achieving High Quality Outcomes at a Lower Cost, Radiology, 297, 482–483, (2020)11- Kaatsch, H. L., Schneider, J., Brockmann, C., Brockmann, M. A., Overhoff, D., Becker, B. V., & Waldeck, S., Radiation exposure during angiographic interventions in interventional radiology - risk and fate of advanced procedures, International journal of radiation biology, 98, 865–872, (2022)

12- Chehab, M. A., Brinjikji, W., Copelan, A., & Venkatesan, A. M., Navigational Tools for Interventional Radiology and Interventional Oncology Applications, Seminars in interventional radiology, 32, 416–427, (2015)

13- Adamus, R., Loose, R., Wucherer, M., Uder, M., & Galster, M., Strahlenschutz in der interventionellen Radiologie [Radiation protection in interventional radiology], Der Radiologe, 56, 275–281, (2016)

14- Salama, K. F., AlObireed, A., AlBagawi, M., AlSufayan, Y., & AlSerheed, M., Assessment of occupational radiation exposure among medical staff in health-care facilities in the Eastern Province, Kingdom of Saudi Arabia. Indian journal of occupational and environmental medicine, 20, 21–25, (2016)

15- Alkhorayef, M., Al-Mohammed, H. I., Mayhoub, F. H., Sulieman, A., Salah, H., Yousef, M., Alomair, O. I., & Bradley, D. A., Staff radiation dose and estimated risk in an interventional radiology department, Radiation Physics and Chemistry, 178, (2021)

16- Sailer AM, Paulis L, Vergoossen L, Kovac AO, Wijnhoven G, Schurink GWH, et al. Real-Time Patient and Staff Radiation Dose Monitoring in IR Practice. CardioVascular and Interventional Radiology, :421–9, (2016)

17- Bundy JJ, Chick JFB, Hage AN, Gemmete JJ, Srinivasa RN, Johnson EJ, et al. Contemporary Interventional Radiology Dosimetry: Analysis of 4,784 Discrete Procedures at a Single Institution. Journal of the American College of Radiology: JACR, 1214–21, (2018)

مراقبة الجرعة الإشعاعية المهنية في قسم الأشعة التداخلية في مدينة الملك عبدالعزيز الطبية في جدة

هند الزهراني [١] ، شوق القحطاني [١] ، أفنان الغامدي [١] ، محمد اللبان[٢]، خالد المالكي [٣] ، أحمد سبحي[٤]

١ قسم العلوم الإشعاعية، كلية العلوم الطبية التطبيقية، جامعة الملك سعود بن عبد العزيز للعلوم الصحية، الشؤون الصحية بالحرس الوطني، جدة، المملكة العربية السعودية.

٢ ضابط السلامة الإشعاعية وخبير مؤهل، الشؤون الصحية بالحرس الوطني، جدة، المملكة العربية السعودية.

٣ قسم الأشعة التداخلية، مدينة الملك عبد العزيز الطبية، الشؤون الصحية بالحرس الوطني، جدة، المملكة العربية السعودية.

٤ كلية العلوم والمهن الصحية، جامعة الملك سعود بن عبد العزيز للعلوم الصحية، الشؤون الصحية بالحرس الوطني، جدة، المملكة العربية السعودية.

مستخلص. تعد الأشعة التداخلية مجالًا جديدًا نسبيًا ومتزايد الأهمية في مجال الرعاية الصحية، حيث تقدم إجراءات طفيفة التوغل و فترات تعافي أقصر. ورغم ذلك، مع زيادة تعقيد التدخلات وطول مدتها، يزداد خطر تعرض الطاقم الطبي للإشعاع. ولمعالجة هذه المشكلة، تم بذل جهود كبيرة لتطوير تدابير الحماية من الإشعاع والمبادئ التوجيهية لتقليل الجرعات وضمان سلامة موظفي أقسام الأشعة التداخلية. ولذلك، فإن الغرض من هذه الدراسة هو قياس الجرعات للعاملين في مجال الأشعة التداخلية وتحديد الموظفين الذين تعرضوا لأكبر قدر من الإشعاع، بالإضافة إلى رسم خريطة إشعاعية للمناطق الموجودة في قسم الأشعة التداخلية.

تم قياس البيانات باستخدام جهاز قياس يسمى OSL و تم ارتداؤه تحت مئزر الرصاص المستخدم للحماية من الإشعاع. استندت منهجية جمع بيانات الجرعات الإشعاعية للموظفين إلى الإجراءات الأكثر شيوعًا خلال شهري جمع البيانات، والتي تضمنت القسطرة المركزية المدخلة طرفيًا، وتفويه أو فتح الكلية، وقسطرة الشريان التاجي، و فلترالوريد الأجوف السفلي، وتصوير الناسور الوريدي، وإصمام الأوعية، وتصوير الأوعية الدماغية، ووضع الدعامات.

وأظهرت الدراسة أن أعلى جرعات OSL تم تسجيلها خلال إجراءي إصمام الأوعية وقسطرة الشريان التاجي. في إجراء إصمام الأوعية، تم تسجيل متوسط قيم SDE لأطباء الأشعة والتقنيين والممرضات على أنها (٠,٠٠٤٠)،

(٠,٠٠٢٦)، و (٠,٠٠٢١) تتابعاً. و في قسطرة الشريان التاجي، كان متوسط قيم SDE لأطباء الأشعة والتقنيين والممرضات (٠,٠٠٣٣)، (٠,٠٠٢١)، و (٠,٠٠١٧) تتابعاً. يشير هذا إلى أن أطباء الأشعة تلقوا أعلى جرعة إشعاعية. بالإضافة إلى ذلك، وجدت الدراسة أن المنطقتين ١ و٥ كانت الأكثر تعرضًا للإشعاع، بينما لم تظهر المناطق ٦ و٧ و٨ و٩ أي تعرض للإشعاع على الإطلاق. أصبح الفهم الأفضل للجرعة المهنية في الأشعة التداخلية ممكنًا بفضل قياسات مقياس الجرعات myOSL. علاوة على ذلك، تم اقتراح العديد من التوصيات لخفض الجرعة للعاملين وزيادة السلامة والحماية من الإشعاع في قسم الأشعة التداخلية.