Evaluating the Radiation Dose Involved in Interventional Radiology Procedures

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Abstract**—**Radiologic interventional studies use fluoroscopy imaging guidance to perform both diagnostic and therapeutic procedures. These could result in high radiation doses being delivered to the patients and also to the radiology team. This is due to the prolonged fluoroscopy time and the large number of images taken, even when dose-minimizing techniques and modern fluoroscopic tools are applied. Hence, these procedures are part of the everyday routine of interventional radiology doctors, assistant nurses, and radiographers. Thus, it is important to estimate the radiation exposure dose they received in order to give objective advice and reduce both patient and radiology team radiation exposure dose. The aim of this study was to find out the total radiation dose reaching the radiologist and the patient during an interventional procedure, and to determine the impact of certain parameters on the patient dose. The radiation dose was measured by TLD devices (Thermoluminescent Dosimeter; radiation dosimeter device). Physicians, patients, nurses, and radiographers wore TLDs during 12 interventional radiology procedures performed in two hospitals, Mubarak and Chest Hospital. This study highlights the need for interventional radiologists to be mindful of the radiation doses received by both patients and medical staff during interventional radiology procedures. The findings emphasize the impact of factors such as fluoroscopy duration and the number of images taken on the patient dose. By raising awareness and providing insights into optimizing techniques and protective measures, this research contributes to the overall goal of reducing radiation doses and ensuring the safety of patients and medical staff.

Keywords**—**Dosimetry, radiation dose, interventional radiology procedures, patient radiation dose.

I. Introduction

INTERVENTIONAL Radiologic (IR) procedures are special procedures that involve using of image guidance methods such as fluoroscopy, MRI, Ultrasound and CT for diagnostic or therapeutic purposes. Angiography, endoscopy, venography, vertebroplasty and kyphoplasty are examples for IR. Image guidance such as endoscope, laparoscope and colonoscopies permit the physician to investigate the channels of various anatomic tubes [1]. In term of using fluoroscopy guidance, this method has many advantages such as having a good quality image and giving actual and magnified images. However, it also has few disadvantages due to its high dose and its limitation to 2D images. Because these procedures are performed under the guidance of fluoroscopy, both the radiologist and the radiologic heath team assistant are subject to radiation dose. Since, these procedures are routinely performed on daily bases, this can lead to these individuals receiving high radiation dose, Hence, to provide objective advice and guidance, different aspect in the arrangements and performance in these imaging-interventional procedures need to be evaluated.

A. Radiation Dose Effects

Ionizing radiation is characterized by having an electromagnetic wave that carries enough energy to ionize or remove electrons from an atom. The interaction of ionizing radiation and a living cell can lead to one out of three options. The cell might either die or repair the damaged part or it canny out the damage genetic part (mutated DNA) and replicate and can become cancerous. The good thing is that cells have different degrees of sensitivity to radiation, some are radiosensitive and other are radioresistant; those that are radio sensitive are characterized by being reproduced all the time and venerable to mutations such as the germ cells and those of a forming fetus [2], [3]. Thus, it is very important that anyone using or working with ionizing radiation adhere to radiation protection regulations in order to not cause any harm. All radiographers should apply the ALARA (As Low As Reasonably Achievable) principle, which aims to minimize the radiation dose to the lowest feasible level. Moreover, they should apply the cardinal principle, which includes increasing the distance between the source and the patient, using shields, wearing lead aprons of at least 0.5 mm Pb/eq, and reducing the exposure time to minimize the radiation dose [2]. In addition, the radiation field should be minimized to the region of interest and the image intensifier should be positioned as close as possible to the patient's body. Furthermore, a previous study [4] highlighted the factors that influence the patient dose during interventional procedure and indicate that if they were not considered properly, this could lead to very high radiation espouse. Some of the factors mentioned include using a fluoroscopic system that provides pulsed fluoroscopy, as compared with non-pulsed system. A system that pulses the beam at 12.5 f/s can reduce the exposure by 80% [4]. Also, avoiding the need to take another exposure to capture an image and instead saving the image during screening (frame grabbing) can help reduce the dose. Various factors may affect the dose variability, including the physician's experience, level of training in radiation protection, and the performance of the x-ray equipment [4], [5].

B. Literature Review

A clinical study conducted by Botwin et al. showed that maximizing the distance, decreasing the time, and the use of shielding is very important during fluoroscopically guided

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lumbar transforaminal epidural steroid injections [6]. Another study agreed on the importance of following the technique mentioned above in order to minimize the patient radiation dose [7]. An interesting study done by Miller and his colleagues, measured the likelihood of radiation-induced skin effects, for a variety of common interventional radiology and to identify procedures associated with a PSD greater than 2 Gy (as a dose limit). The results revealed that the peak skin dose can reach greater values, even above 3 Gy to reach 5 Gy in few instances, as a conclusion, the researcher stated that that few interventional procedures may produce a peak skin dose sufficient to cause deterministic effects in skin. And they suggested that dose data should be recorded routinely during these international procedures, and especially for head and spine embolization procedures [7]. This revealed that even if trained operators perform such a procedure and follow the dose-reducing technology, the patient can in many instances receive a radiation dose [8]. During interventional procedures that involve the using of fluoroscopy, it is recommended that the tabletop exposure rate should not exceed 10 R/min [2]. Also, as stated by the National Environment Agency, for radiation workers, the limit on the effective dose to the whole body is 20 mSv a year averaged over defined periods of 5 years. This require an additional provision which is that the effective dose shall not exceed 50 mSv in any one year [9]. For members of the public the effective dose limit to the whole body is 1 mSv per year [9].

C. Aim

The aim of this research is to measure the radiation dose for physicians, patients, nurses, and radiographers during interventional procedures and determine which parameters have a role in minimizing the patient's dose.

II. Methods

Experiments were conducted on physicians, patients, nurses and radiographers in different hospitals in Kuwait including, Mubarak and Chest hospitals. Data were obtained from several interventional procedures, mainly angiography, to ensure variation in the data. TLDs were distributed to the medical centers, and the radiology team involved in each procedure attach them to their body (4 TLDs for each procedure case). The 4 TLDs are assigned to each individual participating in the procedure, which are: physician, the nurse, the radiographer and the patient. The medical staff will place the TLD under the lead apron and in the upper chest area because this region is the nearest to the X-ray beam, while the patient TLD will be placed under the patient and in the gonads area. The type of the procedure and the time the procedure takes are written down and presented in the tables.

A. TLD

TLD stands for thermoluminescent dosimeter; it is a radiation dosimeter device, which is used for personal monitoring. When the radiation falls on a TLD, the electrons are excited and store energy. After a certain period (this can be monthly, bimonthly, quarterly or even biannual), the TLD badges are sent for reading. The TLD reader consists of a heater. On getting heated, the excited electrons again come back to the ground state and emit light which is then read by a photomultiplier (PMT) [10]. Specifically, TLD will be used in this experiment because it is the radiation detection device that is currently used in the hospitals in Kuwait. Additionally, it has scintillation crystals which are made of cesium iodide (CsI), sodium iodide (NaI), or lithium iodide (LiI), giving the device a fast response time [11].

III. Results

The values presented in Tables I-IV represent the data collected from the interventional radiology procedures performed in Mubarak Hospital. The average background radiation dose was measured. The body background dose was 86.30, 76.34 and the average skin background dose was 78.89, 75.53. The values written in the tables are after the removal of the background values. In addition, it is worth noting that few procedures were therapeutic while others a had diagnostic purpose.

TABLE I
Result for Aorta Stent Angiography Procedure (Therapeutic)

	Serial No.	Body dose (μsv)	Skin dose (μsv)
Case 1	TLD 1 (DR)	6.19	4.43
	TLD 2 (NR)	0	1.73
	TLD 3 (RT)	0	7.02
	TLD 19 (PT)	6220.76	5772.25
Time 8:16 min			

*DR: physician; *NR: nurse; *RT: radiographer; *PT: patient.

TABLE II
Result for Lower Limb Angiography Procedure (Diagnostic)

	Serial No.	Body dose (μsv)	Skin dose (μsv)
Case 2	TLD 4 (DR)	2.1	0
	TLD 5 (NR)	0	1.04
	TLD 6 (RT)	4.68	3.65
	TLD 20 (PT)	1.56	5.57
Time 14:40 min			

TABLE III
Result for Lower Limb Angiography Procedure (Therapeutic)

	Serial No.	Body dose (μsv)	Skin dose (μsv)
Case 3	TLD 7 (DR)	0	0.44
	TLD 8 (NR)	0	15.81
	TLD 9 (RT)	1.32	4.2
	TLD 21 (PT)	572.14	1139.22
Time 13:44 min			

TABLE IV
Result for Lower Limb Angiography Procedure (Therapeutic).

	Serial No.	Body dose (μsv)	Skin dose (μsv)
Case 4	TLD 10 (DR)	3.94	20.03
	TLD 11 (NR)	4.33	25.44
	TLD 12 (RT)	1.31	1.13
	TLD 22 (PT)	2374.37	1892.92
Time 1hour 40 min			

TABLE V
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (THERAPEUTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 5	TLD 13 (DR)	9.16	7.82
	TLD 14 (NR)	14.69	2.37
	TLD 15 (RT)	1.67	0
	TLD 23 (PT)	13427.23	14255.63
Time 8:20 min			

TABLE VI
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (THERAPEUTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 6	TLD 16 (DR)	1.59	4.99
	TLD 17 (NR)	0	0
	TLD 18 (RT)	4.3	0
	TLD 24 (PT)	484.9	663.69
Time 5 min			

TABLE VII
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (THERAPEUTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 7	TLD 25 (DR)	4.79	1.24
	TLD 26 (NR)	7.36	0
	TLD 27 (RT)	xxx	xxx
	TLD 43 (PT)	2027.69	1855.03
Time 4:30 min			

TABLE VIII
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (THERAPEUTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 8	TLD 28 (DR)	0	0
	TLD 29 (NR)	0	0
	TLD 30 (RT)	2.06	1.38
	TLD 44 (PT)	0	0
Time 7:26 min			

TABLE IX
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (THERAPEUTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 9	TLD 31 (DR)	8.55	15.09
	TLD 32 (NR)	5.43	3.02
	TLD 33 (RT)	1.1	0
	TLD 45 (PT)	28891.26	51145.55
Time 25 min			

TABLE X
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (THERAPEUTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 10	TLD 34 (DR)	2.47	0
	TLD 35 (NR)	14.61	10.36
	TLD 36 (RT)	1.29	0
	TLD 46 (PT)	4161.09	4926.31
Time 33 min			

TABLE XI
RESULT FOR CORONARY ANGIOGRAPHY PROCEDURE (DIAGNOSTIC)

	Serial No.	Body dose (µsv)	Skin dose (µsv)
Case 11	TLD 37 (DR)	4389.94	7292.62
	TLD 38 (NR)	0.5	1.02
	TLD 39 (RT)	0	2.33
	TLD 47 (PT)	5.49	0
Time 9:29			

*DR: physician; *NR: nurse; *RT: radiographer; *PT: patient

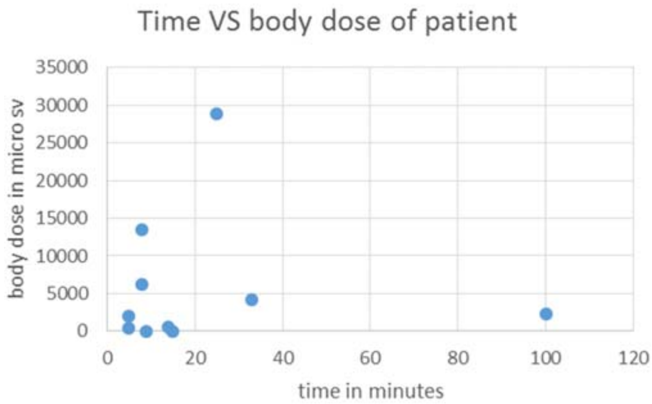

Fig. 1 Relation between the body dose and the time that a procedure will take to complete

The values presented in Tables V-XI represent the data collected for the radiation procedures performed in Chest Hospital. The average background radiation dose was measured. The body background dose was 36.12, 34.34, 37.26, 39.25 and the average skin background dose was 34.03, 30.71, 32.79, 39.11. The values written in the tables are after the removal of the background values.

IV. DISCUSSION

Based on the variation in the results and Fig. 1, it is evident that several factors influence role the dose received by both the patient and the medical team. Factors such as the duration of a procedure (time), the type of procedure (diagnostic or therapeutic), and the source-image receptor distance (SID) play significant roles. Additionally, thorough knowledge of the procedure, awareness of the radiation risks, and effective communication between the physician and the medical team contribute to creating a conducive environment for optimal performance, leading to accurate diagnostic results and improved quality of therapeutic procedures. This, in turn, reduces the time of the procedure and ultimately decreases the dose exposure.

The results show records of a body dose for the nurse and the radiographer in case 1, the nurse in case 2, the physician and the nurse in case 3, the nurse in case 6, the physician and the nurse in case 8, while the radiographer in case 11 is zero. As well as a skin dose for the physician in case 1, the radiographer in case 5, the nurse and the radiographer in case 6, the nurse in case 7, the physician and the nurse in case 8, the radiographer in case 9, the physician and the radiographer in case 10, and the patient in case 11 is zero, indicating no radiation exposure to those individuals. This can be attributed to the use of lead aprons and the considerable distance between the x-ray tube and the individuals involved in the procedure.

It is noteworthy that the radiation exposure values for the radiographer (both body and skin) were consistently lower than those for the doctor and the nurse, this is mostly (most probably). This is most likely due to the knowledge and awareness that radiographers acquire during their training programs. In contrast, doctors and nurses, who primarily focus on patient care and procedure management, may inadvertently lose track of the time and fail to realize that they are increasing their radiation dose.

As expected, results revealed that the longer the time an interventional procedure takes, the higher the radiation exposure dose. Therapeutic procedures typically take more time, resulting higher radiation exposure dose than for diagnostic procedures.

V. Conclusion

The results indicate that while time is a significant factor affecting the radiation exposure for both the patient and the medical team, other factors such as source-image receptor distance (SID), type of procedure, type of lead apron, knowledge about radiation risks, and communication between the team also play crucial roles. In addition, applying the ALARA (As Low As Reasonably Achievable) principle and wearing a good type of lead aprons is essential for minimizing radiation exposure.

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