doi:10.22100/ijhs.v10i4.1147
Original Article

IJHS 2024;10(4):23-28
ijhs.shmu.ac.ir
IJHS
International Journal of Health Studies

Study of Radiation Dose in Common Fluoroscopy Methods in Adult Patients Referred to Namazi Hospital in Shiraz during 2018-2019

Sara Doosideh[1], Rezvan Ravanfar Haghighi[2], Ahmadreza Jaam[3], Fariba Zarei[4*]

[1] Medical Imaging Research Centre, Shiraz University of Medical Sciences, Shiraz, Iran.
[2] Medical Imaging Research Centre, Shiraz University of Medical Sciences, Shiraz, Iran.
[3] Faculty of Mechanics - Shiraz University, Shiraz, Iran.
[4] Medical Imaging Research Centre, Shiraz University of Medical Sciences, Shiraz, Iran.

Received: 22 November 2024
Accepted: 21 December 2024

Abstract

Background: *The basis of the largest source of human radiation exposure is ionizing radiation used in medical and clinical sciences. This study aimed to investigate the radiation dose in common fluoroscopy methods in adult patients referred to Namazi Hospital in Shiraz in 2018.*

Methods: *This cross-sectional study was conducted on 600 adult patients (18 years and older) who were referred to Namazi Hospital in Shiraz for fluoroscopy. Data were collected using a checklist prepared from patient records, including demographic information of patients including age, gender, height, weight, and BMI, and information related to fluoroscopy including type of fluoroscopy, duration of fluoroscopy, and dose of fluoroscopy. Fluoroscopy-related data were extracted from the PACS system or manually based on the final report of each patient's file. Data were analyzed using SPSS18 software and independent t-tests, ANOVA, and Pearson correlation coefficient.*

Results: *The mean age of the patients was 48.56 ± 15.59 years (18-90 years). 36.5% were male and 63.5% were female. The mean BMI was 24.85 ± 4.87 (13.43-67.20). The most commonly used fluoroscopy method was B. SW (43.7%), followed by DEFECO (23.5%), and the least used method was RCG in only 10 patients (1.7%). The mean time of fluoroscopy was 2.08 ± 1.51 (0.1-9.60 minutes). The mean dose received in all fluoroscopy methods was 1650.42. A statistically significant relationship was observed between the dose of fluoroscopy and the duration of fluoroscopy (r=0.0403. P-value<0.001) and BMI (r=0.249, P-value<0.001), and the age of the patients had no significant relationship with the dose received in fluoroscopy (r=0.075, P-value=0.066). The difference in the mean duration of fluoroscopy based on different fluoroscopy methods was statistically significant (P-value<0.001). The difference in the mean dose of fluoroscopy based on different fluoroscopy methods was statistically significant (P-value<0.001).*

Conclusions: *In general, the results of the study showed that most fluoroscopy was performed with the barium swallow method. With increasing fluoroscopy duration and BMI, the dose received by the patient increased significantly, and the highest dose received was observed in the barium enema method and the longest fluoroscopy time was observed in the UGI method, but further and better investigation is still needed to identify the influencing factors.*

Keywords: Fluoroscopy, Radiation dose, Adult, Patients.

***Corresponding to:** F Zarei, **Email:** zareifari@sums.ac.ir

Please cite this paper as: Doosideh S, Ravanfar Haghighi R, Jaam AR, Zarei F. Investigating the Effect of Personality Traits on the Mental Health of Prisoners with the Mediation of Religiosity. Int J Health Stud 2024;10(4):23-28.

Introduction

One of the ways to diagnose and treat diseases is to use ionizing radiation. Accordingly, the largest source of human radiation exposure is ionizing radiation used in medical and clinical sciences. Studies have shown that about 3.6 billion medical radiological tests are performed worldwide annually[1]. As the name suggests, one of the important characteristics of these rays is their ability to produce ionization and excitation in the materials in their path, which may cause damage to healthy cells. Depending on the magnitude of their dose, damage from ionizing radiation can lead to definitive (high exposures in a short time) and incidental (low exposures) effects on the body. Definitive effects occur when dose levels exceed a certain limit called the threshold dose, and the severity of these effects increases with increasing dose. These effects include skin damage, hair loss, cataracts, and cardiovascular diseases. Incidental effects have no dose threshold (they can occur with any small amount of radiation exposure) and their likelihood of occurrence increases with increasing dose. However, its most important complication is an increased risk of hematological and solid malignancies. Although this risk is small, the likelihood of its occurrence increases with increasing exposure to ionizing radiation throughout a person's life[2,3].

In diagnostic radiography, the highest cumulative dose is attributed to fluoroscopy examinations. Given that in therapeutic and diagnostic imaging, it is not possible to limit radiation exposure based on clinical need, the principle of radiation protection is explained based on the justification and optimization of the dose received by patients in imaging procedures to prevent possible radiation-induced injuries.

Accordingly, standards have been established to prevent unnecessary radiation and to reduce the dose received by patients, to the extent that the diagnostic quality of the image is not impaired. Since there is no dose limit for patients exposed to radiation for diagnostic and therapeutic purposes, Determining the dose simply received by patients in various tests, including fluoroscopy (if the diagnostic quality of the images is acceptable), and comparing it with national and international diagnostic reference level (DRL) values is of great importance. Given that diagnostic reference levels of dose have not been performed for common fluoroscopy tests in adults in hospitals affiliated with Shiraz University of Medical Sciences, the purpose of this study is to determine the radiation dose in common fluoroscopy tests in adult patients who are referred to the fluoroscopy department of Namazi Hospital in Shiraz in

2018 and 2019, and to determine the local diagnostic reference level (LDRL) and compare it with the existing national and international standard DRL reference dose values to optimize (increase diagnostic quality and reduce patient dose) fluoroscopy tests.

Materials and Methods

The present study is a cross-sectional study that was conducted in a descriptive-analytical manner in 2018-2019. The study population included all adult patients (18 years and older) who had been referred for fluoroscopy (barium swallow, single and double contrast barium enema, timed barium swallow, defecography, barium meal, retrograde urethrogram, voiding cystourethrogram, distal loopogram, hysterosalpingography). In this study, all adult patients (18 years and older) who had been referred for fluoroscopy and met the inclusion criteria were surveyed in a census. The total number of patients studied in this study was 600. Inclusion criteria included all adult patients (aged 18 years or older) referred to the fluoroscopy department and excluded cumulative dose numbers in DAP units that indicated data that were much higher or much lower than the average value, and fluoroscopy that was not completed, i.e., incomplete for some reason. Also, patients whose fluoroscopy procedure took longer than normal due to inappropriate conditions were excluded from the study.

Data were collected using a checklist prepared from the patient records. This checklist consisted of two parts: the first part included demographic information of the patients including age, gender, height, weight, and BMI, and the second part included information related to fluoroscopy including type of fluoroscopy, duration of fluoroscopy, and dose of fluoroscopy. Data related to fluoroscopy were extracted from the PACS system or manually based on the final report of each patient's file. After the research plan was approved by the Vice-Chancellor of Research, Shiraz University of Medical Sciences, the necessary permits for data collection were obtained. The researchers referred to the archives department of Namazi Hospital, Shiraz, and extracted the files of patients who had undergone fluoroscopy during the study period. The fluoroscopy device used in this study belonged to Mehran Teb Company and was of the remote-control type. The image receiver in this fluoroscopic device is a flat panel direct full-field digital detector. Periodic quality control tests (such as checking the accuracy and precision of kVp, irradiation time, mAs linearity, automatic irradiation control, etc.) are performed regularly by the department physicist to check the performance of the fluoroscopic device. Calibration of the KAP or DAP meter installed on the collimator of the fluoroscopic device using the reference DAP meter is performed periodically to ensure the performance of the DAP meter of the device and determine the calibration coefficient. Image quality and image receiver performance are checked using a phantom containing suitable sections for testing low contrast, spatial resolution or high contrast, and dynamic range periodically and regularly on the fluoroscopic device. SPSS version 18 statistical software and independent t-tests and chi-square were used to analyze the data. The significance level in this study was considered to be 0.05.

Results

The mean age of the patients studied was 48.56 with a standard deviation of 15.59 years. The oldest patient was 90 and the youngest was 18 years old. Most of the patients were in the age group of 35-50 years (34%). 219 (36.5%) were male and 381 (63.5%) were female. The mean age of male patients was 51.17 with a standard deviation of 16.67 years and the mean age of female patients was 46.71 with a standard deviation of 14.64 years. This difference was statistically significant (P-value<0.001). The mean weight of the patients studied was 66.68 with a standard deviation of 13.43 kg. The heaviest patient weighed 115 and the lightest weighed 22 kg. The mean height of the patients was 163.90 cm with a standard deviation of 8.66 cm. The shortest patient was 130 cm and the tallest was 190 cm. The mean BMI was 24.85 cm with a standard deviation of 4.87 (13.67-43.20).

The highest frequency was related to patients who used the B. SW fluoroscopy method (43.7%), followed by the DEFECO method (23.5%). The lowest frequency was related to the RCG method, with only 10 (1.7%) patients undergoing fluoroscopy using this method. And then VCUG, with 2.5% performing fluoroscopy using this method. Among the patients who underwent fluoroscopy using the B. SW method, 13 patients underwent Timed barium sallow, and among the patients who underwent fluoroscopy using the B. EN method, 19 patients underwent Double-contrast Barium Enema. The mean fluoroscopy time was 2.08 with a standard deviation of 1.51 minutes (0.1-9.60 minutes). The mean fluoroscopy time in male patients was significantly longer than in female patients. Also, the fluoroscopy time in patients over 60 years of age was significantly longer than in other age groups. The results of the study also showed that the mean dose received in all fluoroscopy methods was 1650.42 ($Gy.cm^2$). The difference in the mean fluoroscopy dose based on gender and age groups did not show a statistically significant difference (Table 1).

Table 1. Difference in mean dose and duration of fluoroscopy based on gender and age groups

	Variable		Mean	S. D	Median (IQR*)	Pvalue
Fluoroscopy time	Gender	Male	2.44	1.56	2.20(1.30-3.20)	<0.001
		Female	1.87	1.44	1.50(0.8-2.50)	
	Age group	Under 35	1.89	1.53	1.50(0.8-2.50)	0.028
		35-50	1.95	1.40	1.60(0.9-2.50)	
		50-65	2.24	1.68	1.90(1.1-2.82)	
		Over 65	2.37	1.341	2.30(1.50-3)	

Fluoroscopic surface dose (Gy.cm2)	Gender	Male	17.21	19.73	10.96(6.49-22.13)	0.42
		Female	16.09	14.21	10.60(6.18-22.37)	
	Age group	Under 35	13.59	14.56	7.72 (4.26-17.39)	0.10
		35-50	17.53	15.27	11.40(6.67-24.57)	
		50-65	16.88	15.31	11.97 (6.94-22.87.)	
		Over 65	17.98	22.23	11.06(7.53-21.47)	

* Interquartile range

The highest average fluoroscopy time was related to the RCG method (3.77 minutes) followed by the B. EN method (3.52 minutes). The lowest fluoroscopy time was related to the HSG method (0.88 minutes) followed by the DEFECO fluoroscopy method (0.98 minutes). The difference in the average duration of fluoroscopy based on different fluoroscopy methods was statistically significant. The highest average fluoroscopy dose was related to the B. EN method (35.81 Gy.cm^2) followed by the DLG (distal loopogram) method (24.74 Gy.cm^2), and the lowest dose was related to the HSG method (5.94 Gy.cm^2) followed by the B. SW method (9.93 Gy.cm^2). The difference in the average fluoroscopy dose based on different fluoroscopy methods was statistically significant (Table 2).

Table 2 Difference in average dose and duration of fluoroscopy based on different fluoroscopy

Variable	Fluoroscopy method	Mean time (min)	S.D time (min)	Median (IQR*) time (min)	P-value
Time	B. SW	2.28	1.12	2.10(1.50-2.80)	<0.001
	B. EN	3.52	1.98	3.40(2-4.70)	
	DEFECO	0.98	0.69	0.90(0.55-1.20)	
	UGI	3.77	1.91	3.20(2.32-5.37)	
	RCG	2.74	2.50	2.05(0.90-3.72)	
	RUG	1.98	1.11	1.60(1.30-2.30)	
	DLG	3.29	2.08	2.80(1.50-4.95)	
	HSG	0.88	0.83	0.75(0.40-1.07)	
	VCUG	2.90	1.08	3(1.90-3.90)	
Dose	B. SW	9.92	9.45	7.54 (5.33-10.89)	<0.001
	B. EN	35.80	32.30	29.84(15.25-49.58)	
	DEFECO	22.75	13.39	19.80(13.58-27.60)	
	UGI	24.72	15.97	24.19 (10.05-33.85)	
	RCG	18.58	14.80	18.66(5.99-24.62)	
	RUG	13.89	12.19	10.53.5(7.18-15.08)	
	DLG	24.74	18.05	18.16(10.98.5-34.27)	
	HSG	5.93	7.03	4.21(2.96-6.29)	
	VCUG	23.39	16.70	18.08(10.77-35.03)	

There is a linear and direct relationship between the duration of fluoroscopy and the fluoroscopy dose (r=0.403). This observed relationship was statistically significant (P-value<0.001). There is a linear and direct relationship between BMI and fluoroscopy dose (r=0.249). This observed relationship was statistically significant (P-value<0.001). There is a linear and direct relationship between age and fluoroscopy dose (r=0.075). This observed relationship was not statistically significant (P-value=0.0 66) (Figure 1).

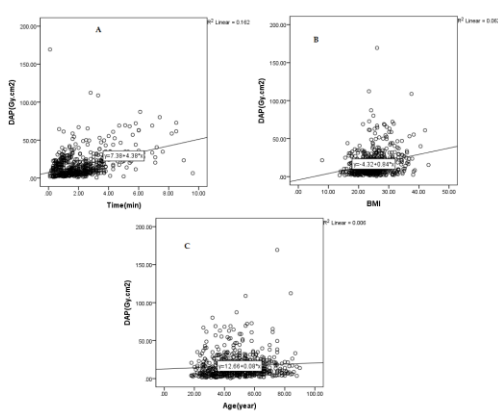

Figure 1 Distribution of surface dose (Gy.m2) of fluoroscopy based on fluoroscopy duration (minutes) (A), body mass index (BMI) (B) and age (years) (C) of patients

Discussion

Based on the results of the present study, the most frequently used fluoroscopy method was B. SW (43.7%), followed by DEFECO (23.5%). The least frequently used method was RCG, with only 10 (1.7%) patients undergoing fluoroscopy using this method. In the study by Farizwana et al[4], who performed 14 types of fluoroscopy examinations, the most commonly requested examination was HSG. Other common examinations were MCUG, Swallow Barium, and Barium Enema. In the study by Wambani et al.[5], MCU and barium meal were the most frequently used fluoroscopy methods. In our study, the higher frequency of the Swallow Barium method may be due to the high prevalence of gastrointestinal problems in Shiraz, which makes doctors prescribe this diagnostic method for them to diagnose the disease. As shown in other studies, HSG fluoroscopy is the most commonly performed procedure in women for infertility, recurrent miscarriage, post-tubal surgery evaluation, and post-cesarean uterine scar evaluation In these studies, most patients were female, which is why HSG fluoroscopy was the most commonly performed procedure[6]. The reason for the difference from other studies could be the lack of a gynecological department in the center under study (Namazi Hospital).

The results of the present study showed that the average fluoroscopy time in the present study was 2.08 minutes. It was also found that the average fluoroscopy time in male patients was significantly longer than that in female patients. The highest average fluoroscopy time was observed in patients older than 60 years, in which the average fluoroscopy time was significantly higher in this age group. In the present study, the highest average fluoroscopy time was related to the RCG method (3.77 minutes) followed by the B. EN (3.52 minutes). The lowest fluoroscopy time was related to the HSG method (0.88 minutes) followed by the DEFECO fluoroscopy method (0.98 minutes). This observed difference was statistically significant. In line with the results of the present study, Chengizi et al. showed that the average fluoroscopy time was 3.17 minutes[7]. In the study of Farizwana et al.[4], the longest fluoroscopy time was observed for barium enema and the shortest time was observed for DSG examination. In the study of Wachabauer et al. in 2010, the minimum fluoroscopy time was calculated for Swallowing (0.1 min) and the maximum for Barium enema (Double Contrast) (0.7 min)[8]. In a study conducted in a Greek hospital by Ahmed et al., the average fluoroscopy time for the same techniques was 5 and 9.7 min, respectively. This time is higher than the fluoroscopy time in the present study[9]. The staff involved in the radiology suite, especially the radiation therapist, should be aware of the duration of fluoroscopy. It is essential to keep the total fluoroscopy time as low as possible to reduce the exposure time for patients. There are policies that all fluoroscopy units should be equipped with a timer that warns the operator not to perform more than the usual amount of fluoroscopy. This time is usually 4.5 or 5 minutes[10].

According to the results of the present study, the average dose received in all fluoroscopy methods was 1650.42 µg/m^2 (16.5 Gy.cm^2). Although the dose received in male patients was higher than in female patients, this difference was not significant. Also, the highest dose received was observed in the age group over 60 years, but age did not have a significant effect on the dose received from fluoroscopy in the present study. The highest average dose of fluoroscopy was related to the B. EN method (35.8Gy.cm^2), followed by the DLG (distal loopogram) method (24.74Gy.cm^2), and the lowest dose was related to the HSG method (5.93Gy.cm^2), followed by the B. SW method (9.92Gy.cm^2). These values indicate that the surface dose (DAP or KAP) in different fluoroscopy methods is statistically significant. According to the results of Farizwana et al.[4], the highest average dose received and the lowest dose received in the DSG method were observed in barium enema examination. The higher dose received in the barium enema method may be due to the longer duration of fluoroscopy in this method. Long fluoroscopy time, especially during interventional procedures, may lead to increased patient dose, which may cause definitive radiation effects in patients[11]. A review study by Pantos, which reviewed articles over 22 years and had a large number of patients, reduced the average absorbed dose of patients, but their absorbed dose range is wide (1.1-2400), and this range can be attributed to operator experience, use of dose reduction techniques, complexity of the tests, and differences in equipment. In this study, it was found that the average dose received by the patient in studies before 200 was 52.5 Gy.cm^2 with an average time of 6.2 minutes, and for studies after 200 was 31.1 Gy.cm^2 with an average time of 7.3 minutes[12].

The higher dose received in the barium enema method may be due to the longer duration of fluoroscopy in this method. Long fluoroscopy time, especially during interventional procedures, may lead to increased patient dose, which may cause definitive radiation effects in patients[13]. A review study by Pantos, which reviewed articles over 22 years and had a large number of patients, reduced the average absorbed dose of patients, but their absorbed dose range is wide (1.1-2400), and this range can be attributed to operator experience, use of dose reduction techniques, complexity of the tests, and differences in equipment. In this study, it was found that the average dose received by the patient in studies before 200 was 52.5 Gy.cm^2 with an average time of 6.2 minutes, and for studies after 200 was 31.1 Gy.cm^2 with an average time of 7.3 minutes[14]. Fluoroscopy procedures reduce the dose to the patient and the radiation therapist[15]. According to Perry, Glaze, and Archer[16], the radiation dose generated during fluoroscopic procedures is highly dependent on the radiation therapist. However, most manufacturers install various devices on fluoroscopic equipment to help reduce the dose to personnel and patients to comply with the ALARA (as low as reasonably achievable) principle[17]. The device used in this study was dose-controlled device and did not require the presence of radiation therapists and radiologists in the fluoroscopic room (during fluoroscopy), so it can be claimed that radiation exposure to these individuals during fluoroscopy is negligible.

The results also showed that there is a significant relationship between the dose received in fluoroscopy, the duration of fluoroscopy, and the patient's BMI. So with the increase in the duration of fluoroscopy and the increase in the patients' BMI, the dose received increased significantly. It was further determined that although the dose received increased with increasing age, this increase was not statistically significant. The results of the study by Farizwana et al.[4] showed that a significant and strong relationship was observed between the dose received by an adult patient and the duration of fluoroscopy. Harbron also showed in his study that there is a significant and strong relationship between the maximum skin radiation dose (DAP) and the time of fluoroscopy, both of which are in line with the results of the present study. Koichi Chida also showed that the weight of patients also has a significant relationship with radiation dose (18). Lazarus et al.[19] in a study in New York showed that there is a limited relationship between fluoroscopy time and radiation dose level (DAP), they also suggested that this method of using fluoroscopy time is not appropriate and sufficient to investigate radiation dose level (DAP). In contrast to the results of the present study, in the study of Giovanni Bibbo et al.[20] in Australia, no statistically significant relationship was observed between surface dose and fluoroscopy time.

The present study had some limitations. One of the limitations of the study is that it was conducted in a single center. Patients referred to this center may not represent all patients requiring fluoroscopy. One of the strengths of this study was that such a study was not conducted. It is suggested that future studies examine the data of several centers. Also, due to the differences in the prevalence of diseases in different regions of Iran, it is better to compare fluoroscopy findings from different cities in future studies. Finally, it should be noted that if quality control programs (Quality Control or QC) are implemented correctly, they will have valuable results such as reducing patient radiation exposure. In general, the results of the study showed that most fluoroscopy was performed with the Swallow Barium method. Gender and age had a significant effect on the time of fluoroscopy, but did not show a significant effect on the dose received by patients. With increasing fluoroscopy time and BMI, the patient's dose received increases significantly (the duration of fluoroscopy has a significant relationship with the dose received by the patient). The highest dose received in the barium enema method and the longest fluoroscopy time belong to the UGI method. The surface dose obtained for common fluoroscopy methods in this study can be used as a local reference dose level (Local DRL) in future studies and also to optimize the dose received by patients in common fluoroscopy methods in Namazi Hospital, Shiraz.

Ethical Considerations

This article is the result of the thesis of Dr. Sara Doosideh, a radiology resident student at Shiraz University of Medical Sciences, which has been registered with the ethical code IR.SUMS.MED.REC.1399.488.

Acknowledgment

The authors would like to thank Shiraz University of Medical Sciences. This article was written without financial support.

Conflict of Interest

The authors of this article declare that they have no conflict of interest.

Funding

This article was written without financial support from the university.

References

1. Chaturvedi A, Jain V. Effect of ionizing radiation on human health. International journal of plant and environment. 2019;5(03):200-5. doi: 10.18811/ijpen.v5i03.8.

2. Radiation UNSCotEoA. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation 2014: Sixty-first Session (21-25 July 2014). 2014.

3. Baselet B, Rombouts C, Benotmane AM, Baatout S, Aerts A. Cardiovascular diseases related to ionizing radiation: The risk of low-dose exposure. International journal of molecular medicine. 2016;38(6):1623-41. doi: 10.3892/ijmm.2016.2777.

4. Ridzwan SFM, Selvarajah SE, Hamid HA. Radiation Dose Management in Fluoroscopy Procedures: Less is More? Jurnal Sains Kesihatan Malaysia. 2016;14(2):103-9. doi: 10.17576/jskm-2016-1402-12.

5. Wambani JS, Korir GK, Tries MA, Korir IK, Sakwa JM. Patient radiation exposure during general fluoroscopy examinations. Journal of applied clinical medical physics. 2014;15(2):262-70. doi: 10.1120/jacmp.v15i2.4555.

6. Watson N, Jones H. Chapman & Nakielny's Guide to Radiological Procedures E-Book: Elsevier Health Sciences; 2017.

7. Changizi V, Mianji F, Ghaderbeygizad F, Mohammadi F. Comparing cardiologists' effective dose of right and left eyes in femoral and radial angiography in a hospital in Mehran. Payavard Salamat. 2019;12(5):398-406.

8. Wachabauer D, Röthlin F, Moshammer HM, Homolka P. Diagnostic Reference Levels for conventional radiography and fluoroscopy in Austria: Results and updated National Diagnostic Reference Levels derived from a nationwide survey. European Journal of Radiology. 2019;113:135-9. doi: 10.1016/j.ejrad.2019.02.015.

9. Ahmed NA, Ibraheem S, Habbani F. Patient doses in interventional cardiology procedures in Sudan. Radiation Protection Dosimetry. 2013;153(4):425-30. doi: 10.1093/rpd/ncs119.

10. Pike S. Technical principles for diagnostic fluoroscopic procedures. 2015.

11. Rivera-Montalvo T. Diagnostic radiology dosimetry: Status and trends. Applied Radiation and Isotopes. 2016;117:74-81. doi: 10.1016/j.apradiso.2016.03.008.

12. Tsapaki V. Radiation dose in interventional cardiology. Imaging in Medicine. 2010;2(3):303. doi: 10.2217/iim.10.20.

13. Meghzifene A, Dance DR, McLean D, Kramer H-M. Dosimetry in diagnostic radiology. European Journal of Radiology. 2010;76(1):11-4. doi: 10.1016/j.ejrad.2010.06.032.

14. Leyton F, Canevaro L, Dourado A, Castello H, Bacelar A, Navarro MT, et al. Radiation risks and the importance of radiological protection in interventional cardiology: a systematic review. Revista Brasileira de Cardiologia Invasiva (English Edition). 2014;22(1):87-98. doi: 10.1016/S2214-1235(15)30184-8.

15. Sherer MAS, Visconti PJ, Ritenour ER, Kelli Haynes M. Radiation protection in medical radiography: Elsevier Health Sciences; 2013.

16. Parry R, Glaze S, Archer B. The AAPM/RSNA physics tutorial for residents-fluoroscopy: patient radiation exposure index. Radiographics. 2001;21:1033-45. doi: 10.1148/radiographics.21.4.g01jl271033.

17. Herrmann TL, Fauber TL, Gill J, Hoffman C, Orth DK, Peterson PA, et al. Best practices in digital radiography. Radiologic technology. 2012;84(1).

18. Harbron R, Dreuil S, Bernier M, Pearce M, Thierry-Chef I, Chapple C, et al. Patient radiation doses in paediatric interventional cardiology procedures: a review. Journal of Radiological Protection. 2016;36(4):R131. doi: 10.1088/0952-4746/36/4/R131.

19. Lazarus MS, Taragin BH, Malouf W, Levin TL, Nororis E, Schoenfeld AH, et al. Radiation dose monitoring in pediatric fluoroscopy: comparison of fluoroscopy time and dose-area product thresholds for identifying high-exposure cases. Pediatric radiology. 2019;49:600-8. doi: 10.1007/s00247-018-04335-8.

20. Bibbo G, Balman D, Linke R. Diagnostic reference levels for common paediatric fluoroscopic examinations performed at a dedicated paediatric Australian hospital. Journal of medical imaging and radiation oncology. 2016;60(4):469-74. doi:10.1111/1754-9485.12478