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Radiation exposure of patients and staff working in angiography and interventional radiology unit

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ABSTRACT

Catheter angiography and interventional radiologic procedures are the medical applications with the highest exposure to radiation. The projection used, in other words the irradiated region of the patient, constantly changes and the change in irradiation geometry due to the movements of the image amplifier is another important factor. Irradiation can be achieved in the form of continuous (fluoroscopic) or sequential static images (filming). In these irradiations the kVp, mA and irradiation time of the system change continuously depending on the patient thickness. The aim of this study was to determine the dose of radiation the staff working in Angiography and Interventional Radiology unit and the patients undergoing intervention were exposed to and to discuss the measures to decrease the dose of radiation. In this study, the dose values of 129 patients and three physicians and two radiotechnologists working in the unit were determined. In order to evaluate the radiation doses of the employees, radiation doses were measured with Optically Stimulated Luminescence (OSL) dosimeters over a period of six months. Doses of the patients during the procedure were measured separately. Total bimonthly and annual dose amounts were determined for the physicians as chest (collar), belt and wrist with the help of OSL dosimeters. Likewise, total bimonthly and annual dose amounts of radiotechnologists were measured as breast (neck) and belt. It was found that the duration of fluoroscopy was 2-3 times higher in radiological procedures than in diagnostic angiography and therefore the patient and radiologist were exposed to more radiation. The exposure radiation dose can be significantly decreased by reducing the number of frames per second during both fluoroscopy and filming.

1. Introduction

While the sources of radiation have negative effects on living things, the benefits it provides by its diagnostic and therapeutic use in medicine cannot be denied. X-rays used in these applications are ionizing radiation. Ionizing radiation can cause significant biological damage to living organisms. These side effects vary depending on the amount and duration of radiation exposure (Tuncel, 1994). In radiological interventions, which are applied with an increasing prevalence, both patients and practitioners are exposed to a much higher dose of radiation when compared with diagnostic tests. Particularly the complexity of radiological vascular interventions increases the duration of fluoroscopy and exposure and thus the amount of radiation to which the patient and the operator are exposed.

Therefore, with regard to radiation safety, the latest EURATOM 2013/59 directive emphasizes the obligation to record and report doses according to all radiological procedures.

The responsibilities of those who direct and perform a radiological procedure are not only limited to providing the rationale and optimization of exposure to the related procedure, but they also include providing the patient with enough information about the benefits and the risks of the procedure related with the radiation that the patient will be exposed to (European Society of Radiology, 2015).

Although the dose of the practitioner is much less than the radiation received by the patient, the total dose they are exposed to during their professional life becomes very important (Miller et al., 2003). Occupational dose limits to be exposed are set by the ICRP in publication 103 (ICRP, 2007) with the following limits: The whole body effective dose limit is 20 mSv per year over a 5-year period provided that it does not exceed 50 mSv in any year. An equivalent dose of 500 mSv per year for the extremities; an average of 500 mSv for 1 cm^2 area of skin; an equivalent dose of 20 mSv a year or 100 mSv in total for five consecutive years provided that it does not exceed 50 mSv in any year have been reported (ICRP, 2012). The purpose of the recommended limits is to avoid possible harmful effects of radiation.

The aim of this study was to determine the radiation exposure of the staff working in the "angiography and interventional radiology unit" under the influence of continuous ionizing radiation and the patients undergoing interventional procedure in this unit.

2. Materials and methods

Measurements in this study were performed in Angiography and Interventional Radiology unit. Five staff (three physicians, two radiotechnologists) and 129 patients were included in the study. Cerebral and peripheral diagnostic angiography, endovascular treatment of cerebral aneurysms, AV fistulas (CCF: caroticocavernous fistula) and AVM (arteriovenous malformation), tumor embolization procedures, and biliary interventions were performed with Artis Q DSA (Siemens, Erlangen-Germany) system. Fluoroscopy was adjusted between 65-70 kV, 40-100 mA, 3.2-8 ms, and 65-75 kV, 330-450 mA, 60-80 ms nominal doses at exposure. The filming was performed at four different speeds (1, 2, 3, 4 frames / sec) depending on the body region and organ of interest. Fluoroscopy was performed at three different speeds (30, 15, 7.5 frames / sec) and normal and low image resolution options. Optimum technical parameters (kV, mA, ms) were automatically adjusted by the exposure control system in the device. While the patient was preparing for the procedure, physicians and radiotechnologists put on 0.5 mm thick lead skirt-vest-neck collar. During the filming, there was no physician or radiologic technologist in the angiography room. During the placement of the catheter and interventional procedures, while the physicians were at the bedside, the technicians stood outside the room or inside the room away from the tube. During long-term operations, lead protectors fixed to the bed and ceiling were also placed between the tube and the physician

Exposure to scattered radiation was measured by Optically Stimulated Luminescence (OSL) dosimeters in physicians and technicians. OSL dosimeters are suitable for use in many geometric figures, they have high accuracy in photon detection, and they can measure wide range of dosages. OSL dosimeters are suitable for use in any part of the body.

For six months, physicians carried three personal OSL dosimeters of chest (collar), belt and wrist dosimeter during working hours, while radiologic technologists carried two personal OSL dosimeters of chest (collar), belt dosimeter. Apart from the radiation received due to the procedures, the dose value of the OSL dosimeter of each physician includes the background value, expressed as the natural radiation of the environment. However, since we need only the dose from the examinations, the "background" value obtained for each physician was deducted from the OSL readings used in the dosimeter and the remaining value was expressed in terms of current intensity as the dose value resulting from direct operations.

These OSL dosimeters were used for the staff and the radiation equivalent dose measurement exposed during the procedure was performed. OSL dosimeters were read in two-month periods and six-months and annual equivalent dose (mSv) results were determined for the staff.

Skin and body equivalent dose measurements and irradiation times of radiation exposure during scopy and exposure were recorded separately for the patients.

3. Results

The procedures were evaluated in two groups as therapeutic and diagnostic. The lowest scopy time was on diagnostic angiography, with an average of nine minutes per procedure.

In therapeutic interventions, the treatment of vascular pathologies such as aneurysm, arteriovenous fistula and AVM had the longest scopy duration with an average of 31 minutes, while the shortest scopy duration was 12 minutes in nonvascular procedures. The average duration of scopy was 23 minutes in therapeutic interventional procedures. The longer the scopy time, the more radiation the patient is exposed to (Table 1).

According to these data, the duration of the scopy and the radiation to which the patients are exposed during this period is very high compared to diagnostic angiography in the interventional procedures.

The fact that this patient-directed radiation is in high duration and amounts indicates that the doctors at the patient's side during the scopy were exposed to high-dose scattered radiation in the interventional procedures (Table 1).

Table 1. Average total equivalent dose amounts taken by patients by type of procedure.

Procedure	Duration (sec.)	Filming		Scopy		Duration (min.)
		Skin dose (Gycm^2)	Body dose (mGy)	Skin dose (Gycm^2)	Body dose (mGy)	
Diagnostic angiography	79	119.11	507	24.07	111	9
Aneurysm, AVM, AVF, Endovascular treatment	117	191.08	1263	67.29	910	31
Embolization procedures	113	213.75	713	114.80	640	25
Nonvascular	1	2.89	19	52.07	452	12
All interventions	77	135.90	665	78.05	667	23

Depending on the procedures performed to the patient, the equivalent dose amounts that the physician and radiotechnologist are exposed to vary depending on whether they are inside or outside the room. The proximity of the doctors to the X-tube also increases the dose received. Obviously high wrist dosimeter values confirm this because the closest part of the physician's hands during the intervention (scopy) is the hands (Table 2).

Table 2. Annual equivalent dose results of physicians and radiotechnologists (mSv).

Physician	Wrist (Annual)	Collar (annual)		Belt (annual)	
		Body	Skin	Body	Skin
I	25.82	4.58	4.49	0	0
II	40.76	0.81	2.90	0.72	3.52
III	12.53	1.82	5.81	1.56	2.94
IV	-	5.85	6.17	0.36	2.72
V	-	0.47	0.44	0.18	0.18

(Numbers I, II and III refer to physicians, IV and V to radiotechnologists.)

On the other hand, it was found that if three frames were taken instead of four frames per second, the dose received by patients decreased by 15-20%, and in the case of two frames, the dose decreased by 30-40% (Table 3).

Table 3. Dose amounts of patients taken per second according to the rate of filming.

Frame rate (frame/sec)	Skin dose per second (μGym^2)	Body dose per second (mGy)
2	138	5
3	150	7
4	178	8

4. Discussion

There are a limited number of studies evaluating the exposure states of radiology workers to ionizing radiation in our country. This study is important to determine the level of radiation exposure, whether these levels are within safety limits, and protection states of patients undergoing angiographic examination and interventional treatment and also radiology staff. In this study, equivalent dose exposure of patients and staff working in radiology unit was investigated. Three physicians, two radiologic technologists and 129 patients were included in the study. Radiology staff did not remove OSL dosimeters during the procedure. Measurement results were obtained in two-month intervals. Skin and body doses of six months and annual doses were calculated.

The diagnostic and therapeutic aspects of radiation in medicine cannot be denied. However, its damage to living organisms cannot be ruled out (Ho et al., 2002). The most important factor for radiology workers is the radiation exposure emitted by X-rays. The radiation-equivalent doses of the staff and the patients who were treated in the Angiography and Interventional Radiology unit in which the study was conducted were recorded. The amount of dose to which the patients were exposed was calculated during diagnostic angiography and therapeutic procedures. It was found that the patients were most exposed to radiation during endovascular treatment of vascular pathologies.

In endovascular treatments, the high dose rate was directly proportional to the duration of the scopy. The amount of equivalent dose taken varies depending on whether the physician and radiotechnologist were in or out of the room. The proximity of the doctors to the X-tube also increases the dose received. One of the reasons why doctors take multiple doses is the presence of complex cases that are difficult to treat. More experienced physicians performing such procedures may be effective in reducing the dose taken.

The results show that the annual dose to which physicians and radiotechnologists are exposed to in the Angiography and Interventional Radiology unit is within the permissible values. Annually maximum 6 mSv body and 6.2 mSv skin dose per employee were measured. Among physicians, the annual equivalent dose of radiation exposed to the extremities was measured as 40.76 mSv. These measured doses are well below the optimum limits. The whole body effective dose limit is 20 mSv per year over a 5-year period provided that it does not exceed 50 mSv in any year. The limits are the equivalent dose of 500 mSv per year for the extremities; the average is 500 mSv per 1 cm^2 area for the skin. As a result, physicians are exposed to more radiation in interventional procedures than diagnostic angiography procedures. In interventional procedures, the duration of the scopy is effective on the dose taken. The radiation dose to which the practitioners are exposed in the angiography room can be greatly reduced by using lead skirts under the patient table and protective lead glass separators at the tube level. On the other hand, especially in therapeutic interventions, shortening the duration of the scope as much as possible and reducing the number of frames per second, by taking into account the safety of the procedure will result in less radiation exposure to both the patient and the physician. During flouroscopy, frame rate should be selected as 10 / sec or 7.5 / sec instead of 30 / sec. As a matter of fact, in our study group, it was found that the radiation exposure decreased by 15-20% and 30-40% respectively, when the frame rate was selected as three or two instead of four per second for filming. In a similar study, it was depicted that the amount of radiation exposed decreased by about half when the "frame" rate was reduced by half (Sakai et al., 2019).

Considering the type of procedure performed by the physicians and the number of patients on whom they performed the procedure, the result of the calculations is that the most important parameters determining the amount of radiation exposed are the type of intervention and the level of simplicity/complexity of the lesion being treated. In parallel with the studies conducted, it was found in our study that the type of the procedure where the physician performing the procedure was least exposed to radiation was nonvascular (biliary) interventions (Degiorgio, 2018). However, when radiofrequency is added to the biliary procedure, the radiation dose exposed increases as the duration of the scopy increases.

In angiographic examinations and fluoroscopy-guided radiological interventions, the amount of radiation that patients and doctors are exposed to depends on factors such as fluoroscopy time and frame rate. The difficulty and complexity of the procedure, the volume of the patient and the experience of the physicians are also important in this context. In addition, the distance of the patient, physician and radiologic technologist to the X-ray tube, the use of lead protections and other variables that reduce the dose intake should be indicated.

In this study, radiation doses exposed by physicians and radiologic technologists in different procedures are presented. It was observed that the doses physicians and radiologic technologists were exposed to did not exceed the ICRP dose limits. Since radiologists and technicians are mainly exposed to radiation during fluoroscopy, reducing the frame rate during fluoroscopy and filming will reduce radiation exposure by half or even more.

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