

## Statistical Analysis of Occupational Radiation Exposure in Interventional Radiology

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### ABSTRACT

**AIM:** The occupational radiation exposure in interventional radiology is hypothetically one of the highest in the medical field. In our medical center multiple specialized interventions are performed including: endoscopy, lithotripsy, orthopedic surgery, vascular, neurological and cardiac catheterization. Analysis of the occupational doses obtained from eleven different monitored groups performing cardiac and non-cardiac fluoroscopically guided procedures are reported.

**MATERIALS AND METHODS:** In this work a statistical analysis was performed on the available data from the occupation radiation dosimetry program during the past five years from 2015 to 2019 at a tertiary care medical Centre. The radiation doses were measured using both optically stimulated dosimetry (OSL) and thermo-

luminescence dosimetry (TLD).

**RESULTS:** The total number of monitored staff was 281. The average dose for the 5 years review period in this study was  $0.29 \pm 0.05$  mSv with maximum doses of 1.43 mSv. The occupational dosimetry system has a minimal detection limit of 0.1 mSv. Comparisons with the internationally published data are discussed.

**CONCLUSIONS:** The reported occupational doses in interventional radiology including fluoroscopically guided procedures was well below the ICRP recommended annual dose limit of 20 mSv. The obtained results are in agreement with internationally reported studies and current trends. The medical use of x-ray imaging during interventional procedures is a safe practice for all categories of involved personnel when adherence to the basic radiation protection methods are closely observed.

**Key words:** Occupational dose; Interventional radiology; Radiation dose; Statistical analysis

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### INTRODUCTION

The number of procedures utilizing image guided noninvasive interventions is increasing, therefore attention must be paid to closely monitor both patients and staff radiation doses as results of that increase. Strict application of radiation protection measures plays an important role in ensuring that occupational exposures will remain below the regulated annual limits for radiation workers. During the last decade the number, complexity and variety of interventions using fluoroscopy guidance has increased. Radiation protection regulations requires routine monitoring of radiation doses received by all staff involved in interventional procedures using fluoroscopy guidance.

Interventional medical radiation workers represent an understudied population worldwide<sup>[1]</sup>, although they receive relatively higher occupational radiation doses than others. Therefore careful

monitoring of their radiation exposures is warranted.

In this work we have analyzed the radiation exposure data of the interventional radiology groups in our medical institution for the years from 2015 to 2019 inclusively.

## METHODS

The personal staff data analyzed are measured radiation dose equivalent values:  $H_p(10)$  which is the radiation dose equivalent received by tissues located at body depth of 10 mm and  $H_p(0.07)$  is for tissues located at depth of 0.07 mm, or commonly known as deep and shallow dose respectively. The doses are measured by personal radiation dosimeters placed under the lead apron. The detection limit is 0.1 mSv. For the lens of the eye dose the recommended quantity is the  $H_p(3)$  estimating a depth of 3 mm and is normally measured using a suitable dosimeter.  $H_p(0.07)$  from a dosimeter worn over the apron can be used as an acceptable approximation for the equivalent eye lens dose when placed near the collar.

All statistical analysis were conducted using the Matlab Statistical and Machine Learning Toolbox (R2016b).

## RESULTS

Table 1 has the summary of the results for eleven groups monitored in this study. In our institution the average annual radiation dose for nursing staff working in the cardiac catheterization laboratory (CathLab) has decreased from 0.74 mSv in 2015 to 0.22 mSv in 2019. the same finding was observed in a recent study from south Korea<sup>[1]</sup>. The same conclusion can also be observed for cardiologists and technologist for the same period from 2015 to 2019 see table 1.

The constant decrease in radiation exposure levels in interventional radiology are due to many factors such as advances in equipment technology, improved radiation protection skills, more use of protective devices such as leaded drapes and ceiling suspended leaded screens. Good radiation protection educational programs.

The little differences in the averaged occupational doses observed among various monitored groups in our medical city (Figure 1) seems

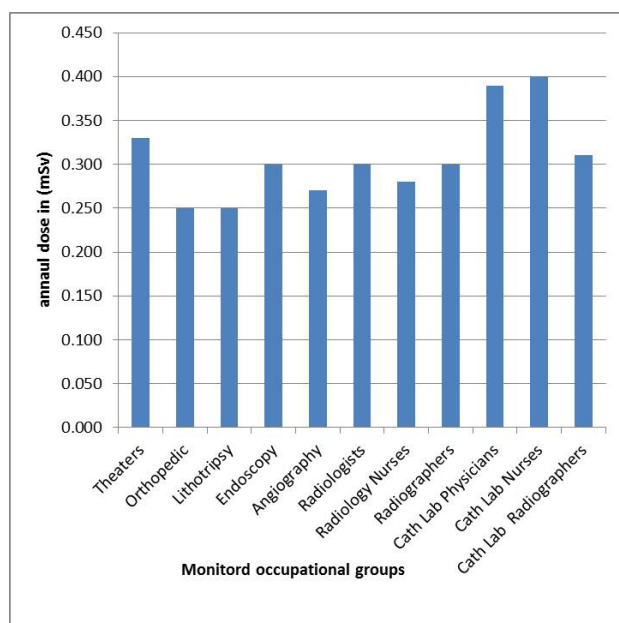


Figure 1 Summary of the monitored groups included in this study showing little differences in the average radiation dose over a period of five years demonstrating good applied radiation protection practices in every application.

to indicated constancy and regularity in the radiation protection practices in the institution as a whole; the main practice was the use of leaded protective devices. The same observations seems also to allocate less importance to the existing differences in the clinical workload, fluoroscopy time and image acquisition modes. Although in the Sanchez, 2012 study, no correlation was found between the workload declared by the radiologists and the average monthly under-apron and extremity readings. This tends to prove that it is possible to protect oneself from scatter radiation and receive minimal doses even when performing a high number of procedures<sup>[2]</sup>.

When good radiation protection measures are applied in interventional radiology the observed differences among the monitored groups such as nurses, technologists and physicians will remain small (Figure 2). A deeper analysis involving multiple variables such as: the number and complexity of the procedures, and the experience of the practitioner is required in order to reveal the potential causes of the small observed differences.

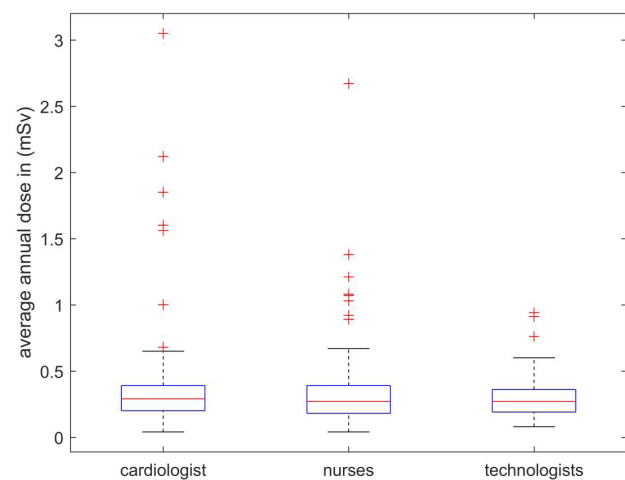


Figure 2 Boxplot for the cardiac catheterization laboratory (CathLab) staff groups. The figure shows higher registered occupational dose for the cardiologist group followed by the nurses and the technologists (see Table 1). The radiation doses for the nurses are more skewed than the other two groups because the red middle line in the box representing the median is not centered in the box, it is actually closer to the bottom line of the box. The upper and lower lines of the box are representing the 75th percentile and the 25th percentile respectively. the red + signs shows outliers data defined as values extending beyond the whiskers length. An outlier is a value that is more than 1.5 times the interquartile range away from the top or bottom of the box.

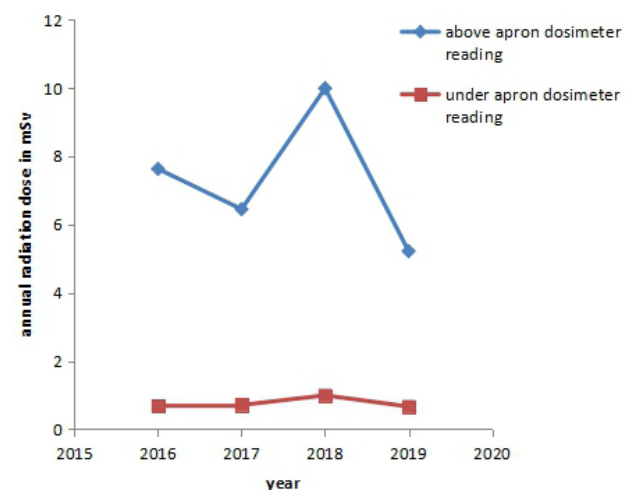


Figure 3 Reading of whole body dosimeters above and under the lead apron for one staff cardiologist

**Table 1** Occupational dose statistics in terms of number of staff monitored and the average, median maximum, minimum and standard deviation of the annual radiation doses for the period from 2015 to 2019 per occupational group of workers in (mSv).

Group	Number monitored staff	average	Standard deviation	Median	Maximum	Minimum
Theaters	18	0.33	0.07	0.34	0.41	0.14
Orthopedic	19	0.25	0.18	0.22	0.97	0.1
Lithotripsy	15	0.25	0.05	0.26	0.34	0.14
Endoscopy	29	0.3	0.12	0.36	0.48	0.1
Angiography	17	0.27	0.17	0.24	0.51	0.06
Radiologists	39	0.3	0.17	0.34	0.76	0.04
Radiology Nurses	30	0.28	0.16	0.33	0.62	0.04
Radiographers	114	0.3	0.14	0.32	0.67	0.04
Cath Lab Physicians	19	0.39	0.31	0.3	1.41	0.1
Cath Lab Nurses	28	0.4	0.28	0.34	1.43	0.11
Cath Lab Radiographers	34	0.31	0.1	0.3	0.62	0.14

Despite the variability of the measured radiation dose rates measured around the fluoroscopy machines used in interventional radiology with the clinical procedures performed; acceptable levels of occupational radiation exposures can be achieved by applying radiation protection recommendations.

In order to verify the effectiveness of the personal leaded aprons used by clinicians in the cardiac center one busy staff has been monitored using two badges one was placed over the apron near the neck area to estimate the dose to the skin and the eyes and the other badge was placed under the apron. The monitoring period was five years; the results of the two badges are shown in figure 3. Routine use of the lead aprons reduced the staff dose by 90% as expected. In fact the average radiation dose reduction calculated over five years was 89%. The under apron badge recorded 11% of the dose values recorded by the over apron badge. Therefore the use of personal leaded aprons is very efficient and powerful method for dose reduction in interventional radiology.

## DISCUSSION

The level of occupational exposure (OE) in interventional radiology (IR) depends on a certain number of factors. The clinical workload or the number of procedures performed by the staff member during the year for example is the most important factor to consider when analyzing occupational dosimetry data. The radiation protection habits and staff education in radiation protection applied principles are another factors directly affecting the level of occupational exposure to radiation.

Clinical staff experience and the complexity and number of procedures performed are also important factors to consider in future studies aiming at radiation dose analysis. In order to reduce the bias introduced by the above mentioned factors affecting the levels of OE in IR, averaging is essentially important to be considered and should be applied on the data especially when specific information is missing or difficult to obtain in the case of retrospective study like this one.

The use of ceiling -suspended protective screens are often used in most IR practice worldwide but not necessarily everywhere in the world. The use of over-apron dosimeter is recommended by the international commission on radiological protection (ICRP), the cardiovascular and interventional radiology society of Europe (CIRSE) and the society of interventional radiology (SIR)<sup>[3]</sup>, but most professionals do not use them as recommended; as matter of fact in our institution we recommend the use of under-apron OSL or TLD personal dosimeters to staff in our personal dosimetry program.

The interventionalists eye dose has gained recent attention due to the adoption of ICRP of annual dose limit of 20 mSv to the lens of the eye<sup>[4]</sup>.

Comprehensive occupational dosimetry programs in IR may include eye and extremity doses monitoring using special personal dosimeters distributed to targeted staff members. In special circumstances' the use of published studies reporting ways to estimate eye, skin and thyroid doses also acceptable means of occupational radiation risk analysis<sup>[5-6]</sup>.

The NCRP:184 report stating that many procedures such as abscess drainage, tissue biopsy, arthrograms and central venous line insertions for which fluoroscopy previously was the main imaging method now only use minimal or no fluoroscopy and diagnostic imaging is now done by CT, ultrasound and magnetic resonance imaging (MRI). This change in technique has resulted in a substantial reduction from 12 to 4 million procedures between 2006 and 2016 in the number of non-cardiac interventional fluoroscopy procedures. Also the average individual effective dose received per patient was reduced from 0.2 to 0.12 mSv during the same period; concerning the cardiac interventional fluoroscopy procedures the total number of procedures remained constant around 4 million procedures and the individual effective dose received per patient was reduced from 0.23 to 0.13 mSv<sup>[7]</sup>.

The average occupational dose in interventional radiology in Croatia was 0.66 mSv in 2000-2002 monitoring period according to the UNSCEAR 2008 report<sup>[8]</sup>. In the Czech republic it was 0.74, 0.13 in Denmark, 0.54 in Greece and 0.29 mSv in the Netherlands. And more recently in the United Arab Emirates they have reported a mean annual effective dose of 0.38 to 0.62 mSv per worker in radiology and cardiology<sup>[9]</sup>. We can see that the data obtained in this study is in agreement with the international trends<sup>[10]</sup>.

## CONCLUSIONS

The reported occupational doses in interventional radiology including fluoroscopically guided procedures was well below the ICRP recommended annual dose limit of 20 mSv. The obtained results are in agreement with internationally reported studies and current trends. The medical use of x-ray imaging during interventional procedures is a safe practice for all categories of involved personnel when close adherence to basic radiation protection methods are observed.

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