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MEDICAL PHYSICS in the BALTIC STATES 2025

PROCEEDINGS OF THE 17th INTERNATIONAL CONFERENCE ON *MEDICAL PHYSICS*

6-8 November, 2025
Kaunas, Lithuania

ISSN 1822-5721

KAUNAS UNIVERSITY OF TECHNOLOGY

MEDICAL PHYSICS IN THE BALTIC STATES

Proceedings of the 17th International Conference on Medical Physics

Kaunas, Lithuania
6 – 8 November, 2025

Executive editor **Diana Adlienė**

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MEDICAL PHYSICS IN THE BALTIC STATES 17 (2025)

Proceedings of International Conference "Medical Physics 2025"
06-08 November 2025, Kaunas, Lithuania

COMPARATIVE STUDY OF OCCUPATIONAL RADIATION EXPOSURE DURING COMMON FLUOROSCOPY AND ANGIOGRAPHY PROCEDURES

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***Abstract*:** Medical personnel performing fluoroscopy and angiography procedures are routinely exposed to ionizing radiation. To ensure effective radiation protection in the workplace, it is essential to identify procedures associated with the highest occupational exposure doses and perform optimization. This study aimed to compare occupational exposure doses received by workers performing different fluoroscopy and angiography procedures and to identify dose optimization means.

Keywords: Occupational Exposure; Radiation Protection; Fluoroscopy; Angiography

1. Introduction

The use of medical imaging has significantly increased due to changes in demographics, and improvements in healthcare delivery. Consequently, medical personnel may experience higher occupational radiation doses as a result of increased workload, which could raise their long-term risk of developing cataracts and radiation-induced malignancies [1].

The usage of fluoroscopy and angiography techniques has become an important part of modern medicine, that includes different medical specialties such as gastroenterology, interventional radiology/oncology, and orthopaedics. Even though these procedures demonstrate great therapeutic and diagnostic benefits, healthcare workers still experience a health risk from the use of ionizing radiation [2].

Ionizing radiation doses to workers depends on multiple factors, including procedure type, duration, anatomical region, C-arm angulation, staff positioning and behavior in operating room, and the use of personal protective equipment [3].

To evaluate $H_p(10)$ doses, passive dosimetry, such as optically stimulated luminescence (OSL) or thermoluminescent (TL) dosimeters is routinely implemented in clinical practice. While this method reliably provides cumulative dose, it does not inform workers about real-time exposure or procedure-specific risks, and these methods are further limited by high uncertainty and a relatively high minimum detectable dose [4]. Therefore, it is important to gain a deeper understanding of dose variations across different procedure types and anatomical regions.

The aim of this study was to compare exposure doses received by workers performing orthopaedical trauma, endoscopic retrograde cholangiopancreatography and radioembolization with Ho-166 procedures.

2. Methods and materials

The study was conducted at Vilnius University Hospital Santaros Klinikos during the period from 2024 to 2025.

Occupational radiation doses $H_p(10)$ to physicians and radiology technologists were collected during fluoroscopic and angiographic procedures: orthopaedical trauma surgery, endoscopic retrograde cholangiopancreatography (ERCP), and radioembolization with Ho-166. Additionally, to further evaluate ionizing radiation exposure doses in orthopaedical procedures, they were subdivided into 5 anatomical regions: shoulder/humerus, forearm/wrist/hand, hip/pelvis, knee/tibia, and ankle/foot (Fig. 1).

During orthopaedical trauma procedures, fluoroscopy is used to guide fracture reduction and implant positioning [5], with the C-arm operated by the radiology technologist. During an ERCP procedure, the guidewire is inserted onto the common bile duct using a C-arm. Afterwards a catheter is placed for contrast injection so as the physician could obtain visualization of the biliary and pancreatic ducts in real time. During this procedure, C-arm is operated by a radiology technologist [6]. Radioembolization with Ho-166 is performed with an angiography system under catheter guidance by the interventional radiologist, while the radiology technologist assists in the preparation and injection of Ho-166 microspheres. This type of procedure is performed to treat hepatic cancer [7].

To evaluate personal dose equivalent Hp(10) doses, DMC 3000 active personal dosimeters (APD) by Mirion Technologies were used, worn at chest level over personal radiation protective equipment. The dimensions of the dosimeter were 87 x 60 x 21 mm, and the dose equivalent range was 0.1 µSv to 10 Sv. All dosimeters have been metrologically verified by the Vilnius Metrology Centre.

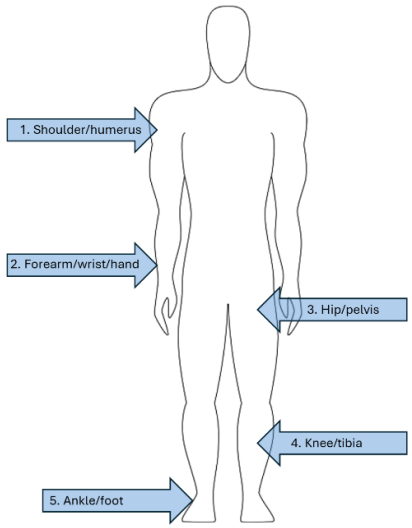

Fig. 1. Anatomical regions of orthopaedical procedures.

Additionally, to assess the correlation between personnel dose and examination parameters, data such as dose area product (DAP), air kerma, and fluoroscopy time were collected.

During orthopaedical and ERCP procedures, fluoroscopy was performed using Philips Healthcare BV Endura (manufactured in 2015) and OEC Elite C-arm (manufactured in 2020) units, whereas radioembolization procedures were carried out with a Philips Healthcare Azurion 7 Cath lab system (manufactured in 2020).

Statistical analysis was calculated using R environment (RStudio version 2025.05.1+513) with Rcmdr package. The Shapiro-Wilk test was used to assess the normality of continuous variables. Since occupational radiation dose values were not normally distributed, results are presented as median with interquartile range (IQR). Comparisons between physician and radiology technologist doses within each procedure group were performed using the Wilcoxon signed-rank test. To compare the radiation doses obtained during different types of procedures, the Kruskal–Wallis test was performed. A p-value <0.05 was considered statistically significant.

3. Results and discussion

The results of physician and radiology technologist doses, as well as DAP, fluoroscopy time, and air kerma, are summarized in Table 1. The highest radiation physician doses were received during radioembolization with Ho-166 (median 27.1 µSv, IQR 11.9-29.2 µSv), meanwhile the doses during ERCP and orthopaedical procedures were substantially lower, resulting in 4.2 (IQR 3.5-4.6 µSv) and 0.9 (IQR 0.4-2.6) µSv, respectively. Also, a Kruskal–Wallis test showed a statistically significant difference in physician radiation doses across procedure types ($p < 0.001$). The highest exposure doses in interventional radiologists during radioembolization can be explained by the combined use of X-rays and additional irradiation from Ho-166 radionuclides, resulting in two distinct sources of exposure. During this type of procedure, interventional radiologists are mainly exposed to scattered radiation from fluoroscopy, meanwhile radiology technologists receive a relatively higher doses from Ho-166 due to their involvement in preparing, handling radioactive microspheres and related materials.

Comparing the occupational exposure distribution of radiology technologists, the same pattern as for physicians was observed: the highest doses were recorded during radioembolization with Ho-166 (median 11.9 µSv, IQR 5.3-13.3 µSv), followed by ERCP (median 0.4 µSv, IQR 0.2-0.5 µSv), and orthopaedical procedures (median 0.1 µSv, IQR 0.0-0.2 µSv).

Analyzing examination parameters also showed that radioembolization with Ho-166 had the highest values, requiring significantly longer fluoroscopy times (median 276 seconds), higher DAP values (median 17.59 Gy·cm², Fig. 2) and more air kerma (median 167.00 mGy) than ERCP (median 62 s, 0.65 Gy·cm², 3.19 mGy), and orthopaedical procedures (median 16 s, 0.09 Gy·cm², 0.21 mGy).

Across all procedure types, the median occupational radiation doses for physicians were significantly higher than those for radiology technologists ($p < 0.001$; see Fig. 3).

The median dose for orthopaedical procedures was 0.9 µSv for physicians compared to for technologists (0.1 µSv), for ERCP - 4.2 versus 0.4 µSv, and for radioembolization with Ho-166 - 27.1 versus 11.9 µSv. Depending on the procedure type, physicians generally received doses that were up to 10 times higher than those given to radiology technologists. This consistent difference can be explained by the fact that during procedures, physicians are closer to the patient and X-ray source, whereas technologists are generally positioned at a greater distance, resulting in substantially lower exposure.

Figure 4 presents the comparison of physician doses across different anatomical regions. To maintain readability, two extreme outliers found in the orthopaedical hip/pelvis procedures (39.3 and 37.5 µSv) were not included in the boxplot visualization, however, the statistical analysis included their values.

In comparison between different orthopaedical procedures, the highest median doses for physicians were found to be during hip/pelvis operations (median 2.5 µSv). Lower median doses were recorded for knee/tibia, forearm/wrist/hand, ankle/foot, and shoulder/humerus procedures (1.2, 0.6, 0.6, and 0.6 µSv, respectively).

According to the results shown in Figure 4, the hip/pelvis anatomical region group showed the broadest distribution of physician doses, suggesting a wide range of exposures. The differences in case complexity, body anatomy, surgical time, and other factors that have a profound effect on fluoroscopy consumption can each account for this variability.

Table 1. Occupational radiation doses and examination parameters during different fluoroscopic/angiographic procedures

Procedure / Region (number of procedures)	Physician dose (µSv)		Radiology technologist dose (µSv)		DAP (Gy·cm²)	Fluoroscopy time (s)	Air kerma (mGy)
	Median (IQR)	Min-max	Median (IQR)	Min-max	Median (IQR)		
Orthopaedical, total (71)	0.9 (0.4-2.6)	0.1-39.3	0.1 (0.0-0.2)	0.0-0.9	0.09 (0.05-0.28)	16 (9-42)	0.21 (0.11-1.03)
– Shoulder/Humerus (8)	0.6 (0.3-1.2)	0.0-9.0	0.1 (0.0-0.2)	0.0-0.3	0.09 (0.04-0.10)	7 (2-13)	0.20 (0.20-0.33)
– Forearm/Wrist/ Hand (13)	0.6 (0.3-0.9)	0.2-3.1	0.1 (0.0-0.1)	0.0-0.3	0.05 (0.04-0.07)	14 (10-23)	0.12 (0.09-0.16)
– Hip/Pelvis (25)	2.5 (1.4-7.1)	0.1-39.3	0.1 (0.1-0.3)	0.0-0.8	0.34 (0.16-0.71)	33 (21-56)	1.70 (0.88-2.30)
– Knee/Tibia (7)	1.2 (0.5-2.5)	0.1-2.8	0.1 (0.1-0.4)	0.0-0.9	0.11 (0.06-0.41)	70 (35-76)	0.72 (0.33-0.93)
– Ankle/Foot (18)	0.6 (0.2-0.9)	0.1-4.2	0.1 (0.0-0.1)	0.0-0.3	0.06 (0.04-0.08	10 (6-17)	0.13 (0.10-0.17)
ERCP (7)	4.2 (3.5-4.6)	2.1-5.5	0.4 (0.2-0.5)	0.0-0.5	0.65 (0.55-0.97)	62 (57-69)	3.19 (2.44-3.76)
Radioembolization (Ho-166, 13)	27.1 (11.9-29.2)	5.1-105.6	11.9 (5.3-13.3)	2.0-27.9	17.59 (9.47-19.1)	276 (204-372)	167.00 (85.60-233.00)

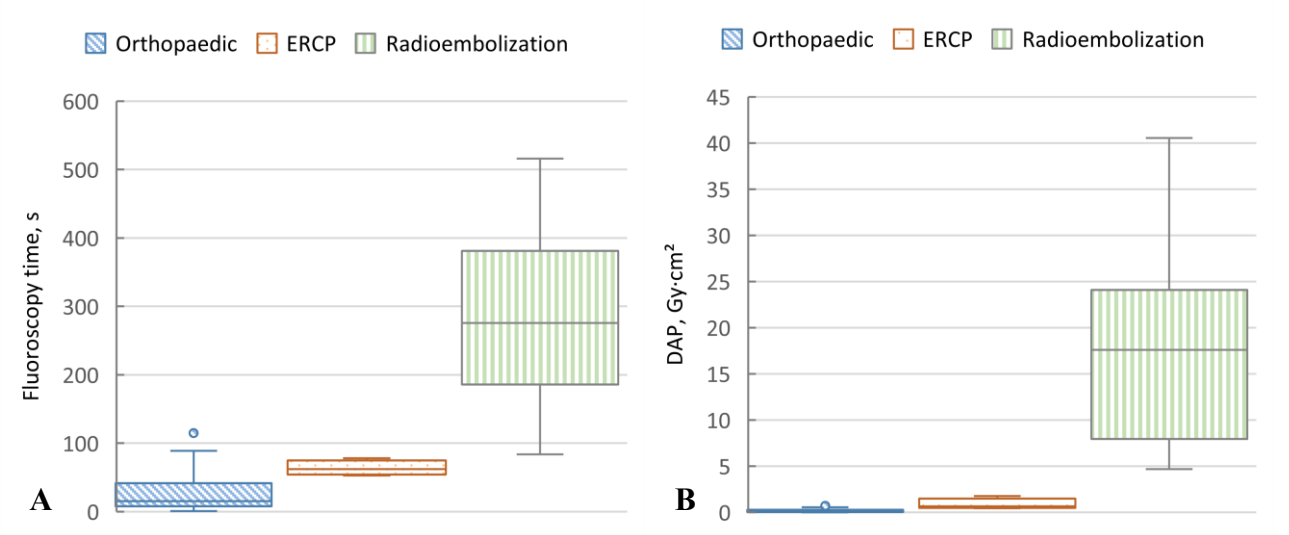

Fig. 2. Comparison of fluoroscopy time (A) and DAP values (B) across orthopaedical, ERCP and radioembolization procedures

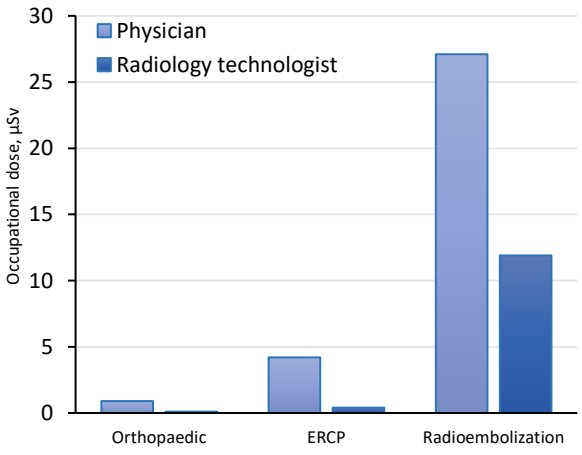

Fig. 3. Comparison of median doses between physicians and radiology technologists across different procedures

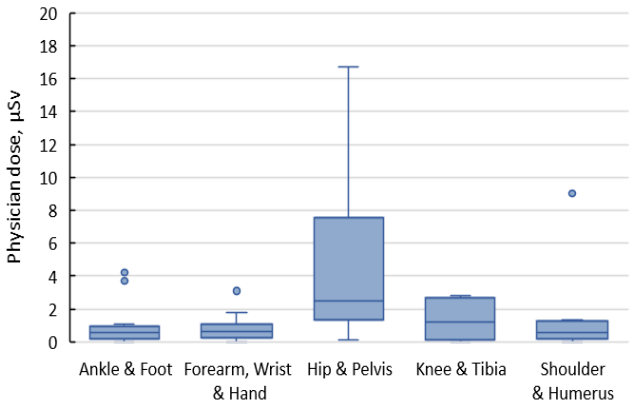

Fig. 4. Comparison of physician doses across different orthopaedical procedures

Evaluation of the doses of radiology technologists during different orthopaedical procedures were found to be low, with a median of 0.1 μSv across all anatomical regions. The highest doses were found during knee/tibia and hip/pelvis operations (maximum values 0.9 and 0.8, respectively), however during majority of procedures no measurable dose was detected, with the dosimeters frequently recording values of zero.

4. Conclusions

Occupational ionizing radiation exposure doses were found to differ between procedure types and anatomical regions. The highest doses were received during radioembolization with Ho-166, while ERCP and orthopaedical procedures resulted in much lower exposure to physicians and radiology technologists. Such procedural parameters, as fluoroscopy time, DAP, and air kerma, closely mirrored this distribution, demonstrating that more complex and prolonged interventions result in higher doses to personnel.

Based on these results, it is indicated that monitoring and protective measures should be adapted to the specificity and characteristics of radiological procedure. A better understanding of these factors can lead to the application of more effective strategies aimed at reducing occupational exposure in clinical practice and this data can also be used for dose prediction and to further improvement of radiation safety.

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