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Original Article

Assessment of Radiation Dose Levels Associated with C-Arm Fluoroscopy in Orthopedics and Traumatology Operating Rooms: A Technical Study on Radiation Area Monitoring

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ABSTRACT

Objective: One of the surgical teams that uses fluoroscopy most frequently during operations is the orthopedics and traumatology team. This study aims to indicate that the radiation dose decreases with distance and to stimulate awareness of radiation protection of the team through real-time measurements during fluoroscopy.

Methods: The study was carried out in the operating rooms of orthopedics and traumatology clinic between 1.08.2025 and 31.08.2025. The radiation dose emitted from the fluoroscopy during imaging in both AP and LAT positions of the X-ray tube for each case was measured with a Geiger-Müller detector at defined distances inside the room, and recorded in the data form.

Results: Real-time measurements were performed during 62 operations. Of these 62 operations, 15 were upper extremity, 39 were lower extremity and 8 were pelvis/acetabulum surgeries. A total of 3062 imaging were recorded in 62 cases, with a mean of 49 per case, and a total of 2051.54 seconds of imaging time, with a mean of 33.09 seconds per case. The measurements taken at A1, A5 and L1, L5 points which are closer to the primary source, were statistically significantly higher than the measurements taken at further distances, $p<0.05$.

Conclusion: In addition to annual and periodic radiation area monitoring of operating rooms at our institution, this study has increased awareness of the orthopedics and traumatology team through detailed, real-time measurements. The results underlined once again the importance and effectiveness of applying the distance rule as well as the use of personal shielding equipment for radiation protection.

INTRODUCTION

Shortly after Roentgen's discovery in 1895, X-rays began to be used in medical imaging. Conventional fluoroscopy and angiography were the first imaging modalities used intraoperatively.[1] Over time, the use of intraoperative fluoroscopy has enabled a significant change in surgical techniques and postoperative patient outcomes.[2]

Mobile image intensifier system (C-arm) is widely used in surgical operations, especially in orthopedic surgery, and it provides real-time imaging and accurate guidance throughout the surgical process and shortens the operation time.[3] Especially in cases conducted under the guidance of C-arm systems, it offers early recovery advantages by minimizing postoperative wounds and pain.[4] However, these devices produce artificial ionizing radiation (X-rays) and their widespread use in the diagnosis or treatment exposes healthcare workers and patients to a certain amount of radiation.[5]

Ionizing radiation has adverse biological effects on living organisms that may vary depending on the amount of exposure dose and the duration of exposure.[6,7] The biological effects of ionizing radiation depend on the type and amount of energy. To define the amount or type of radiation dose exposure due to any medical intervention we use dose units. The unit of absorbed radiation dose on biologic material is the Gray (Gy). The equivalent dose unit obtained by multiplying the absorbed dose by the biological effective quality factor of the radiation type and is used in radiation protection. The unit of equivalent dose (H) is Sievert (Sv). Effective Dose (E) defines the total risk throughout the body and for individual critical organs in Sv. Ionization in air unit is roentgen (R). It is a dosimetric concept based on the ionization ability of radiation in the air. Since we are working with X-ray, we can use the conversion for roentgen and Sievert, 100 mR/h=1 mSv/h.

The cumulative radiation dose (total exposure over time) is expressed in mSv or mSv/year. The instantaneous radiation intensity is expressed as μSv/h. Based on the measured intensity, a rough estimate of cumulative dose can be made: 1 μSv/h × 24 hours × 365 days ≈ 8.76 mSv/year. This value corresponds to continuous exposure for 24 hours a day, 365 days a year.

We are exposed to different amounts of radiation with different imaging techniques. While a normal Lung Anterior-Posterior (AP) radiograph is 0.02 mSv,[8] dose values ranging from 5.1 mSv,[9] to 10-40 mSv[10] have been reported for Lung Computerized Tomography (CT) in different studies.[11]

The National Council for Radiation Protection (NCRP) and the International Council for Radiation Protection (ICRP) announces with regular reports annual cumulative dose radiation exposure limits. Based on stocastic events effective dose limit 50 mSv at any year / 20 mSv average for five consecutive years for radiation workers and 1mSv for public.[12,13] The ICRP Limits for eye lens are reduced 150 mSv to 20 mSv by increased knowledge about the biologic hazards of the radiation.[14,15]

The use of intraoperative fluoroscopy has increased with the development of minimally invasive procedures and technology, resulting in increased radiation exposure of surgeons and operating room (OR) team.[16,17] And fluoroscopy plays an important role especially in orthopedics and spine surgery.[18]

Chou et al.[19] investigated the prevalence of cancer among female orthopedic, urological, and plastic surgeons in the United States. The study found that female orthopedic surgeons had a higher than expected prevalence of cancers that may or may not be caused by occupational exposure to ionizing radiation. Specifically, breast cancer was reported to be 2.5 times more common among female orthopedic surgeons who used fluoroscopy.

Following the intraoperative fluoroscopy-induced radiation exposure, orthopedic surgeons do not experience serious organ damage from radiation exceeding threshold values. However, ionizing radiation accumulates over a long period of time and has the effect of causing genetic mutations or various cancers.[20,21] These effects, defined as stochastic effects, are not related to the amount of radiation dose exposed.

This situation underlines the importance of radiation protection awareness and performing the operation with the least possible radiation exposure. Three basic elements defined as radiation protection principles by the ICRP-Justification, Optimization (AsLowAsReasonablyAchievable-ALARA), and Dose Limitations-must be taken into consideration in clinical management and during surgery by the surgeons and the OR team.[22]

Studies have highlighted the influence of optimizing imaging technique and working within a reasonably achievable dose, aka the ALARA principle, while using fluoroscopy during a case.[23] We can categorize the principles of fluoroscopy protection for the OR team under four headings: Distance and position (distance 'D'), duration (exposure 'E'), use of barrier (barrier 'B'), and technical features of the device (technique 'T').[24]

In the OR, the distance rule is the easiest to comply with and on of the most effective method for radiation protection, radiation decreases inversely proportional to the square of the distance. To minimize the number of scattered photons, the fluoroscopy device should be positioned appropriately and the OR team should stand on the correct side of the fluoroscopy. The X-ray tube must be under the table. When taking a lateral (LAT) image, the team should be positioned on the opposite side of the X-ray tube. With this technique, radiation scattered from the patient cannot reach us. If it is not possible to apply the distance rule during imaging, taking a position opposite the X-ray tube reduces the radiation dose we will be exposed to by up to 10 times. By increasing the distance between the X-ray tube and the patient, both the patient's dose and the team's exposure dose will decrease.[24]

The duration of radiation exposure is directly proportional to the amount of radiation to be received. Therefore, in preoperative planning, determining the location of fluoroscopy inside the OR, marking the area to be imaged on the patient's body if possible, and being familiar with the other medical images of the patient. And also keeping the last image on the screen or recording the previous images by using the technological features of the fluoroscopic device will prevent the repetition of imaging during the case.[24]

Additionally, all shielding equipment and barriers must be available in the OR and must be worn whenever fluoroscopy is used. These equipment prevent radiation exposure at different rates depending on the regions where they are used. Lead-coated (0.15 mm) glasses reduce the amount of radiation reaching the eye by 70%. It was found that exposure was reduced by 2.5 times after thyroid shielding was used. A lead apron increases protection by 16 times in the AP plane and 4 times in the LAT plane.

Lead alloy-coated gloves are difficult to use but can reduce exposure by up to 35%.[25] The question 'Did everyone wear protective clothing?' should be asked out loud before each shooting, or should be warned with a loud voice during the shooting scopy.[26]

An article titled 'Radiation Exposure in Orthopedics' published in 2020 analyzed the historical processes and research data of the use of orthopedists in the United States. The report highlighted that orthopedic surgeons should embrace the ALARA principle: To lead by taking all available precautions to protect all members of the OR from radiation exposure while performing the most appropriate procedure for patients whenever possible. Furthermore, the study suggested that orthopedic surgeons and assistants need to receive adequate training on proposed security precautions to help reduce these potential risks, the emphasis on radiation safety and protection in this context be universally included in graduate medical education.[21]

Another study conducted in the UK with orthopedics and traumatology teams highlight the lack of knowledge and awareness of radiation protection guidelines and the resulting insufficient use of personal protective equipment in procedures involving fluoroscopy. The study recommends mandatory training for all OR team. Additional suggestions for methods to increase radiation protection awareness include the use of posters in the OR, regular inspections to monitor the use of personal protective equipment, and discussion of the results in clinical management meetings. [27] Also annual periodic measurements of all OR that uses fluoroscopy is necessary for the team to observe real-time measurements during a case and be aware of the ionizing radiation.

The main purpose of the study is to record the radiation measurements taken with the Geiger Muller (GM) radiation area detector during the intraoperative fluoroscopy imaging at defined distances with different X-ray tube positions (AP / LAT) in the OR of orthopedics and traumatology clinic. Analysis of recorded radiation doses within the scope of case subgroups and fluoroscopy tube positions, determination of radiation dose levels and observation of the reduction in the dose with the distance.

The second purpose of the study is to stimulate radiation protection awareness in surgeons and OR team via real-time measurements with a GM radiation monitoring detector and to increase awareness of the existence of radiation as an invisible type of energy. As a result, to increase the implementation of radiation protection principles and radiation protection precautions during fluoroscopic imaging.

MATERIALS AND METHODS

Our study was conducted in the OR of our hospital's orthopedics and traumatology clinic using a GM radiation area monitoring detector obtained from the radiation oncology clinic. The study was carried out during workdays between 1.08.2025 and 31.08.2025; during this period, cases using fluoroscopy were observed.

The amount of radiation dose measured with GM during fluoroscopic imaging was recorded on a data collection form for each case. The Geiger Muller dose rate meter used in the measurements is NEB brand 211 model, calibration date was 2 December 2024. Doses were measured at defined distances inside the room and at different positions of fluoroscopy (AP / LAT) and recorded on the data collection form. No extra fluoroscopic imaging was performed for this study.

C-arm fluoroscopy devices used in OR are technologically advanced devices with automatic exposure control mode. With this mode, the device automatically sets the kVp and mAs values, the parameters that affect the exposure dose during imaging, taking into account patient thickness and the imaing position. High-quality images are achieved with the least possible dose exposure. This mode is used actively in all shootings. The technician also sets the child / adult mode on the device before shooting.

To obtain more analytical observation and to guide the radiation physicist performing the measurements, the defined distances were numbered and schematized on the data collection form. (Fig. 1) A data recording form has been designed for two different fluoroscopy X-ray tube positions, AP/LAT. In each case, the radiation dose measured at the defined distances and directions, and recorded on the relevant line on the dose table, Figure 1A. For AP position defined distances; A 1-3, A 2-4, A 5-8, A 6-7 were 50 cm, A9 and A10 were 100 cm from the operating table. For AP position defined distances; L 1-3, L 2-4, L 5-8, L 6-7 were 50 cm, L 9 and L 10 100 cm were from the operating table.

Parameters to be recorded: Total number of fluoroscopy imaging, total imaging time, dose values measured with GM at positions 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 on AP position of the fluoroscopy Figure 1B, dose values read with GM at positions 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 on LAT position of the fluoroscopy Figure 1C.

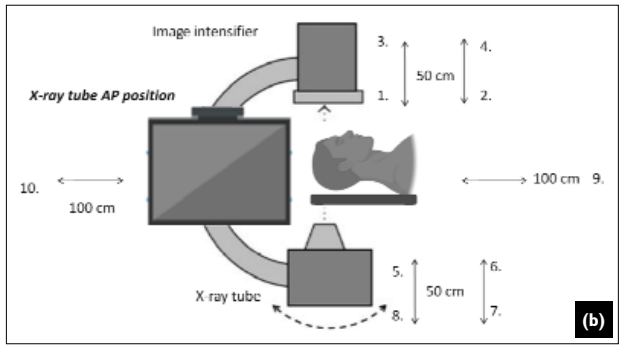
The data forms, were divided into case subgroups at the end of the observation and each case subgroup was reported individually. (Table 1) The closest distances to the primary sourse (X-ray tube), may change according to the operation side of the case, were A1-L1(represents the same point at different positions) or A5-L5 points.

Descriptive analysis was performed for mean, minimum (min) and maximum (max) values of measured dose values and recorded time data. Mean dose values at different distances of case subgroups compared via paired-sample t-test for parametric and Wilcoxon 2-related samples test for nonparametric in SPSS 27.0. The p value for statistical significance was determined as $p<0.05$.

Ethical approval for this study was obtained from Kartal Dr. Lütfi Kırdar City Hospital Ethics Committee, taken on 25.06.2025 (No: 2025/010.99/17/26), and this study was conducted in accordance with the Declaration of Helsinki.

Case No					Case Procedure					
Total Imaging Number					Total Imaging Time					
Dose at defined distances for AP position	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Dose at defined distances for LAT position	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

(a)



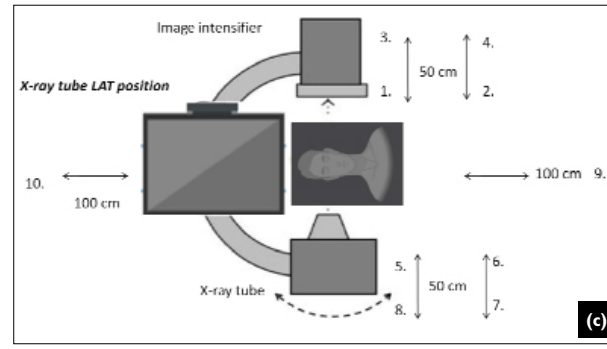


Figure 1. Data form for a single case **(a)** Table of measured radiation dose at defined points. **(b)** Defined dose distances for AP X-ray tube position. **(c)** Defined dose distances for LAT X-ray tube position.

RESULTS

Real-time measurements were performed during 62 operations in our hospital's orthopedics and traumatology OR's for 16 working days between 01.08.2025 and 30.08.2025. Of these 62 operations, 15 were upper extremity, 39 were lower extremity and 8 were pelvis/acetabulum surgeries. A total of 3062 imaging were recorded in 62 cases, with a mean of 49 imaging per case, and a total of 2051.54sec of imaging time, with a mean of 33.09sec per case. The measured dose unit with the GM detector was µR/h. We created our tables based on µSv/h for easier comparison with international annual dose limitations represented as mSv. As an example of unit conversion, 100µR/h = 1µSv/h. Background readings in operating rooms were between 4 - 12 µR/h ≈ 0,04-0,12 µSv/h.

Of the 15 upper extremity surgeries, 6 were closed reduction and pinning for pediatric supracondylar humerus fracture and 9 were open reduction and osteosynthesis with plate for distal radius fractures. In 15 upper extremity surgery cases, a total of 800 imaging were taken, with a mean of 53 imaging. The total imaging time for these 15 cases was 536.35sec, and the mean was 36.13sec. (Table 1)

Of the 39 lower extremity surgeries, 26 were in the hip region (proximal femoral nailing in 21 and dynamic hip nailing in 5), 5 were femoral nailing or biological plating, and 8 were nailing or minimally invasive plating. In 39 upper extremity surgery cases, a total of 1816 imaging were taken, with a mean of 47 imaging. The total imaging time for these 39 cases was 1217.12sec, and the mean was 31.19sec. (Table 1)

In 8 pelvis / acetabulum surgery cases, a total of 446 imaging were taken, with a mean of 56 imaging. The total imaging time for these 8 cases was 299.22sec, and the mean was 37.40sec. (Table 1)

During upper extremity surgery, fluoroscopic imaging was performed only in the AP position in 14 of 15 cases. This

Table 1. Total / mean imaging number and total / mean imaging time for case subgroups

	Upper Extremity	Lower Extermity	Pelvic Area
Number of cases	15	39	8
Total imaging	800	1816	446
Mean imaging per case	53	47	56
Min imaging / Max imaging	12 / 223	10 / 212	12 / 203
Total imaging time (sec.)	536.35	1217.12	299.22
Mean total imaging time per case (sec.)	36.13	31.19	37.40

Table 2. Mean dose values at defined distances at the AP imaging position and statistical analysis of the measurements at different distances in upper extremity cases

Defined distances for AP position	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Mean dose μSv/h	0.935	0.592	0.339	0.317	0.622	0.553	0.362	0.482	0.196	0.201
p value (comparison by distance)	A1-A3 p=0.002		A2-A4 p=0.041		A5-A8 p=0.029		A6-A7 p=0.002		A9-A10 p=0.495	
	A1-A2 p=0.047		A3-A4 p=0.198		A5-A6 p=0.078		A7-A8 p=0.910			

Table 3. Mean dose values at defined distances at the AP and ALT imaging positions and statistical analysis of the measurements at different distances in lower extremity cases

Defined distances for for AP position	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Mean dose μSv/h	0.904	0.745	0.398	0.394	0.958	0.812	0.331	0.349	0.251	0.239
p value (comparison by distance)	A1-A3 p=0.000		A2-A4 p=0.000		A5-A8 p=0.000		A6-A7 p=0.000		A9-A10 p=0.907	
	A1-A2 p=0.0367		A3-A4 p=0.070		A5-A6 p=0.049		A7-A8 p=0.260			
Defined distances for LAT position	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Mean dose μSv/h	0.929	0.733	0.386	0.400	1.184	0.902	0.429	0.909	0.239	0.235
p value (comparison by distance)	L1-L3 p=0.000		L2-L 4 p=0.000		L 5-L 8 p=0.000		L 6- L 7 p=0.000		L 9- L 10 p=0.795	
	L 1-L2 p=0.000		L 3-L 4 p=0.818		L 5-L 6 p=0.000		L 7- L 8 p=0.544			

was related to the upper extremity anatomy and surgical techniques. Dose values recorded were compared statistically, with the Wilcoxon 2-related samples test.

Measurements taken at distances close to the primary source are statistically significantly higher than measurements taken further back (50 cm) from the same point, p<0.005, except at points A9 and A10 (100 cm). Since A9-A10 are at a sufficient distance, they did not establish a statistically significant superiority over each other, p=0.495. The measurement taken at position A1 is significantly higher compared to both the more posterior position (50cm) A3 (p=0.002) and the relatively distal position (50cm) A2 (p=0.047). (Table 2)

In lower extremity surgery, both AP and LAT positioned fluoroscopy images were taken. This was related to the lower extremity anatomy and surgical techniques. Dose values recorded were compared statistically with paired-sample t-test.

Measurements taken at distances close to the primary source are statistically significantly higher than measurements taken further back from the same point in both AP and LAT fluoroscopy positions, p<0.005, except for points A9-A10 and L9-L10. Since A9-A10 and L9-L10 are at a sufficient distance, p=0.907 for AP and p=0.795 for LAT positions. (Table 3)

Also the measurement taken at position A1 is significantly higher compared to both the more posterior position A3(p=0.000) and the relatively distal position A2 (p=0.0367). The same statistical significance was observed for A5, L1 and L5 points. The A5 compared to both A8 (p=0.000) and A6 (p=0.049). The L1 compared to both L3(p=0.000) and L2 (p=0.000). The L5 compared to both L8 (p=0.000) and L6 (p=0.000). (Table 3)

In pelvis / acetabulum surgery, fluoroscopy images were taken both AP and LAT positions. This was related to the pelvic anatomy and surgical techniques. Dose values were compared statistically, with Wilcoxon 2-related samples test.

Measurements taken at distances close to the primary source are statistically significantly higher than measurements taken further back from the same point in both AP and LAT fluoroscopy positions, p<0.005, except for points A9-A10 and L9-L10. Since A9-A10 and L9-L10 at a sufficient distance, they did not establish a statistically significant superiority over each other, p=0.703 for AP and p=0.055 for LAT positions. (Table 4)

Table 4. Mean dose values at defined distances at the AP and ALT imaging positions and statistical analysis of the measurements at different distances in pelvis /acetabulum cases

Defined distances for for AP position	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Mean dose µSv/h	2.559	1.883	0.679	0.671	2.467	1.935	0.635	0.749	0.274	0.275
p value (comparison by distance)	A1-A3 p=0.012		A2-A4 p=0.012		A5-A8 p=0.012		A6-A7 p=0.012		A9-A10 p=0.703	
	A1-A2 p=0.047		A3-A4 p=0.674		A5-A6 p=0.049		A7-A8 p=0.183			
Defined distances for LAT position	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Mean dose µSv/h	5.224	3.384	2.759	1.594	2.504	2.105	1.238	1.145	0.398	0.367
p value (comparison by distance)	L1-L3 p=0.046		L2-L 4 p=0.028		L 5-L 8 p=0.028		L 6- L 7 p=0.046		L 9- L 10 p=0.055	
	L 1-L2 p=0.046		L 3-L 4 p=0.596		L 5-L 6 p=0.028		L 7- L 8 p=0.753			

Table 5. Estimated mean dose values and corresponding daily mean dose values measured at AP position distances and LAT position distances in the sum of subgroups

Defined distances for for AP position	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
Mean dose µSv/h	1.466	1.074	0.472	0.461	1.349	1.099	0.443	0.527	0.240	0.238
	0.092	0.067	0.029	0.029	0.084	0.069	0.028	0.033	0.015	0.015
Defined distances for	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**
LAT position Mean	3.077	2.058	1.573	0.997	1.844	1.504	0.833	1.027	0.319	0.301
dose µSv/h	0.192	0.129	0.098	0.062	0.115	0.094	0.052	0.064	0.019	0.018

Also the measurement taken at position A1 is significantly higher compared to both the more posterior position A3 (p=0.012) and the relatively distal position A2 (p=0.047). The same statistical significance was observed for A5, L1 and L5 points. The A5 compared to both A8 (p=0.012) and A6 (p=0.049). The L1 compared to both L3 (p=0.046) and L2 (p=0.046). The L5 compared to both L8 (p=0.028) and L6 (p=0.028). (Table 4)

The results provide evidence for the principle of distance for all case subgroups.

Mean dose values from all AP position distances and LAT position distances and corresponding daily dose values for 16 working days were estimated from the sum of all case subgroup measurements. The highest mean dose measurement per day for fluoroscopy-AP position were A1=0.092 µSv/h and A5=0.084 µSv/h. The highest mean dose measurement per day for fluoroscopy-LAT position were L1=0.192 µSv/h and L2=0.129 µSv/h. (Table 5)

For mean dose and daily mean dose values in the LAT position were higher than those in the AP position. The LAT imaging position was most commonly used in lower extremity and pelvic surgery cases, and dose data collected from these two groups were high. Because these anatomical regions are thicker thus in the LAT position, tube generates X-rays with higher penetration and energy for appropriate image quality. With this result, the relationship between the anatomical area to be imaged the exposure dose and the X-ray tube position was observed.

Another conclusion from our study results is dose reduction rate. The measurement taken at one distance and the measurement at a relatively posterior distance (50 cm) were compared and dose reduction ratios were calculated for both AP and LAT positions. The mean doses taken from Table 5, which presents the analysis of total cases. Measurements at A1, A2, A5 and A6 were 1.466 µSv/h, 1.074 µSv/h, 1.349 µSv/h and 1.099 µSv/h, respectively. And the dose reduction rates were estimated for the corresponding distances; for A1-A3 32.20%, A2-A4 42.99%, A5-A8 38.81% and A6-A7 40.37% dose reduction in 50cm. For LAT position; L1, L2, L5 and L6 were 3.077 µSv/h, 2.058 µSv/h, 1.844 µSv/h and 1.504 µSv/h, respectively. The dose reduction rates were estimated for the corresponding distances; for L1-L3 30.70%, L2-L4 48.20%, L5-L8 55.43% and L6-L7 55.33% dose reduction in 50 cm. When the distance increased by 50cm, a dose decrease between 30% and 55% was observed.

The effect of variables such as imaging technique, anatomical area, position of the X-ray tube and distance to the primary source on the radiation dose exposure is obvious with these results. Furthermore, it is crucial the apply the distance rule while using personal shielding equipment.

DISCUSSION

The biological effects of ionizing radiation are well understood; to minimize these effects and ensure a safe working environment, for the OR team, being trained in radiation protection principles and having awareness of radiation safety are a essential. While using fluoroscopy during a case, studies have emphasized the influence of optimizing imaging technique and working within a reasonably achievable dose, aka ALARA principle.[22,23]

In a study monitoring radiation emitted during C-arm fluoroscopy imaging, doses measured across a 60 cm radius from the beam center (X-ray tube) were reduced by an average of 66.3%, and doses measured at distances greater than 60 cm were less than 0.1 mSv/h in both scenarios.[5]

In our study, the average dose reduction rate was 38.60% for AP fluoroscopy position and 47.42% for LAT fluoroscopy position. Since we have compared the measurements from a 50cm distance difference, the decrease rate is lower. While the dose decreases with the square of the distance, a little distance makes a big difference. Still, our results are parallel to both the previous study and the processing principle of the distance rule. Also in our study, we observed a dose lower than 2 µSv/h at all points 50 cm away. With developing tecnology and for the better surgery / patient outcomes the use of fluoroscopy is a standart; where the focus should be on working under minimal exposure techniques and using personal protective equipment.

Besides personal awareness, institutional awareness and support on radiation protection is very important. An other study conducted in our hospital focused on determining radiation dose levels in the orthopedics and traumatology OR a decade ago. In this study 4 optically stimulated luminescence (OSL) dosimeters were used. Dosimeter-1 was placed below the foot-end of the operating table, dosimeter-2 was placed below the head-end, dosimeter-3 was placed on the wall at a height of 60 cm (200 cm from the foot end), and dosimeter-4 was placed on the wall at a height of 60cm (200 cm from the head end). Estimated daily dose values were 8.70 µSv, 6.55 µSv, 0.72 µSv and 0.50 µSv in dosimeters 1-4, respectively.[28]

According our data, highest daily mean dose at AP imaging position was 0.092 µSv/h (A1) and lowest 0.015µSv/h (A10). And highest daily mean dose at LAT imaging position was 0.192 µSv/h(L1) and lowest 0.018 µSv/h (L10). (Table 5) Relatively lower doses were observed in our measurement results.

The reason for the lower daily dose measurements in our study is the GM detector and the difference between the OSL. We would like to emphasize that the data from the GM detector, measured at defined distances, are instantaneous dose readings in µR/h. They provide a relative overview and do not represent the individual absorbed dose. Reports of personal dosimeters provide more accurate data on individual dose exposure and dose unit will be represented in mSv. Another possible explanation for the dose difference is the increased awareness of radiation protection in recent years, which may have resulted in fewer exposures, as well as the impact of technological advances in imaging.

In a radiation protection awareness study conducted with surgeons at our institution, more than half of the survey questions were answered correctly (≥50%), indicating a high level of radiation protection awareness and knowledge among our surgeons.[29] Ultimately, the orthopedics and traumatology team and the operating room staff in our hospital demonstrate a high level of radiation safety awareness, and our institution actively supports and prioritizes radiation protection and safety.

Conclusion

The use of imaging and technology is important for better surgical outcomes. The use of ionizing radiation requires the implementation of radiation protection principles and actions for a safe working environment. To provide these requirements, the theatre team needs to be educated up to date and aware of radiation safety. In addition, the dose reduction modes of the device used must be well known. Together with annual and periodic monitoring of dose levels at our institution's OR, radiation protection education is repeated systematically for work groups.

This study clearly demonstrated that radiation dose exposure decreases with distance. And the theatre team was able to observe this during real-time measurements performed, which is a strength of our study and improved radiation safety awareness. And the results underlined once again the importance of applying the distance rule as well as the use of personal shielding equipment for radiation protection.

Ethics Committee Approval

Ethical approval for this study was obtained from Kartal Dr. Lütfi Kırdar City Hospital Ethics Committee (Date: 25.06.2025, Decision No: 2025/010.99/17/26).

Informed Consent

Retrospective study.

Peer-review

Externally peer-reviewed.

Authorship Contributions

Concept: N.C., M.S.A., S.K.G.; Design: N.C., S.K.G.; Supervision: E.E., S.K.G., R.D.; Data collection &/or processing: N.C., M.S.A., E.E.; Analysis and/or interpretation: N.C., S.K.G.; Literature search: N.C., M.S.A.; Writing: N.C.; Critical review: E.E., S.K.G., R.D.

Conflict of Interest

None declared.

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Ortopedi ve Travmatoloji Ameliyathanelerinde C-Kollu Floroskopi ile İlişkili Radyasyon Doz Düzeylerinin Değerlendirilmesi: Radyasyon Alanı İzleme Üzerine Teknik Bir Çalışma

Amaç: Ameliyatlar sırasında floroskopiyi en sık kullanan cerrahi ekiplerden biri ortopedi ve travmatoloji ekibidir. Bu çalışma, floroskopi kaynaklı radyasyon dozunun mesafeyle azaldığını göstermeyi ve floroskopi çekim sırasında gerçek zamanlı ölçümler yoluyla ekibin radyasyon korunma konusunda farkındalığını artırmayı amaçlamaktadır.

Gereç ve Yöntem: Çalışma, 01.08.2025-31.08.2025 tarihleri arasında ortopedi ve travmatoloji kliniği ameliyathanelerinde gerçekleştirildi. Her olgu için X-ray tüpünün hem AP hem de LAT pozisyonlarında görüntüleme sırasında floroskopiden yayılan radyasyon dozu, oda içerisinde belirlenen mesafelerde Geiger-Müller dedektörü ile ölçülerek veri formuna kaydedildi.

Bulgular: Gerçek zamanlı ölçümler 62 operasyon sırasında gerçekleştirildi. Bu 62 operasyonun 15'i üst ekstremite, 39'u alt ekstremite ve 8'i pelvis/asetabulum cerrahisiydi. 62 vakada toplam 3062 görüntüleme alındı, vaka başına ortalama 49 görüntüleme ve toplam 2051.54 saniye görüntüleme süresi, vaka başına ortalama 33.09 saniye olarak raporlandı. Birincil kaynağa daha yakın olan A1, A5 ve L1, L5 mesafelerinden alınan ölçümler, daha uzak mesafelerde alınan ölçümlerden istatistiksel olarak anlamlı derecede yüksektir ($p<0.05$).

Sonuç: Kurumumuzdaki ameliyathanelerin yıllık ve periyodik radyasyon alanı izlemelerine ek olarak, bu çalışma sırasında ortopedi ve travmatoloji ekibinin detaylı ve gerçek zamanlı ölçümler yoluyla farkındalığı artırmıştır. Sonuçlar, radyasyondan korunmada mesafe kuralının uygulanmasının kişisel koruyucu ekipman kullanımı kadar önemli ve etkin olduğunu bir kez daha vurgulamıştır.

Anahtar Sözcükler: Ameliyathane; floroskopi; ortopedi ve travmatoloji; radyasyon doz düzeyleri.