

Exposure to ionizing radiation in orthopedic surgery residents in a referral hospital

Exposición a radiación ionizante en médicos residentes de ortopedia en un hospital de referencia

Suemmy Gaytán-Fernández, Rodolfo G. Barragan-Hervella, Jorge Quiroz-Williams*, Carlos L. Rodríguez Palacios, and Gilberto Sánchez-González

Unidad Médica de Alta Especialidad Hospital de Traumatología y Ortopedia Manuel Ávila Camacho, Instituto Mexicano del Seguro Social, Puebla, Pue., Mexico

Abstract

Objective: To describe and analyze the exposure to ionizing radiation of orthopedic residents. **Method:** A prospective study was carried out to evaluate the degree of exposure to ionizing radiation with a bandage dosimeter placed under the lead apron for medical residents for 10 months. An online survey measured the degree of knowledge about radiation safety. **Results:** 54 resident physicians participated. 55.6% report having knowledge of the existence of radiological protection equipment and 40.7% report that they had previous training in its use. 77.8% use the leaded apron and 31.5% use thyroid protection. 81.5% were positioned less than 1 meter from the source of the X-ray production of the arc in C. The total mean radiation exposure was 2.9 ± 2.17 mSv (95% confidence interval: 1.25-14.28; $p = 0.424$). **Conclusions:** Orthopedic medical residents present radiation doses below the International Commission on Radiological Protection recommended limit. However, there is a lack of knowledge of radiation protection and as well as a lack of interest and ignorance of the adverse effects of radiation.

Keywords: Ionizing radiation. Orthopaedics. Radiation safety. Protection. Medical training. Residents.

Resumen

Objetivo: Describir y analizar la exposición a radiación ionizante de los residentes de ortopedia. **Método:** Se realizó un estudio prospectivo para evaluar el grado de exposición a radiación ionizante con un dosímetro de placa colocado debajo del mandil plomado a médicos residentes, por 10 meses. Mediante una encuesta en línea se midió el grado de conocimientos sobre seguridad radiológica. **Resultados:** Participaron 54 médicos residentes. El 55.6% refiere tener conocimiento de la existencia de equipo de protección radiológica y el 40.7% refiere que tuvo entrenamiento previo en su uso. El 77.8% utiliza el mandil plomado y el 31.5% la protección tiroidea. El 81.5% se posicionó a menos de 1 metro de la fuente de producción de rayos X del arco en C. La exposición a la radiación media total fue de 2.9 ± 2.17 mSv (intervalo de confianza del 95%: 1.25-14.28; $p = 0.424$). **Conclusiones:** Los médicos residentes de ortopedia presentan dosis de radiación menores que el límite recomendado por la International Commission on Radiological Protection. Sin embargo, existe una falta de conocimientos sobre protección radiológica, así como falta de interés e ignorancia de los efectos adversos de la radiación.

Palabras clave: Radiación ionizante. Ortopedia. Seguridad radiológica. Protección. Residencia médica. Residentes.

*Correspondence:

Jorge Quiroz-Williams

E-mail: jorge.quirozw@imss.gob.mx; jquiwill@hotmail.com

2444-0507/© 2021 Academia Mexicana de Cirugía. Published by Permanyer. This is an open access article under the terms of the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Date of reception: 10-08-2021

Date of acceptance: 07-09-2021

DOI: 10.24875/CIRUE.M23000429

Cir Cir (Eng). 2023;91(1):62-70

Contents available at PubMed

www.cirugiaycirujanos.com

Introduction

The discovery of x-rays and their application in medicine revolutionized the management and diagnosis of diseases and conditions. The setback, though, is that ionizing radiation produces chemical changes in cells damaging the DNA and increasing the risk of certain conditions, such as cancer¹⁻⁵. The annual dose threshold of ionizing radiation according to the International Commission on Radiological Protection (ICRP) established back in 1956, is 50 mSv for workers. However, it was reduced down to 20 mSv per year by 1990^{1,4}.

For over 50 years, orthopedic surgery has used fluoroscopy and x-rays as aids in numerous surgical procedures^{4,5}, becoming the standard of use in orthopedic surgery. Currently, the highest level of exposure is seen in vertebroplasty and kyphoplasty^{5,6}, followed by hip fracture reduction with dynamic screw^{7,8}, and centromedullary nailing of long bones^{6,7}. As a result, orthopedic surgeons have been occupationally exposed to ionizing radiation for decades, sometimes receiving significant amounts that exceed the annual doses recommended⁹. However, since the introduction of radiation protection equipment (RPE)^{2,3,10-14} and updates and improvements in fluoroscopy machines, radiation doses have dropped significantly for both surgeons and patients¹⁵. New imaging technologies, such as computer-assisted navigation, have also contributed to reducing exposure⁶.

Factors that may favor radiation exposure to radiation for orthopedic surgeons include fluoroscopy time and distance from the radiation source. Some of the radiological protection measures recommended include keeping some kind of distance between the surgeon's hands and the radiation source^{11,16,17} and the use of RPE, such as lead aprons and collars^{3,7,18,19}.

Lead aprons are the most widely used RPE of all, with many surgeons using them routinely^{14,20}. Another commonly used RPE is the lead collar, but resistance to its use varies between 4% and 14%^{7,14}. As a matter of fact, less than 50% of orthopedic surgeons use it, despite reporting its availability²⁰. The surgeon's hands are the part of the body most easily exposed to radiation, and lead gloves can effectively reduce the doses of radiation^{3,9,15-18,21-23}. However, they are not as effective when placed directly against the beam, giving a false sense of security in some cases²⁴. Studies have shown that the doses of radiation to the hands range somewhere between 0.1 mSv and 1 mSv per procedure^{16,17,19,22}, while doses to the chest and

thyroid range from 0.154 mSv to 0.526 mSv. However, when using lead aprons and collars, the mSv values were below the dosimeter detection threshold (< 0.010 mSv)^{3,15,19,22}. The use of lead glasses reduces the likelihood of cataracts in the lens³, allowing for more fluoroscopic views before reaching the annual dose threshold of 20 mSv of radiation^{9,13,15}.

During their training and skill development period, orthopedic residents have a higher exposure to ionizing radiation especially when they're performing surgical procedures. This is due to their proximity to the x-ray source^{20,25,26} while performing most surgeries using fluoroscopy, an inadequate use of RPE^{14,20}, and not having enough information on the risks associated with exposure to radiation². The exposure level of orthopedic surgery residents in our setting has not been studied, but given their higher surgical activity compared to other countries, it is essential to study their exposure and compare it with the allowed threshold for health care personnel. Therefore, the objective of this study was to describe and analyze the exposure to ionizing radiation in orthopedic surgery residents in our setting.

Method

This was a prospective, longitudinal, and observational study conducted among medical graduates in the process of obtaining their medical specialization in orthopedics from January through November 2020. The study received approval from the health research and ethics committees with registration no. R-2020-2105-038. The study included all years of orthopedic residency, comprising all medical orthopedic residents.

Each medical resident was given a plate dosimeter (InLight, Landauer, Sweden) to carry across their entire working day, especially during surgeries and visits to tomography rooms, to measure radiation exposure. The dosimeter was placed below the lead apron on the surgical gown, at pocket level, as this is the area with the least radiation exposure underneath the lead apron, according to the medical literature available^{3,15,16,26,27} (Fig 1). The dosimeter was changed every month for a period of 10 months. The radiation absorbed was measured by the radiology service provider in the hospital each month. The dosimeter has a half-life of 90 years and a 99.1% sensitivity rate.

To assess the behavior and knowledge on radiological safety and fluoroscopy use, each medical resident was sent an email with a link to a previously created survey on Google Forms (see Annex 1).



Figure 1. Dosimeter location.

Regarding the statistical analysis, the association of variables was conducted using the Student t test. P values ≤ 0.05 were considered statistically significant.

Results

The overall sample size included 54 participants, 81% of whom ($n = 43$) were men and 19% ($n = 11$), women. The mean age of the participants was 29.09 years, with a range of 25 to 41 years and a standard deviation of 2.631.

This was the distribution by year of residency: residency year #1 (R1), 16.7% ($n = 18$), residency year #2 (R2), 20.4% ($n = 11$), residency year #3 (R3), 29.6% ($n = 16$), and residency year #4 (R4), 16.6% ($n = 9$) (Fig. 2).

In terms of comorbidity assessment, 33.3% of participants had overweight/obesity. One participant had thyroiditis, another had asthma, and a third one, depression, all of whom were under treatment. Regarding the history of cancer, 2 participants reported having had gastric cancer, and 1, low-grade intraepithelial lesion in the cervix.

Regarding the frequency of radiation exposure, 27.8% reported being exposed to radiation 2 to 5 times/week; 33.3%, 6 to 10 times/week; and 38.9% > 10 times/week.

Regarding training on radiological protection, 59.3% reported having received previous training, while only 22.2% reported having received proper training on radiological safety. As a result, 87% of all medical residents did not feel safe while being exposed to radiation during fluoroscopy procedures, as opposed to 7% who said they actually felt safe (Table 1).

The study also measured the level of knowledge and compliance to radiological protection measures in the operating room. Results showed that 61.1% had the knowledge and applied the measures, 24.1% had the knowledge but did not apply them, and 14.8% did not have the knowledge or applied the measures. Additionally, only 16.7% of participants reported being aware of radiation hazard signs in the operating rooms where fluoroscopy is more widely used (Table 1).

In terms of awareness on the availability of RPE for medical residents at the hospital, 55.6% reported being aware of their existence, 38.9% not knowing anything about RPE, and 5.6% not being quite sure about the existence of RPE (Table 1).

Regarding the use of RPE, among the medical residents who actually use it, 77.8% used lead aprons; 31.5% used thyroid protection; and 5.6%, radiation protection glasses (Table 2). Only 13% of the participants were aware that they needed to check the integrity of their RPE before using it and actually did so, 53.7% knew about the need to verify the integrity of RPE but did not comply, and 33.3% were not sure whether such verification was necessary (Table 2).

To measure exposure to ionizing radiation, 87% of participants used dosimeters, while 13% did not. Most medical residents wore dosimeters during surgeries (83.3%) and while patients underwent CT scans (90.7%) (Table 2). Regarding CT scans, 77.6% of the medical residents used RPE during their stays in the CT room (Table 1).

Regarding the storage of the dosimeters, only 38.9% of the medical residents left them in their hospital lockers, despite each resident signing an agreement taking responsibility for the dosimeter. According to the rules effective at the center, dosimeters should be kept in the residents' personal lockers within the hospital premises, as dosimeters are not allowed to be taken outside the unit (Table 3).

Regarding knowledge of routine dosimeter measurements, 25.9% said they were aware of them,

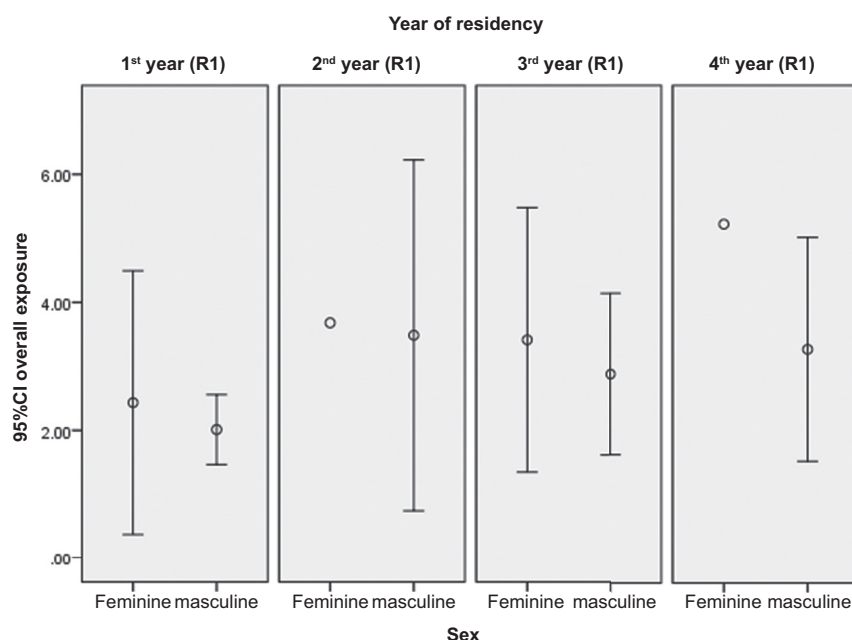


Figure 2. Overall measurement of ionizing radiation exposure based on sex and year of specialty in orthopedic surgery residents.

Table 1. Training and knowledge on radiological protection and safety in resident physicians (n = 54)

Topic	% (n)
Radiological protection training	
Yes	59.3 (32)
No	40.7 (22)
Radiological safety training	
Yes	22.2 (12)
No	77.8 (42)
Feeling of safety during exposure to radiation in fluoroscopies or x-ray studies	
Yes	13.8 (7)
No	87 (47)
Knowledge on radiological protection measures at the OR	
Yes, the resident knows the measures and implements them	61.1 (33)
Yes, the resident knows the measures but does not implement them	24.1 (13)
No, the resident does not know the measures or implement them	14.8 (8)
Knowledge on the existence of radiological hazard signs in surgical rooms with fluoroscopy	
Yes	16.7 (9)
No	83.4 (45)
Knowledge on the existence of RPE available for resident physicians in the hospital	
Yes	55.6 (30)
No	38.9 (21)
Not sure whether there are RPE or not	5.6 (3)

RPE: radiological protection equipment.

61.1% knew something about them but did not take appropriate measurements, and 13% did not know anything or took any measurements (Table 3).

When activities in the operating room related to exposure to ionizing radiation while performing postoperative

radiographic controls were analyzed, we found that the medical resident was responsible for holding the portable x-ray machine 81.5% of the times. Regarding the personnel handling the fluoroscope during surgeries, 82.9% of the times, we found it was another medical

Table 2. Use of radiological protection equipment in resident physicians (n = 54)

Equipment	% (n)
Lead apron usage	
Yes	77.8 (42)
No	22.2 (12)
Thyroid shield usage	
Yes	31.5 (17)
No	68.5 (37)
Radiological eyewear usage	
Yes	5.6 (3)
No	94.4 (51)
Verification of EPR integrity prior to use	
Yes	13 (7)
No	53.7 (29)
Don't know	33.3 (18)
RPE usage while accessing the CT room with the patient	
Yes	75.9 (41)
No	24.1 (13)

CT: computed tomography; RPE: radiological protection equipment.

Table 3. Use and storage of dosimeters by resident physicians (n = 54)

	% (n)
General dosimeter usage	
Yes	87 (47)
No	13 (7)
Dosimeter carried during surgeries	
Yes	83.3 (45)
No	16.7 (9)
Dosimeter carried while accessing the CT room with the patient	
Yes	90.7 (49)
No	9.3 (5)
Dosimeter storage	
In the hospital locker room	38.9 (21)
Carries it in a backpack	3.7 (2)
At home	57.4 (31)
Routine dosimeter measurements	
Knowledgeable and takes these measurements	25.9 (14)
Knowledgeable but doesn't take these measurements	61.1 (33)
Not knowledgeable and doesn't take these measurements	13 (7)

CT: computed tomography.

resident outside the surgical team, while 17.2% of the times, it was actually a member of the surgical team (Table 4).

Regarding the distance from the fluoroscopy machine during surgeries where the fluoroscope is actually located, 81.5% of the residents placed themselves 1 or 2

Table 4. OR activities related to exposure to ionizing radiation in resident physicians (n = 54)

Activity	% (n)
Holding the x-ray machine during postoperative radiographic controls	
Yes	81.5 (44)
No	18.5 (10)
Handling the fluoroscope during surgeries	
Resident physician from the surgical team	18.5 (10)
A different resident physician unrelated to the surgical team	81.5 (44)

steps away from the machine (< 1 meter), 16.7% less than 3 meters away, and 1.9% said that they did not pay any attention to the distance from the fluoroscopy machine. Additionally, during surgeries, 59.3% of the residents reported that the x-ray tube of the C-arm fluoroscopy machine was located above the operating table, while only 25.9% said it was placed underneath the table. Additionally, 14.8% of the residents surveyed did not consider the location of the x-ray tube an important issue.

When the medical residents acted as the first or second assistant during surgeries, 48.1% placed themselves close to the x-ray tube, 33.3% next to the x-ray tube, while 18.5% did not care where they placed themselves. Most residents (98.1%) believed fluoroscopy shots are actually taken recurrently during surgery.

Regarding the assessment of dosimeter measurements taken on a monthly basis and based on sex (Table 5), the means were determined using the Student t test, with a 95% confidence interval (95%CI) while assuming equal variances. The mean total exposure to ionizing radiation in women was 3.260 ± 1.688 mSv compared to 2.807 ± 2.304 mSv in men, with an overall mean exposure of 2.9 ± 2.17 mSv (CI95%, 1.25-14.28; $p = 0.424$) (Table 5 and Fig. 2).

Regarding the assessment of monthly dosimeter measurements based on the year of residency, means were determined using the Student t test, with a 95% confidence interval (CI), assuming equal variances among subgroups (R1 and R2, R3, and R4). The overall exposure to ionizing radiation per year was: 2.105 ± 1.006 mSv for R1; 3.503 ± 2.635 mSv for R2; 3.079 ± 1.798 mSv for R3; and 3.480 ± 2.063 mSv for R4 (Table 6 and Fig. 2).

Discussion

The field of orthopedic surgery increasingly relies on fluoroscopy and x-ray imaging during surgical

Table 5. Measurement of exposure to ionizing radiation per month and sex based on resident physicians

Month	Exposure (mSv) Mean $\pm$ SD	Range*	p
January	Women: 0.445 $\pm$ 0.731 Men: 0.338 $\pm$ 0.642	-0.328-0.541	0.626
February	Women: 0.363 $\pm$ 0.455 Men: 0.564 $\pm$ 1.917	-1.328-0.925	0.721
March	Women: 0.215 $\pm$ 0.224 Men: 0.1898 $\pm$ 0.214	-0.117-0.167	0.722
April	Women: 0.245 $\pm$ 0.108 Men: 0.262 $\pm$ 0.254	-0.169-0.134	0.819
May	Women: 0.286 $\pm$ 0.444 Men: 0.243 $\pm$ 0.432	-0.243-0.328	0.764
June	Women: 0.233 $\pm$ 0.226 Men: 0.243 $\pm$ 0.216	-0.157-0.129	0.846
July	Women: 0.365 $\pm$ 0.383 Men: 0.276 $\pm$ 0.403	-0.173-0.351	0.499
August	Women: 0.219 $\pm$ 0.068 Men: 0.213 $\pm$ 0.372	-0.076-0.0892	0.874
September	Women: 0.369 $\pm$ 0.525 Men: 0.242 $\pm$ 0.189	-0.663-0.319	0.193
October	Women: 0.520 $\pm$ 0.731 Men: 0.233 $\pm$ 0.163	-0.047-0.528	0.020
Overall Exposure	Women: 3.260 $\pm$ 1.688 Men: 2.807 $\pm$ 2.304	-0.984-1.890	0.529
	Overall: 2.9 $\pm$ 2.17	1.25-14.28	0.424

SD: standard deviation. *Calculated with a 95% confidence interval.

procedures as aids for treatment and quality control. Orthopedic surgeons are continuously exposed to ionizing radiation and its potential biological effects on the body, with a high probability of developing radiation-induced cancers due to chronic exposure to low doses over time, leading to an increased risk of cancer after 10-15 years^{1,3}. Therefore, to mitigate radiation exposure and reduce stochastic effects, the measures recommended by the ICRP are maintaining a security distance from the radiation source and using RPE such as lead aprons, thyroid collars, lead gloves, and protective eyewear.

The study states that 77.8% of all medical residents wear lead aprons, compared to only 31.5% who wear thyroid collars. Lead aprons are the most commonly used RPE, followed by thyroid collars, with a lower percentage of usage and some resistance among the surgical staff to wearing them, despite their availability^{2,6,14,20,27}. The hospital provides RPE to all medical residents, including lead aprons, thyroid collars, and lead eyewear. Also, the

Table 6. Measurement of exposure to ionizing radiation per month and by specialization level in resident physicians

Month	Exposure (mSv) Mean $\pm$ SD	Range*	p
January		-0.459-0.213	0.000
R1	-		
R2	0.336 $\pm$ 0.257		
R3	0.633 $\pm$ 0.877	-0.767-0.757	0.990
R4	0.638 $\pm$ 0.908		
February		-3.261-0.183	0.005
R1	-		
R2	0.564 $\pm$ 1.917	-0.637-0.304	
R3	0.384 $\pm$ 0.353		0.471
R4	0.551 $\pm$ 0.789		
March		-0.304-0.203	0.00
R1	-		
R2	0.189 $\pm$ 0.214		
R3	0.287 $\pm$ 0.223	-0.265-0.134	0.506
R4	0.352 $\pm$ 0.248		
April		-0.163-0.314	0.520
R1	0.299 $\pm$ 0.379		
R2	0.224 $\pm$ 0.068		0.710
R3	0.239 $\pm$ 0.098	-0.102-0.071	
R4	0.254 $\pm$ 0.104		
May		-0.231-0.585	0.380
R1	0.326 $\pm$ 0.654		
R2	0.148 $\pm$ 0.035		
R3	0.169 $\pm$ 0.078	-0.471-0.047	0.104
R4	0.381 $\pm$ 0.498		
June		-0.013-0.273	0.073
R1	0.276 $\pm$ 0.228		
R2	0.146 $\pm$ 0.033		
R3	0.206 $\pm$ 0.109	-0.448-0.128	0.241
R4	0.366 $\pm$ 0.372		
July		-0.138-0.656	0.192
R1	0.450 $\pm$ 0.637		
R2	0.191 $\pm$ 0.048		0.498
R3	0.250 $\pm$ 0.221	-0.105-0.209	
R4	0.198 $\pm$ 0.060		
August		-0.058-0.577	0.104
R1	0.184 $\pm$ 0.046		
R2	0.205 $\pm$ 0.051		
R3	0.256 $\pm$ 0.240	-0.108-0.195	0.561
R4	0.212 $\pm$ 0.641		
September		-0.188-0.360	0.525
R1	0.313 $\pm$ 0.434		
R2	0.227 $\pm$ 0.091		
R3	0.243 $\pm$ 0.641	-0.181-0.229	0.809
R4	0.284 $\pm$ 0.234		
October		-0.121-0.168	0.741
R1	0.257 $\pm$ 0.205		
R2	0.234 $\pm$ 0.143		
R3	0.393 $\pm$ 0.641	-0.353-0.569	0.633
R4	0.284 $\pm$ 0.234		
Total Exposure		-3.245-0.449	0.132
R1	2.105 $\pm$ 1.006		
R2	3.503 $\pm$ 2.635		
R3 R4	3.079 $\pm$ 1.798	-0.203-1.232	0.616

R1, first-year resident; R2: second-year resident; R3, third-year resident; R4, fourth-year resident; SD, standard deviation.

*Calculated with a 95% confidence interval.

hospital Education and Research Directorate has issued a mandate to deny access to the operating room if RPE are not worn during surgeries involving fluoroscopy. Some resistance to the use of RPE has been reported, particularly thyroid collars, despite the fact that 55.6% of the residents are aware of the availability of RPE for medical residents.

Regarding the distance kept by the surgeon from the x-ray source, the greater the distance, the lower the risk of being exposed to ionizing radiation. According to the survey, 81.5% of the residents placed themselves at a distance of < 1 meter from the x-ray source. The medical literature available tells us that the chances of experiencing stochastic effects due to occupational exposure to ionizing radiation are limited when the OR personnel keeps more than just 1 meter as a security distance from the x-ray source and wears lead aprons^{3,9,26,28}.

We should mention that having the x-ray source of the fluoroscope located underneath the operating table means that the dose of radiation is lower in the surgeon's chest, pelvis, and fingers³, provided the surgeon wears a lead apron to protect his/her chest and gonadal region. In contrast to the study conducted in our hospital, we found that in 59.3% of all surgeries performed using fluoroscopy, the x-ray tube is often placed above the operating table, compared to 25.9% of the cases where it is placed underneath the table.

However, the study demonstrated that the 11-month cumulative overall exposure dose for orthopedic surgery residents at the hospital had a mean of 2.9 ± 2.17 mSv, which is below the threshold recommended by the ICRP of 20 mSv^{5,23} despite the fact that 13% of all medical residents did not wear the dosimeter at some point during their routine clinical practice (during rotations and on-call duties) or used the RPE appropriately, and 81.5% placed themselves less than 1 meter away from the x-ray source. A study conducted among consolidated physicians and orthopedic surgery residents showed that the dose received was lower than the dose recommended²⁵. A different study conducted in Turkey²⁶ compared radiation exposure in orthopedic surgeries and found that the overall annual exposure to ionizing radiation was lower than the threshold set by the International Commission on Radiological Protection (ICRP). Nonetheless, occupational radiation exposure was higher in assistant physicians than surgeons. The authors of this study attributed the

higher exposure observed to the fact that the x-ray source is often located closer to the side of the assistant surgeon (< 1 meter away) despite the use of lead aprons and thyroid shields.

We should mention that this is the first study ever conducted in Mexico and Latin America with orthopedic surgery residents, a group with higher exposure rates to ionizing radiation. Like Matityahu et al.⁶ say, younger surgeons have a higher risk of exposure because they use fluoroscopy more often during surgery compared to more experienced surgeons. Medical residents from most Mexican hospitals, especially those in their third and fourth year of residency (R3 and R4), display a greater surgical activity. They participate in more surgical procedures during their on-call duties and make greater use of the fluoroscope in orthopedic surgeries. Due to their inexperience and lack of skills, they may be more exposed to x-ray than consolidated physicians, which leads to more exposure to ionizing radiation. A strength of this study is the significant sample size, which is the first of its kind in the region.

The study also found that women were more exposed to radiation than men. The analysis hypothesizes that this could be due to an inadequate use of the dosimeter, not following the instructions on how to wear it underneath the lead apron or exposure to ionizing radiation through other means or failure to wear the RPE during fluoroscopy-guided surgeries. This finding was made during the monthly follow-up conducted by the company responsible for measuring exposure to radiation. To address this issue, the female medical residents who showed greater exposure were called on the proper use of the dosimeter and the importance of wearing RPE properly.

The study has some limitations, such as the measurement of exposure for first-year residents (R1) being conducted only for 8 months instead of the entire year, because since the medical specialization course starts in March, after October 2020, the dosimeter was not available to take 1-year measurements. Additionally, there is a lack of awareness among medical residents on the risks involved in prolonged exposure to ionizing radiation and its stochastic effects on the body. To address this issue, starting March 2021, all medical residents are reinforced on radiological protection measures and given an organizational chart on the proper use of RPE and verification of its integrity (Figs. 3 and 4) to build up awareness on its proper use.



Figure 3. Dosimeter location underneath the lead apron.

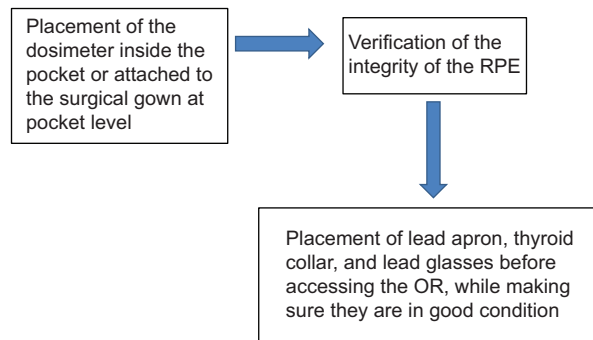


Figure 4. Flowchart for the verification of radiation protection equipment (RPE) prior to accessing an orthopedic surgery unit where fluoroscope is often used.

Conclusions

The study demonstrated that orthopedic surgery residents receive doses of radiation below the threshold recommended by the ICRP. However, it also revealed a lack of knowledge among residents regarding radiological protection and the adverse events associated

with radiation, despite having received prior training on the use of RPE and radiological safety issues.

To address this issue, greater awareness and consciousness is needed among medical residents on the proper use of complete RPE during orthopedic surgeries involving fluoroscopy. Additionally, continuous medical education programs on radiological protection measures should be added to the medical specialization course to better provide the health care personnel with knowledge on radiological safety.

Acknowledgements

The authors wish to thank the staff from the radiology and imaging modality unit of Unidad Médica de Alta Especialidad Hospital de Traumatología y Ortopedia Manuel Ávila Camacho in Puebla, Mexico for their unconditional support.

Funding

None whatsoever.

Conflicts of interest

none reported.

Ethical disclosures

Protection of human subjects and animals in research. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Patients' data protection. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

Supplementary data

Supplementary data for this study is available at the following DOI: 10.24875/CIRUE.M23000429. This material is provided by the corresponding author and published online for the reader's own benefit. The content of the supplementary data is the authors' sole responsibility.

References

1. Vivas MR, Herrera HS, Guyot JP, Santini Araujo MG, Dello Russo B, Castellini J. Informe sobre la radio-exposición en el personal quirúrgico de ortopedia y traumatología. Principios, marco legal y análisis situacional en la Argentina. *Rev Asoc Argent Ortop Traumatol*. 2018;83:210.
2. Frane N, Megas A, Stapleton E, Ganz M, Bitterman AD. Radiation Exposure in orthopaedics. *JBJS Rev*. 2020;8:e0060.
3. Van Der Merwe B. Radiation dose to surgeons in theatre. *South African J Surg*. 2012;50:26-9.
4. Clement CH, Stewart FA, Akleyev AV, Hauer-Jensen M, Hendry JH, Kleiman NJ, et al. ICRP publication 118:ICRP statement on tissue reactions and early and late effects of radiation in normal tissues and organs. Threshold doses for tissue reactions in a radiation protection context. *Ann ICRP*. 2012;41:1-322.
5. ICRP. ICRP publication 103:Recommendations 2007 de la Commission Internationale de Protection Radiologique. *Ann ICRP*. 2007;37:1-417.
6. Matityahu A, Duffy RK, Goldhahn S, Joeris A, Richter PH, Gebhard F. The great unknown —a systematic literature review about risk associated with intraoperative imaging during orthopaedic surgeries. *Injury*. 2017;48:1727-34.
7. Devalia KL, Peter VK, Madanur MA, Braithwaite JJ. Exposure of the thyroid to radiation during routine orthopaedic procedures. *Acta Orthop Belg*. 2006;72:615-20.
8. Giachino AA, Cheng M. Irradiation of the surgeon during pinning of femoral fractures. *J Bone Jt Surg - Ser B*. 1980;62:227-9.
9. Singer G. Occupational radiation exposure to the surgeon. *J Am Acad Orthop Surg*. 2005;13:69-76.
10. Khan IA, Kamalasekaran S, Ali Fazal M. Risk of ionising radiation to trainee orthopaedic surgeons. *Acta Orthop Belg*. 2012;78:106-10.
11. Mechlenburg I, Dagaard H, Soballe K. Radiation exposure to the orthopaedic surgeon during periacetabular osteotomy. *Int Orthop*. 2009;33:1747-51.
12. Lee K, Lee KM, Park MS, Lee B, Kwon DG, Chung CY. Measurements of surgeons' exposure to ionizing radiation dose during intraoperative use of C-arm fluoroscopy. *Spine (Phila Pa 1976)*. 2012;37:1240-4.
13. Burns S, Thornton R, Dauer LT, Quinn B, Miodownik D, Hak DJ. Typical fluoroscopic views of the hip and pelvis. *J Bone Jt Surg*. 2013;95:1307-12.
14. Devalia KL, Guha A, Devadoss VG. The need to protect the thyroid gland during image intensifier use in orthopaedic procedures. *Acta Orthop Belg*. 2004;70:474-7.
15. Mroz TE, Yamashita T, Davros WJ, Lieberman IH. Radiation exposure to the surgeon and the patient during kyphoplasty. *J Spinal Disord Tech*. 2008;21:96-100.
16. Von Wrangel A, Cederblad A, Rodríguez-Catarino M. Fluoroscopically guided percutaneous vertebroplasty: assessment of radiation doses and implementation of procedural routines to reduce operator exposure. *Acta Radiol*. 2009;50:490-6.
17. Tuohy CJ, Weikert DR, Watson JT, Lee DH. Hand and body radiation exposure with the use of mini C-arm fluoroscopy. *J Hand Surg Am*. 2011;36:632-8.
18. Synowitz M, Kiwit J. Surgeon's radiation exposure during percutaneous vertebroplasty. *J Neurosurg Spine*. 2006;4:106-9.
19. Harstall R, Heini PF, Mini RL, Orlor R. Radiation exposure to the surgeon during fluoroscopically assisted percutaneous vertebroplasty: a prospective study. *Spine (Phila Pa 1976)*. 2005;30:1893-8.
20. Fidan F, Çetin MU, Kazdal C, Kılıç F, Özkaya U. Behaviour and knowledge skill levels of orthopedic surgeons about radiation safety and fluoroscopy use: a survey analysis. *Acta Orthop Traumatol Turc*. 2019;53:301-5.
21. Koh IJ, Kim MW, Kim MS, Jang SW, Park DC, In Y. The patient's perception does not differ following subvastus and medial parapatellar approaches in total knee arthroplasty: a simultaneous bilateral randomized study. *J Arthroplasty*. 2016;31:112-7.
22. Li YY, Huang TJ, Cheng CC, Wu MH, Lee CY. Comparing radiation exposure during percutaneous vertebroplasty using one vs two-fluoroscopic technique. *BMC Musculoskelet Disord*. 2013;14:38.
23. Singer G. Radiation exposure to the hands from mini C-arm fluoroscopy. *J Hand Surg Am*. 2005;30:795-7.
24. Struelens L, Schoonjans W, Schils F, De Smedt K, Vanhavere F. Extremity and eye lens dosimetry for medical staff performing vertebroplasty and kyphoplasty procedures. *J Radiol Prot*. 2013;33:635-45.
25. Gausden EB, Christ AB, Zeldin R, Lane JM, McCarthy MM. Tracking cumulative radiation exposure in orthopaedic surgeons and residents. *J Bone Jt Surg - Am Vol*. 2017;99:1324-9.
26. Tasbas BA, Yagmurlu MF, Bayrakci K, Ucaner A, Heybeli M. Which one is at risk in intraoperative fluoroscopy? Assistant surgeon or orthopaedic surgeon? *Arch Orthop Trauma Surg*. 2003;123:242-4.
27. Ahn Y, Kim CH, Lee JH, Lee SH, Kim JS. Radiation exposure to the surgeon during percutaneous endoscopic lumbar discectomy: a prospective study. *Spine (Phila Pa 1976)*. 2013;38:617-25.
28. Abdullah KG, Bishop FS, Lubelski D, Steinmetz MP, Benzel EC, Mroz TE. Radiation exposure to the spine surgeon in lumbar and thoracolumbar fusions with the use of an intraoperative computed tomographic 3-dimensional imaging system. *Spine (Phila Pa 1976)*. 2012;37:E1074-8.