Radiation Exposure in Orthopaedics in Argentina

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ABSTRACT

Introduction: Many orthopedic surgical procedures require the use of fluoroscopic imaging, exposing surgeons to ionizing radiation. This study aims to assess the practices, frequency of intraoperative imaging use, level of knowledge, and adherence to radiological protection measures among orthopedic surgeons in Argentina. **Materials and Methods:** This was an analytical, observational, cross-sectional study based on an online survey conducted among orthopedic surgeons in Argentina between September 2020 and October 2021. The survey included 18 questions collecting sociodemographic, professional, and occupational data related to the use of intraoperative fluoroscopy, radiation protection measures, and knowledge of radiation exposure risks. **Results:** A total of 919 responses were collected. Nearly half of the participants (48.7%) reported using fluoroscopy more than once per week. However, 73.9% were unaware of their actual exposure time, 60.5% did not know whether protective equipment was regularly replaced, and only 10% reported using a dosimeter. The most commonly used protective device was the lead apron, yet only one-third of respondents used thyroid protection. Training in ionizing radiation was deemed insufficient, with 97% of respondents expressing interest in receiving formal education on the topic. **Conclusions:** There is a need to raise awareness among orthopedic surgeons regarding radiation exposure. Most surgical procedures lack adequate radiological protection, and there are no mandatory training programs, standardized protocols, or monitoring systems in place.

Keywords: Ionizing radiation; exposure; radiation protection; fluoroscopy; orthopedic surgery; occupational hazard.

Level of Evidence: IV

Exposición a la radiación en Ortopedia y Traumatología, en la Argentina

RESUMEN

Introducción: Múltiples procedimientos en cirugía ortopédica implican el uso de imágenes radioscópicas, lo que plantea un riesgo mayor de exposición a radiación ionizante para los cirujanos. Este estudio tiene como objetivo identificar las prácticas, la frecuencia de uso de imágenes intraoperatorias, el nivel de conocimiento y el empleo de elementos de protección radiológica de los médicos especialistas en ortopedia y traumatología de la Argentina. **Materiales y Métodos:** Estudio analítico observacional transversal. Se realizó en base a una encuesta en línea a traumatólogos de nuestro país, entre septiembre de 2020 y octubre de 2021. Mediante 18 preguntas se recabaron datos sociodemográficos, profesionales y laborales relacionados con el uso de la radioscopia intraoperatoria, las medidas de protección y el respectivo conocimiento. **Resultados:** Se recibieron 919 respuestas a la encuesta. La mitad de los participantes (48.7%) utiliza radioscopia más de una vez por semana. El 73.9% desconoce el tiempo real de exposición, la mayoría (60.5%) ignora si se renuevan los elementos de protección, y solo el 10% usa dosímetro. El elemento de protección más utilizado es el chaleco de plomo; sin embargo, solo un tercio emplea protección tiroidea. La formación académica en radiaciones ionizantes es insuficiente y al 97% de los encuestados le interesaría recibirla. **Conclusiones:** Existe una necesidad de concientización sobre la radiación por parte del cirujano ortopédico. La protección radiológica en la mayoría de los procedimientos quirúrgicos es inadecuada, no existen programas formativos obligatorios, protocolos de uso ni el respectivo control.

Palabras clave: Radiación ionizante; radioexposición; radioprotección; radioscopia; cirugía ortopédica; riesgo laboral.

Nivel de Evidencia: IV

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INTRODUCTION

The use of fluoroscopy has increased significantly in trauma surgery. This technology offers advantages such as reduced surgical times and the possibility of developing less invasive techniques, which contribute to decreased morbidity in patients.[1-3] However, it also increases radiation exposure for surgical teams, with adverse effects that may not become evident until decades later.[1-4] It is critical to understand that fluoroscopy employs ionizing radiation, which carries potentially harmful health effects, including genetic damage, an increased risk of cancer, and impairment of the hematopoietic system.[2,4-7]

In Argentina, as in other countries, regulations on radiation protection in healthcare are established by agencies such as the Nuclear Regulatory Authority, based on international guidelines from the *International Commission on Radiological Protection* (ICRP)[5] and the World Health Organization. According to these regulations, the dose limit for the general public is 1 mSv per year from natural and artificial sources, including X-rays, CT scans, and other radiological procedures. For occupational exposure, the maximum permissible limits are 20 mSv per year for whole-body exposure, 20 mSv for the lens, 150 mSv for the thyroid, and 500 mSv for the hands.[1,2,5,8]

Various studies have assessed the radiation dose received by surgical personnel (both medical and non-medical) at different body sites and during specific procedures to estimate exposure and the associated cancer risk.[4,6-10] Mastrangelo et al.[9] conducted a study in an Italian healthcare center between 1976 and 2000 and reported that orthopedic surgeons using fluoroscopy were five times more likely to develop cancer than healthcare workers not exposed to radiation. Additionally, the incidence of cancer in general— including skin, colon, lung, lymphoma, and chondrosarcoma—was higher. In 2009, Chou et al.[11] surveyed female orthopedic surgeons who were members of the American Academy of Orthopaedic Surgeons (AAOS) and reported that the prevalence of cancer was 85% higher than in the general population, with similar characteristics in terms of sex, age, and race.[10,11]

In Argentina, some studies have been conducted, such as the one by Vanoli et al.[12] which focused exclusively on wrist fracture fixation procedures, and the one by Bazán et al, on spine fractures.[13] The Research Committee of the Asociación Argentina de Ortopedia y Traumatología also conducted a survey on the use of dosimeters in accredited services.[14] However, to our knowledge, no national reports have been published that comprehensively analyze radiation exposure in orthopedic practice, including protective measures and the level of knowledge on the subject.

The aim of this study was to analyze the results of a survey identifying practices involving radiation exposure in the field of orthopedics and traumatology in Argentina, considering the frequency of fluoroscopy use, the level of knowledge, and the utilization of radiological protection elements.

MATERIALS AND METHODS

Through the Asociación Argentina de Ortopedia y Traumatología, an online survey was conducted using the SurveyMonkey® platform between September 2020 and October 2021. The survey was sent via email to all orthopedic surgeons registered in the association's database (including professionals with varying years of experience as well as residents and fellows) and was also disseminated through social media for voluntary completion.

The survey consisted of 18 questions, including mandatory and optional closed-ended questions, some with a single-response option and others allowing multiple responses (Annex).

Demographic data (sex, age, and region of practice) and occupational data (type of practice, subspecialty, and years of experience) were collected. Regarding fluoroscopy, participants were asked about its frequency of use, the type and frequency of radiological protection employed, the equipment used, and dose measurement. The survey also inquired about knowledge of the allowable dose limit, use of dosimeters, training received, and awareness of radiation exposure risks. The study complied with the Declaration of Helsinki, ensuring the anonymity of participants and healthcare institutions.

Statistical Analysis

The collected responses were entered into an Excel® (Microsoft®) spreadsheet. A descriptive analysis of the variables was performed, with results expressed as frequency and percentage based on the number of responses obtained for each question.

RESULTS

A total of 919 orthopedic surgeons responded to the survey. Some questions were optional, and the number of responses ranged from 913 to 919.

Demographic Data

87.9% (808 respondents) were men, and 11.7% (107) were women (four respondents omitted their gender). A total of 71.3% were under 50 years of age (Table 1).

Regarding length of practice, most respondents were specialists (86.5%), and 70% had more than five years of experience. In terms of employment, 43.1% (n = 396) reported working exclusively in the private sector. Geographically, 42.2% practiced in the AMBA region (Buenos Aires Metropolitan Area), followed by the Pampa region (31.9%). Concerning subspecialization, 36.5% worked in orthopedic trauma, followed by hip and knee (26.1%) (Table 1).

Table 1. Demographic data of the patients

	Total (n = 919)
Gender*	
Male	808 (87.9%)
Age	
<40	337 (36.7%)
40-49	318 (34.6%)
50-59	167 (18.2%)
60 or more	97 (10.6%)
Specialization**	
Specialist, more than 5 years	643 (70.0%)
Specialist, less than 5 years	135 (14.7%)
Fellow	23 (2.5%)
Resident	115 (12.5%)
Type of institution	
Private and public	393 (42.8%)
Private	396 (43.1%)
Public	130 (14.1%)
Surgical field#	
Hip and knee	240 (26.1%)
Spine	58 (6.3%)
Shoulder and elbow	40 (4.4%)
Hand	74 (8.1%)
Leg and foot	105 (11.4%)
Trauma/Orthopedic trauma	335 (36.5%)
Pediatric Traumatology	54 (5.9%)
Oncologic traumatology	11 (1.2%)
Region where you work##	
Buenos Aires Metropolitan Area	388 (42.2%)
Cuyo (San Juan, San Luis, Mendoza)	52 (5.7%)
Northeast (Formosa, Misiones, Chaco, Corrientes)	27 (2.9%)
Northwest (Jujuy, Salta, Tucumán, Catamarca, Santiago del Estero, La Rioja)	80 (8.7%)
Pampas (Entre Ríos, Santa Fe, Córdoba, Buenos Aires, La Pampa)	293 (31.9%)
Patagonia (Neuquén, Río Negro, Chubut, Santa Cruz, Tierra del Fuego)	76 (8.3%)
Do you belong to any association/society? Check the one(s) that apply	
AAOT	849 (92.4%)
Specialty Association/Society	468 (50.9%)
Regional Association/Society	326 (35.5%)
None	29 (3.2%)

*4 not answered; **3 not answered; #2 not answered; ##3 not answered.

Use of Fluoroscopy

Of the 919 responses, the most frequently used equipment during surgery was the C-arm (97.9%). Regarding frequency of use, almost half (48.7%) used fluoroscopy more than once a week, and 94.6% used pulsed fluoroscopy. Additionally, the majority (73.9%, n = 679) indicated that they did not monitor the actual time of radiation exposure. Those who reported never using fluoroscopy (2.4%) belonged to various subspecialties (Table 2).

Table 2. Use of fluoroscopy

	Total (n = 919)
What type of intraoperative equipment do you use? Check the applicable one(s)	
C-arm (open)	900 (97.9%)
O-arm (closed)	5 (0.5%)
Mini C-arm	13 (1.4%)
Intraoperative tomography	2 (0.2%)
Intraoperative navigation	16 (1.7%)
Do you use fluoroscopy in your usual surgical practice?*	
More than once a week	448 (48.7%)
3 or 4 times per month	227 (24.7%)
1 or 2 times per month	146 (15.9%)
Less than 6 times per year	75 (8%)
Never	22 (2.4%)
How do you use the image intensifier?**	
Continuously	40 (4.4%)
In pulsed form	869 (94.6%)
Do you control the actual exposure time?#	
No	679 (73.9%)
Yes	233 (25.4%)

*1 not answered; **10 not answered; #7 not answered.

Protection

The question on protective elements allowed multiple responses, enabling some options to be combined. A total of 88.3% of respondents (n = 809) used a lead vest or apron (710 wore a one-piece vest, and 99 used a two-piece vest); 38.6% used thyroid protection; 3.4% used leaded glasses; and 0.1% used leaded gloves (Table 3, Figure 1).

Regarding the frequency of use, 11.9% (n = 109) reported not using any protective equipment, while 37.2% always used it, and 11.8% used it half the time. Specifically, concerning lead vests, 94.8% of respondents indicated that the vest belonged to the institution where they worked, while in 22 cases, it was the surgeon's personal property. When asked about vest renewal, 60.5% were unaware of it, and 23.1% stated that it was not renewed (Table 3).

Table 3. Use of protective elements and data corresponding to leaded aprons

	Total (n = 919)
In surgeries with fluoroscopy, you use (check all that apply)	
One-piece leaded apron	710 (77.3%)
Two-piece leaded apron	99 (10.8%)
Thyroid protection (collar)	355 (38.6%)
Leaded goggles or glasses	31 (3.4%)
Leaded gloves	1 (0.1%)
Distance more than 2 m from the emitter	109 (11.9%)
Dosimeter	93 (10.1%)
You use protection equipment*	
Always	342 (37.2%)
75% of surgeries	249 (27.1%)
50% of surgeries	108 (11.8%)
Less than 50%	107 (11.6%)
Never	109 (11.9%)
The lead vest belongs to**	
The institution	871 (94.8%)
The surgeon	22 (2.4%)
The lead vest is renewed#	
Once a year	17 (1.8%)
Every 2 years	57 (6.2%)
Every 3 years	64 (7.0%)
I do not know	556 (60.5%)
It is not renewed	212 (23.1%)

*4 not answered; **26 not answered; #13 not answered.

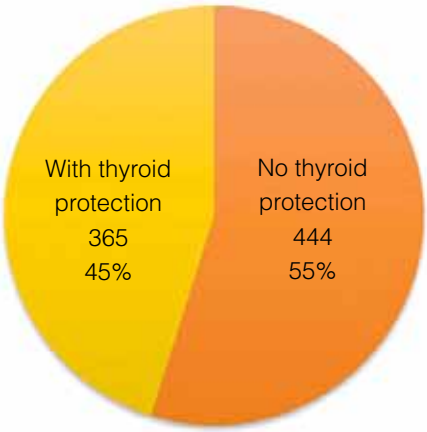
Among those maintaining a distance greater than two meters from the radiation source, 53% reported not using any protective equipment.

Only 10.1% of participants used dosimeters to measure their radiation exposure, with similar percentages across work environments (private 9.6%, public 12.3%, mixed 9.9%) (Figure 1).

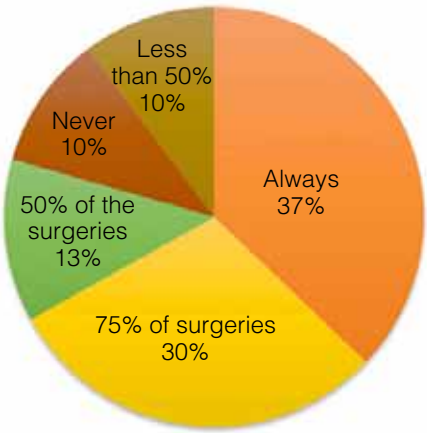
Education and Knowledge

Of the 916 responses received (three omitted), 89.7% (n = 824) stated that they were unaware of the maximum permissible radiation exposure per year, and only 17.2% had received specific training on the use of fluoroscopy and protective measures. Additionally, 97.6% of respondents expressed interest in incorporating such training into their professional education (Figure 2).

A



B



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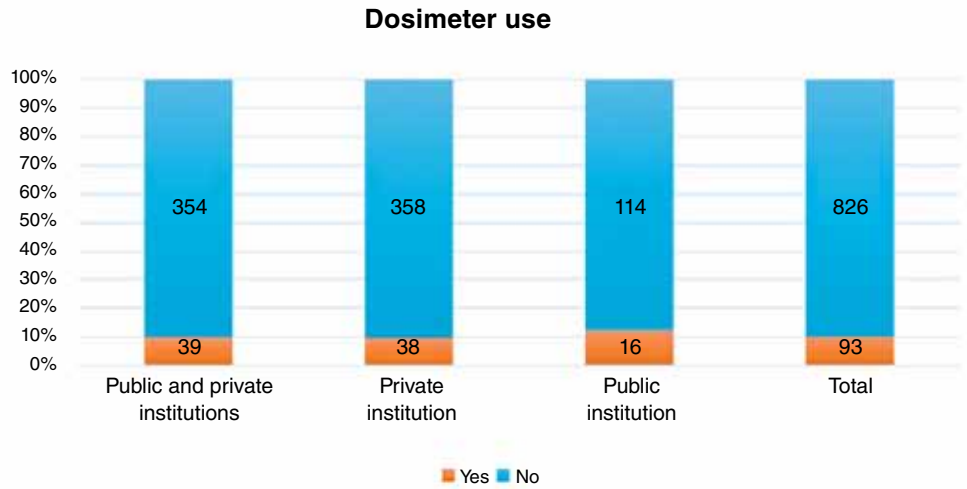
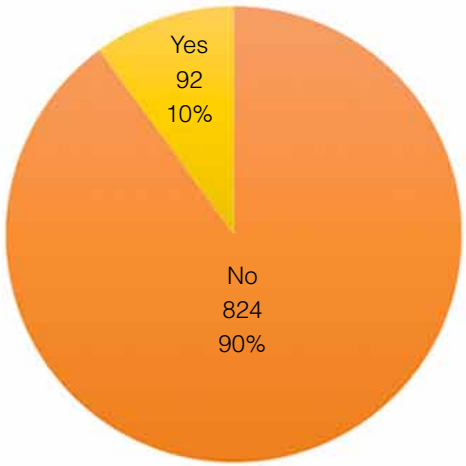


Figure 1. A. Use of leaded vest/apron (1 or 2 pieces) with or without thyroid protection. **B.** Frequency of use of radiological protection elements in those who use fluoroscopy more than once a week. **C.** Use of dosimeter according to the work environment.

A



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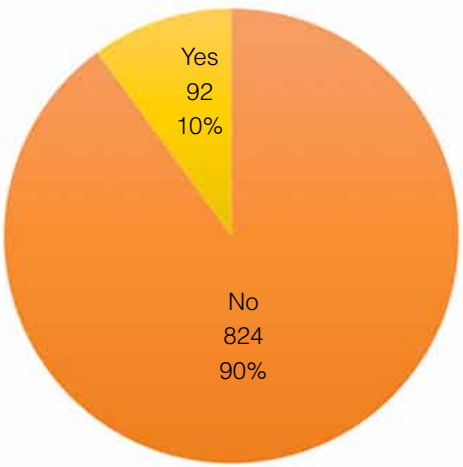

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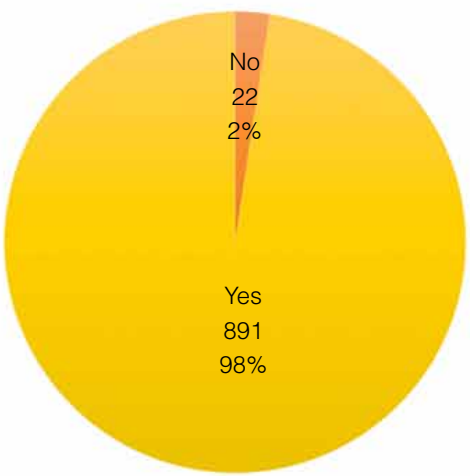

Figure 2. **A.** Knowledge of radiation limits. **B.** Received training in fluoroscopy. **C.** Would be interested in making it part of their training.

Subspecialties

Among different subspecialties, those who used fluoroscopy frequently (more than once a week) were hand surgeons (63%), trauma surgeons (62%), and leg and foot specialists (56%). Comparatively, those who had received training in fluoroscopy use were mostly foot and ankle surgeons (25.7%, n = 105), whereas in trauma, only 15% had received instruction (Figure 3).

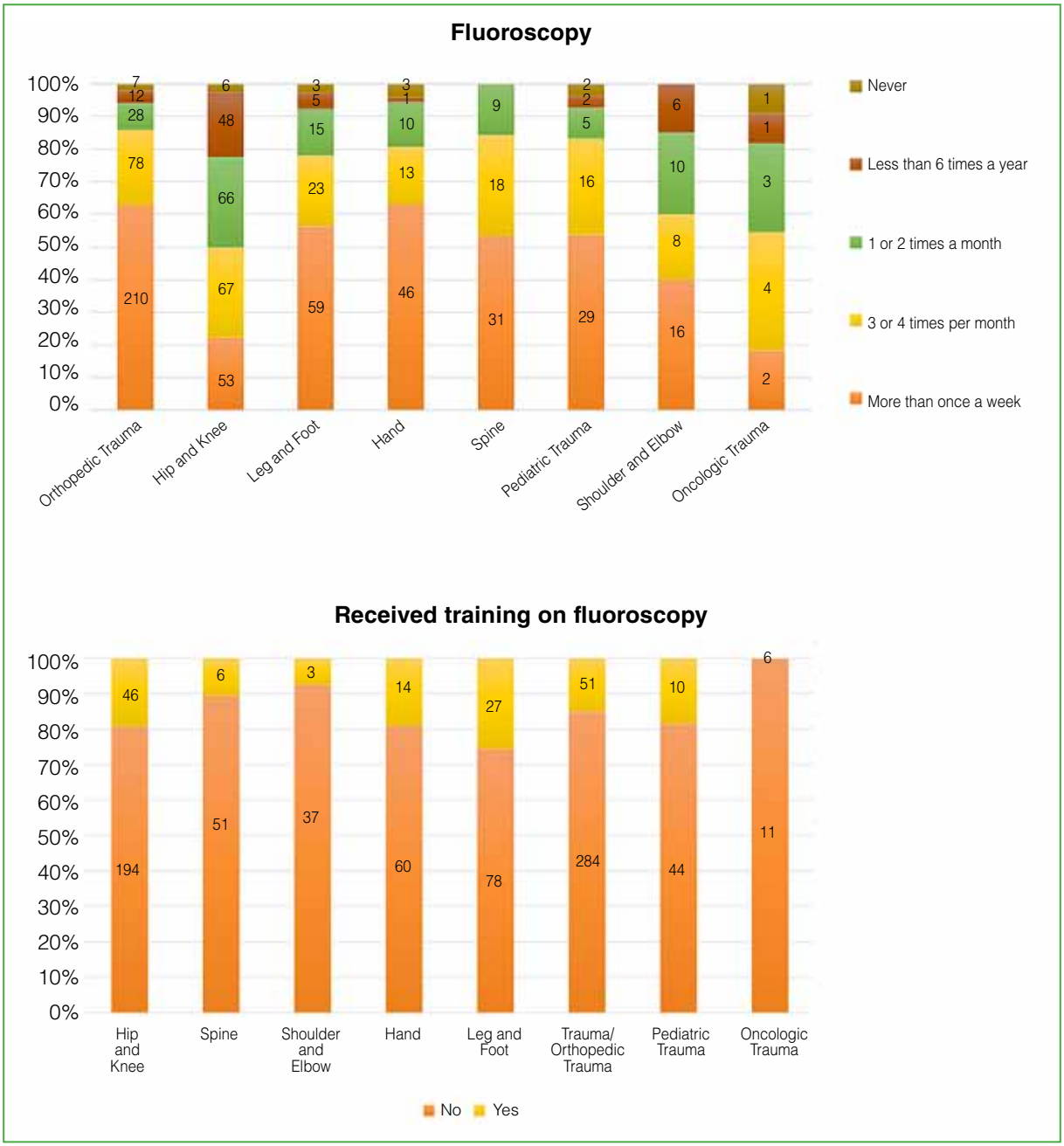

Figure 3. **A.** Frequency of use of fluoroscopy according to subspecialty. **B.** Fluoroscopy training according to subspecialty.

DISCUSSION

Orthopedic surgeons are increasingly exposed to ionizing radiation during various procedures. Multiple studies have shown that they have a higher risk of developing cancer compared to healthcare workers who are not exposed to radiation.[7,9-11] The literature also emphasizes the importance of implementing key radiation protection measures, summarized by the acronym ALARA (As Low As Reasonably Achievable).[3,8] However, adherence to these measures remains inconsistent.[6-8,15]

A major issue is the absence of universally applied guidelines to minimize exposure, not only for surgeons but also for medical and non-medical personnel present in the operating room, as well as for patients.[3] Radiation exposure varies significantly by subspecialty and procedure type. Spine and trauma surgeries involve the highest levels of exposure due to frequent intraoperative fluoroscopy use, particularly in procedures such as vertebroplasties and kyphoplasty, followed by pelvic surgery, hip surgery, and osteosynthesis with intramedullary devices.[2,3,8,15,16] In our survey, hand and trauma surgeons reported the highest fluoroscopy use, consistent with existing literature.

The tissues most sensitive to radiation exposure include red bone marrow, the colon, lungs, stomach, and breasts.[1,4,7] However, surgeons' hands are typically the most exposed anatomical region due to their proximity to the radiation source.[4,6-8,17] Additionally, although the thyroid gland and eyes receive lower doses, they are highly sensitive to radiation.[2,5-7,17] Proper shielding of these regions is crucial; however, many surgeons often neglect these areas compared to other organs, such as the thorax, abdomen, and gonads, as noted by Kaplan et al.[7] and Vanoli et al.[12]

Thyroid protectors and vests are the most common protective elements. It is recommended that they have a minimum lead thickness of 0.25 mm (which reduces exposure by more than 90%) or 0.50 mm (which reduces exposure by up to 99%). Ideally, they should provide circumferential coverage, including the thyroid gland.[1,3,4,7] Despite their availability, their use remains inconsistent.[2,7,8,17] Thyroid protectors are often integrated into vests, but when used separately, their usage rates range from 24% to 30%, with some studies reporting rates as low as 4%.[2,6-8] In our survey, 88% of respondents reported using lead vests, but fewer than 40% used thyroid protection.

Radiation exposure is a known risk factor for conditions such as adenomas, thyroiditis, hypothyroidism, and malignant neoplasms—85% of papillary carcinomas are radiation-induced.[6,7,9]

Furthermore, the effectiveness of protective equipment heavily depends on individual compliance. Previous studies have indicated that many surgeons do not adhere to radiation safety recommendations.[7,15] In our survey, 11.9% of respondents did not use any protection, 11.8% used it occasionally, and only 37.2% used it consistently, highlighting a lack of awareness or knowledge about the importance of radiation safety and the potential consequences of inadequate protection.

A fundamental aspect to consider is that the protective function of these elements is compromised by inadequate storage and maintenance. Kaplan et al.[7] emphasize the importance of performing annual quality controls.[3,4] However, in our survey, 60.5% of respondents did not know whether the lead vests at their institution were renewed, and 23% stated that they were not renewed. Notably, 94.8% of the participants indicated that the vests belonged to the institution.

Eye protection is generally inadequate, with usage ranging from 2.5% to 5%, likely due to a lack of awareness regarding the risk of cataracts from ionizing radiation exposure.[3-6] The pathogenesis involves opacification of the crystalline lens, specifically in its posterior portion.[1,3,6,7] Burns et al.[16] reported a 90% reduction in exposure with the use of leaded glasses in pelvic and hip surgeries.[7,16] In our survey, only 3.4% of respondents reported using eye protection, reflecting this lack of awareness.

Lead gloves are effective only if they are not directly exposed to the radiation beam. When automatic exposure control is activated, radiation levels increase when gloves are detected.[2,7,17-19] They often create a false sense of security; therefore, direct exposure should be avoided. In our study, lead glove usage was rare, reported by only 0.1% of respondents.

Radiation dose monitoring is an essential practice that should be applied to all personnel exposed in the operating room. However, only 10% of respondents reported using dosimeters in both public and private healthcare settings, indicating a lack of adequate control and monitoring[1,14,18,20]

All personnel exposed to radiation in the operating room should wear individual dosimeters, and their data should be collected and analyzed by the facility's radiation safety department.[1,14,18,20] However, only 10% of respondents in our study reported using them. Joeris et al. found that approximately half of orthopedic surgeons had never used a dosimeter, and among those who had, only half received information about their radiation exposure levels.[21] Al Mohammad et al.[20] reported that only 5.5% of surgeons used dosimeters.

Similarly, there is a general lack of knowledge regarding radiation exposure limits. Eighty-nine percent of respondents were unaware of the existence of occupational exposure limits, and 73.9% did not monitor their radiation exposure time. This finding is consistent with international reports suggesting a widespread lack of awareness regarding the occupational exposure limits established by the ICRP.[3,7]

There are two types of C-arm fluoroscopes: the standard and the mini C-arm. While the latter is recognized for its versatility and potential to reduce surgeon exposure, improper use can increase radiation exposure, particularly to the hands.[3,4,7] In our survey, the standard C-arm was the most commonly used device (97.9%), and 94.6% of respondents reported using the pulsed mode. The way the equipment is used is a crucial factor: continuous fluoroscopy, capturing 30 to 35 images per second, significantly increases radiation exposure compared to pulsed mode, which generates only 1 to 5 images per second.[4,7,18,19]

Finally, only 17.2% of respondents had received specific training in radiation protection during their education, underscoring the urgent need to incorporate this knowledge into training programs (97% expressed interest in receiving such training). Previous studies have highlighted the lack of radiation safety training among orthopedic surgeons.[4,7,21] Pires et al.[22] and Kaplan et al.[7] have noted the absence of a standardized radiation safety curriculum during medical training. Saroki et al. found that 91.2% of orthopedic surgeons believed they needed additional training on radiation exposure.[23]

This study has certain limitations, such as the lack of actual radiation exposure quantification, preventing us from determining whether surgeons and residents exceed the ICRP-recommended limits. Additionally, the sample was not homogeneous in terms of subspecialties, with a higher representation of trauma, hand, and foot surgeons, which may limit comparisons across specialties. Despite these limitations, this is the first study in Argentina to investigate occupational radiation exposure among orthopedic surgeons, providing valuable data to improve surgical practices.

The question remains: how much radiation are orthopedic surgeons, operating room staff, and patients actually exposed to during various procedures?

CONCLUSIONS

Our survey aimed to collect key information on radiological protection practices among orthopedic surgeons in Argentina. The findings highlight the need to implement measures to reduce radiation exposure. The results reveal widespread deficiencies in knowledge regarding radiation risks, doses received, exposure limits, and radiation safety techniques, both among specialists and residents. Radiation monitoring should be mandatory for all occupationally exposed personnel; however, in orthopedic surgery, its use remains unregulated. Although current exposure levels may be within established limits, any exposure poses long-term risks. Further research is needed in this area.

It is essential to incorporate radiation safety training programs into residency curricula and continuing postgraduate education to ensure safer and more responsible surgical practices.

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