Commentary: Worldwide Knowledge and Attitude of Spine Surgeons Regarding Radiation Exposure

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Received, March 26, 2018.
Accepted, May 10, 2018.

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Spine surgery often requires the use of radiation by means of fluoroscopy during surgery, and fluoroscopy-assisted spinal procedures are on the rise worldwide.[1] This is due to the dramatic growth in popularity of minimally invasive surgery (MIS) techniques and endoscopy, which often require real-time fluoroscopic visualization to perform precise intraoperative localization and minimize instrument and implant malposition.[2,3] This has led to an increase in the exposure of spine surgeons to radiation. Not only is there no dose of radiation known to be safe, but low dose radiation during fluoroscopy-assisted surgeries can accumulate during the surgeon's lifetime, potentially leading to stochastic effects such as cancer and cataracts.[4-10] The literature shows high radiation exposure among spine surgeons, sometimes surpassing the recommended dose limits.[11,12]

Simple practices necessary to maximize radiation safety during the fluoroscopy include standing on the side of the image intensifier rather than radiation source to minimize reflected radiation, taking several steps away from the field to increase distance from the radiation source, rotating the head away from the source to minimize eye exposure, using pulse-mode fluoroscopy to limit dose, and wearing lead barriers.[4,11-18] Spine surgeons worldwide need prior knowledge regarding radiation safety to realize the importance of these techniques. Information concerning the spine surgeons' knowledge and attitudes regarding radiation safety during fluoroscopy-assisted procedures is scarce in the literature. The information available has reported poor overall radiation safety knowledge and attitudes among surgeons, but the literature to date is not specific to spinal surgeons.[19-23]

The authors hypothesize that knowledge and attitudes regarding radiation safety would be different among spine surgeons of different specialties and regions of the world, and that radiation safety practices would likewise vary. The authors evaluate the knowledge and attitudes of spine surgeons worldwide through the largest and most broadly distributed study to-date on the topic, using questionnaires and surgical scenario.

METHODS

Type of Study

A cross-sectional study was performed using a radiation safety survey. The questionnaire was sent to spine surgeons, both Neurosurgeons and Orthopedic spine surgeons, who were members of AOSpine worldwide.

Radiation Safety Questionnaire

The survey was composed of 16 questions, 3 on general information and 13 specific questions to evaluate the surgeon's knowledge and attitude regarding radiation safety. A clinical scenario was used in 2 questions. The variables analyzed were country, age, specialty, years of experience, dosimeter badge usage, surgeon position during lateral lumbar fluoroscopy, the position of the fluoroscope to deliver less radiation to the patient, lead barrier usage, and practices to reduce the patient's and surgeon's radiation exposure during surgery.

The questionnaire was sent 3 times by e-mail to AOSpine members in each of 5 regions: Asia Pacific (AP), Europe (EU), Latin America (LA), North America (NA), and Middle East (ME), at an interval of 10 days from December 15th of 2016 to April 15th of 2017. The e-mail contained an explanation about the importance of the topic, the need to understand the gaps, and a link to the questionnaire. The questionnaire was provided in Portuguese, Spanish, and English language versions.

Statistical Analysis

Categorical data were presented as counts and percentages. Attitudes and knowledge were compared among countries if the number of responses was above 40. Comparisons were conducted using Chi-square test or Fisher's exact test. Post hoc comparisons were adjusted by Bonferroni procedure. The significance level was set at $P < .05$. Data were processed and analyzed using SPSS version 22.0 (IMB Corp, Armonk, New York).

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TABLE 1. Numbers of AOSpine Survey Participants by Region, as Well as Years of Spine Surgeons' Experience and Specialty Background

Characteristic	No. (%)
Region	
Latin America	371 (38.0)
Europe	248 (25.2)
Asia Pacific	204 (20.8)
North America	112 (11.4)
Middle East	44 (4.5)
Years of activity	
<10 yr	442 (45.1)
≥10 yr	537 (54.9)
Specialty	
Orthopedic	631 (64.5)
Neurosurgery	348 (35.5)

RESULTS

Sample Size

The total number of respondents was 979 (15.0%) from the 6524 members of AOSpine. AOSpine is an organization of spine surgeons from all over the world, with >99% of the members being spine surgeons and <1% being spine researchers. The questionnaire was sent to 1450 members of AOSpine LA and 371 surgeons answered (25.6%), 1468 members of AOSpine EU and 248 answered (16.9%), 2359 members of AOSpine AP and 204 answered (8.6%), 640 members of AOSpine NA and 112 answered (17.5%), and 607 members of AOSpine ME and 44 answered (7.3%).

Surgeon's Characteristics

Surgeons' characteristics, such as country of activity, specialty, and years of experience are shown in Table 1.

Radiation Exposure Cautions

Surgeons' answers to specific radiation exposure questions are presented in Table 2.

The correct position of the image intensifier to reduce the patient radiation during anterior–posterior spine fluoroscopy was known by 61.0% of the surgeons (Figures 1A and 1B). For surgeon-positioning during lateral lumbar fluoroscopy (Figures 1C and 1D), the correct answer was given by 36.7% of the surgeons.

Radiation Safety of Different Specialties With Different Levels of Experience

Knowledge and attitude of spine surgeons regarding radiation exposure by specialty and experience are shown in Table 3.

Knowledge and Attitude of Surgeons From Different Regions

The knowledge and attitude of surgeons from different regions regarding radiation exposure are presented in Table 4. Surgeons' responses regarding practices during fluoroscopy are illustrated in Figure 2.

DISCUSSION

It is well-known that excessive exposure to ionizing radiation can lead to cancer and cataracts.[9,10] In spite of recommended dose limits for occupational and public exposure, there is no specific dose threshold which denotes an absence of risk or absolute safety.[24-26] We undertook this study to assess the knowledge and attitude of spine surgeons from all over the world regarding radiation exposure during spine procedures.

We found that, regardless of the region of the world, the specialty or experience of the surgeon, far too many spine surgeons worldwide are not aware of basic radiation safety practices. The present paper showed that a dosimeter badge is never or rarely used, 79.3% did not know to place the patient as far from the radiation source as possible, 77.9% did not know that they should stand behind the radiation source, 74.9% of the participants did not know radiation dose limits, 63.3% were unfamiliar with the best surgeon-positioning during lateral lumbar fluoroscopy, 47.6% did not use pulse-mode fluoroscopy, and 39% did not know the correct position of the image intensifier to reduce patient radiation exposure during anterior–posterior spine fluoroscopy, and lower percentage of answers about good practice of radiation safety.

The increased popularity of MIS techniques necessarily comes with the need for more precise anatomical localization. There is such a great concern about the exposure of surgeons to radiation that it was among the top 3 reasons why surgeons were reluctant to adopt MIS procedures.[27] The greater need for radiation during minimally invasive transforaminal lumbar interbody fusion (MIS TLIF) when compared to open transforaminal lumbar interbody fusion was recognized by 83.9% of spine surgeons. To overcome the radiation problems, navigation-based systems can replace fluoroscopy.[28-31] Worldwide, in our study, only 23.2% of the spine surgeons have the technology available to use it.

Monitoring the Effective Dose

The International Commission on Radiation Protection (ICRP) and the United States National Council on Radiation Protection (NCRP) have minimal differences regarding occupational dose limits.[24,26,32] The ICRP established a total effective dose limit of an average of 20 mSv/yr in 5 yr or not more than 50 mSv in 1 yr. NCRP recommends less than 50 mSv of exposure in a single year, but also cumulative lifetime effective dose limits of 10 mSv multiplied by the worker's years of life. However, these doses are for classified workers (eg, radiologists). Spine surgeons are considered nonclassified workers.[32] The radiation dose limits

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TABLE 2. Surgeons' Answers Regarding Radiation Exposure

Questions	Total = 979 n (%)
Lead protection usage	
Lead apron	948 (96.8)
Thyroid protection	650 (66.4)
Lead glasses	169 (17.3)
Lead gloves	70 (7.2)
Usage of dosimeter badge	
Never or rarely	664 (67.8)
Sometimes	208 (21.2)
Always	107 (10.9)
Knowledge about own radiation exposure dose limits	246 (25.1)
Best surgeon position during lateral lumbar fluoroscopy	
On the side of the image intensifier	359 (36.7)
On the side of the X-ray source	518 (52.9)
I don't know	102 (10.4)
Best position of the fluoroscopy to deliver less radiation to the patient	
Image intensifier near the patient	597 (61.0)
X-ray source near the patient	234 (23.9)
I don't know	148 (15.1)
Percentage of irradiation during TLIF procedure	
Higher in MIS techniques	818 (83.6)
Higher in open techniques	30 (3.1)
No difference	84 (8.6)
I don't know	47 (4.8)
Storage of the lead apron in your hospital	
Folded	254 (25.9)
On shelves	585 (59.7)
Both	140 (14.3)
Practice used to protect yourself and patient from fluoroscopy irradiation during surgery	
Standing behind of the radiation source	314 (32.1)
Using the fluoroscope in pulse mode	513 (52.4)
Placing the patient as far from the radiation source as possible	203 (20.7)
Removing the hand from the field during fluoroscopy	658 (67.2)
Standing one or two steps away from the fluoroscope	755 (77.1)
Using computer-assisted navigation whenever possible	181 (18.5)
Fluoroscope equipment acquisition	
$<$5 yr	213 (21.8)
$\geq$5 yr	644 (65.8)
I don't know	122 (12.5)
Availability of navigation system	
I don't have a navigation system	633 (64.7)
I have but I don't use it	118 (12.1)
I use it	228 (23.3)
Reducing the time of irradiation by navigation techniques	
The radiation exposure is similar using navigation or not	48 (4.9)
There is less exposure to radiation when the navigation techniques are used	285 (29.1)
The radiation exposure is higher when the navigation techniques are used	107 (10.9)
I don't know	539 (55.1)
Steps of open lumbar arthrodesis requiring use of fluoroscopy	
When marking the region to be operated	322 (32.8)
During cannulation and insertion of the pedicle screws	615 (62.8)
During preparation and insertion of the interbody cage	455 (46.5)
Only for control after implanting the devices	370 (37.8)
Steps of idiopathic scoliosis for which fluoroscopy is essential	
Pedicular instrumentation	347 (35.4)
Uncertainty about pedicle cannulation	251 (25.6)
Only at the end of the "free hand" pedicle screw insertion	320 (32.7)
Nonessential if there is an X-ray available for control	61 (6.2)

TLIF: Transforaminal lumbar interbody fusion.

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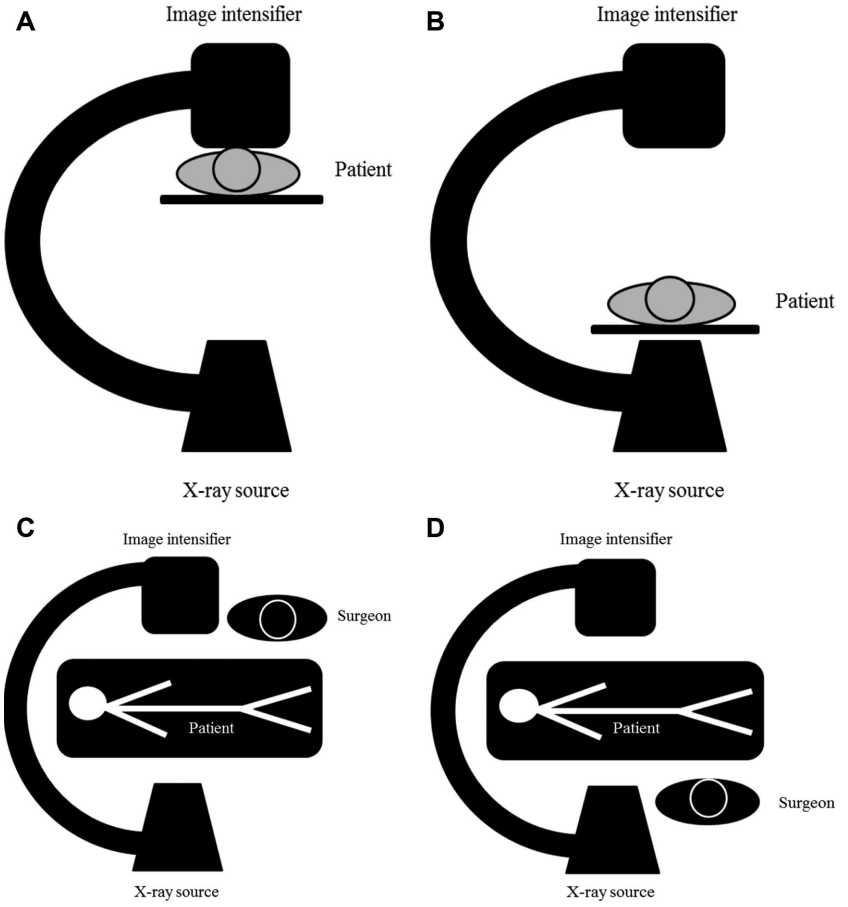

FIGURE 1. *Image of the questionnaire, showing options of anterior–posterior fluoroscopy with the patient positioned far from X-ray source* **A** *or near the X-ray source* **B**. *The correct answer, represented by the scenario that delivers less radiation to the patient, is option* **A**. *Another question included options showing lateral lumbar fluoroscopy with the surgeon positioned ipsilateral to the image intensifier* **C** *or ipsilateral to the X-ray source* **D**. *The correct answer, in terms of surgeon's radiation exposure, is option* **C**.

in this case should be 30% of the limits for classified workers (ie, radiologists), for instance, a dose limit to skin and feet of 150 mSv/yr, instead of 500 mSv. [26,32] It was suggested that the radiation dose limits for a spine surgeon who treats adolescent idiopathic scoliosis with pedicle screws assessed by fluoroscopy will be surpassed in 10 yr.[12]

The dosimeter badge usage is neglected by 67.8% of the spine surgeon. These results are better, but not less worrying than a large Turkish study, where only 5% of 1024 orthopedic surgeons reported using a dosimeter badge during fluoroscopy.[21] Jentzsch et al[3] showed a more frequent use of dosimeters—44% of the lead consultants, residents, medical students, and medical technical assistants used them more than 50% of the time. Although we observed some differences in frequency among regions, the most frequent use was in the EU (20.6%), but still showing a lower percentage. If one does not use the dosimeter badge, one cannot know how much one has been exposed. The dosimeter badge should be positioned under the lead apron to be precisely measured and the dose to the eyes is best assessed by positioning the dosimeter above the thyroid lead.[24]

Best Practice in Radiation Safety

Wearing a Lead Apron

The lead apron was used by 948 (96%) surgeons in the present study, whereas thyroid protectors, lead glasses, and lead gloves were used respectively by 650 (66.4%), 169 (17.3%), and 70 (7.2%) of the participants. The availability and use of thyroid shields in the orthopedic scenario of 179 hospitals showed that 55% had no thyroid shields available and, from those hospitals that have the thyroid protector, it was used regularly only by 16% of the surgeons.[22] Similarly, an Irish study showed that a thyroid

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TABLE 3. Knowledge and Attitude of Spine Surgeon Regarding Radiation Exposure by Specialty and Experience

	Specialty			Experience		
Knowledge and attitude	**Ortho n = 631**	**Neuro n = 348**	***P***	**<10 yr n = 442**	**≥10 yr n = 537**	***P***
Dosimeter usage	60 (9.5)	47 (13.5)	.07	35 (7.9)	72 (13.4)	.007
Correct position of the surgeon in relation to the image intensifier	251 (39.8)	108 (31.0)	.007	168 (38.0)	191 (35.6)	.46
Correct positioning of the patient in relation to anterior–posterior image intensifier	396 (62.8)	201 (57.8)	.13	277 (62.7)	320 (59.6)	.36
Equipment usage						
Lead apron	611 (96.8)	337 (96.8)	> .99	432 (97.7)	516 (96.1)	.20
Thyroid shield	397 (62.9)	253 (72.7)	.002	304 (68.8)	346 (64.4)	.15
Lead glasses	112 (17.7)	57 (16.4)	.66	87 (19.7)	82 (15.3)	.75
Lead gloves	42 (6.7)	28 (8.0)	.44	21 (4.8)	49 (9.1)	.009
Practices during fluoroscopy						
Staying behind source	174 (27.6)	140 (40.2)	< .001	129 (29.2)	185 (34.5)	.09
Usage of pulse-mode	343 (54.4)	170 (48.9)	.11	207 (46.8)	306 (57.0)	.002
Patient far from source	133 (21.1)	70 (20.1)	.74	90 (20.4)	113 (21.0)	.81
No hands on field	431 (68.3)	227 (65.2)	.35	287 (64.9)	371 (69.1)	.17
Step back	508 (80.5)	247 (71.0)	.001	334 (75.6)	421 (78.4)	.32
Usage of navigation	78 (12.4)	103 (29.6)	< .001	72 (16.3)	109 (20.3)	.12

Numbers outside parentheses represent number of surgeons. Numbers inside parentheses represent percentage of surgeons.

shield was not used in many cases due to lack of availability and lack of comfort.[23]

It is well-documented in the literature that the usage of these barriers significantly reduces radiation exposure, but the protection provided is far from 100%.[12,18] Indeed, Ul Haque et al[12] showed that thyroid exposure was 13.49 mSv/yr with the dosimeter badge in front of thyroid shield and 4.31 mSv/yr with the dosimeter badge under the thyroid shield, representing 66% of protection. Finnerty and Brennan[18] observed that 73% of 41 lead aprons that were in current use were also outside the tolerance limits for lead equivalence.

The manner in which one stores a lead apron may damage it. For instance, folding it may lead to the development of cracks, impairing its effectiveness in terms of radiation protection. Hanging the aprons is considered to be the best practice to prevent these cracks. In our study, the majority of surgeons (59.7%) stated that lead aprons are stored on shelves in their hospitals. In addition, 40.2% answered that they are stored folded or both folded and hanging.

Positioning of Surgeon, Staff, and Patient During Fluoroscopy

Whenever possible, anterior–posterior fluoroscopy, which delivers less scattered radiation, should be preferentially utilized over lateral views. This is due to the increased width of the patient in the lateral orientation.[3]

The best practice is staying on the side of the image intensifier during lateral lumbar fluoroscopy to receive a lower dose of radiation (2.2 mrem/min) when compared to staying on the X-ray source side (53.3 m 54m/min). [11] This happens because a huge amount of radiation scatters back from the patient to the X-ray source side. The intensity of this phenomenon is directly related to the patient's body mass index (Figures 3A and 3B). The same rule is not observed during lateral cervical spine surgery where radiation exposure is very similar on both sides, because the cervical region is thinner than the lumbar region (Figure 3C).[33] In general, the surgeon should stay on the image intensifier side. Incorrect answers regarding the surgeon's positioning were observed in the majority, in this survey. In the present study, 63.3% of surgeons stated incorrectly that they would be less exposed during lumbar surgery if they stayed ipsilateral to the X-ray source.

During anterior–posterior fluoroscopy, positioning the X-ray source superiorly exposes the surgeon to a higher dose of radiation than positioning it inferiorly. This occurs due to the phenomenon of radiation scattering, as shown in Figure 4. However, for patients, the exposure is greater when the X-ray source is positioned inferiorly than superiorly.[34]

Positioning of the Patient Near the Image Intensifier

The patient needs to be positioned as far as possible from the image intensifier to decrease radiation exposure.[33] In this scenario, the radiation dose to the patient was 6.5 rads, compared to 16.5 rads when the patient was positioned near the X-ray source.[33] The present survey showed the incorrect answer by 39.0% of the responders.

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TABLE 4. Knowledge and Attitude of Spine Surgeon Regarding Radiation Exposure by Region

	Regions					
Knowledge and attitude	**LA n = 371**	**EU n = 248**	**AP n = 204**	**NA n = 112**	**ME n = 44**	***P***
Dosimeter usage	31[a] (8.4)	51[b] (20.6)	9[a] (4.4)	13[a,b] (11.6)	3[a,b] (6.8)	< .001
Correct position of the surgeon in relation to the image intensifier	124[a] (33.4)	91[a] (36.7)	65[a] (31.9)	69[b] (61.6)	10[a] (22.7)	< .001
Correct positioning of the patient in relation to anterior–posterior image intensifier	218[a] (58.8)	157[a] (63.3)	126[a] (61.8)	71[a] (63.4)	25[a] (56.8)	.74
Equipment usage						
Lead apron	364[a] (98.1)	234[a] (94.4)	199[a] (97.5)	107[a] (95.5)	44[a] (100)	.53
Thyroid shield	238[a,b] (64.2)	178[b] (71.8)	130[a,b] (63.7)	85[b] (75.9)	19[a] (43.2)	.001
Lead glasses	75[a] (20.2)	40[a] (16.1)	37[a] (18.1)	13[a] (11.6)	4[b] (9.1)	.002
Lead gloves	26[a] (7.0)	23[a] (9.3)	12[a] (5.9)	7[a] (6.3)	2[b] (4.5)	< .001
Practices during fluoroscopy						
Staying behind source	109[a] (29.4)	106[b] (42.7)	66[a,b] (32.4)	23[a] (20.5)	10[a,b] (22.7)	< .001
Usage of pulse-mode	191[a] (51.5)	141[a] (56.9)	97[a] (47.5)	64[a] (57.1)	20[a] (45.5)	.21
Patient far from source	55[a] (14.8)	64[b] (25.8)	53[b] (26.0)	25[a,b] (22.3)	6[a,b] (13.6)	.002
No hands on field	219[a] (59.0)	201[b] (81.0)	128[a] (62.7)	89[b] (79.5)	21[a] (47.7)	< .001
Step back	280[a] (75.5)	187[a] (75.4)	163[a] (79.9)	91[a] (81.3)	34[a] (77.3)	.56
Usage of navigation	43[a] (11.6)	62[b] (25.0)	41[a,b] (20.1)	29[b] (25.9)	6[a,b] (13.6)	< .001

Numbers outside parentheses represent number of surgeons. Numbers inside parentheses represent percentage of surgeons.
The column proportions test assigns [a] and [b] to the categories of the column variable. For each pair of columns, the column proportions (for each row) are compared. If a pair of values is significantly different from each other at the .05 level, the values have different subscript letters assigned to them.

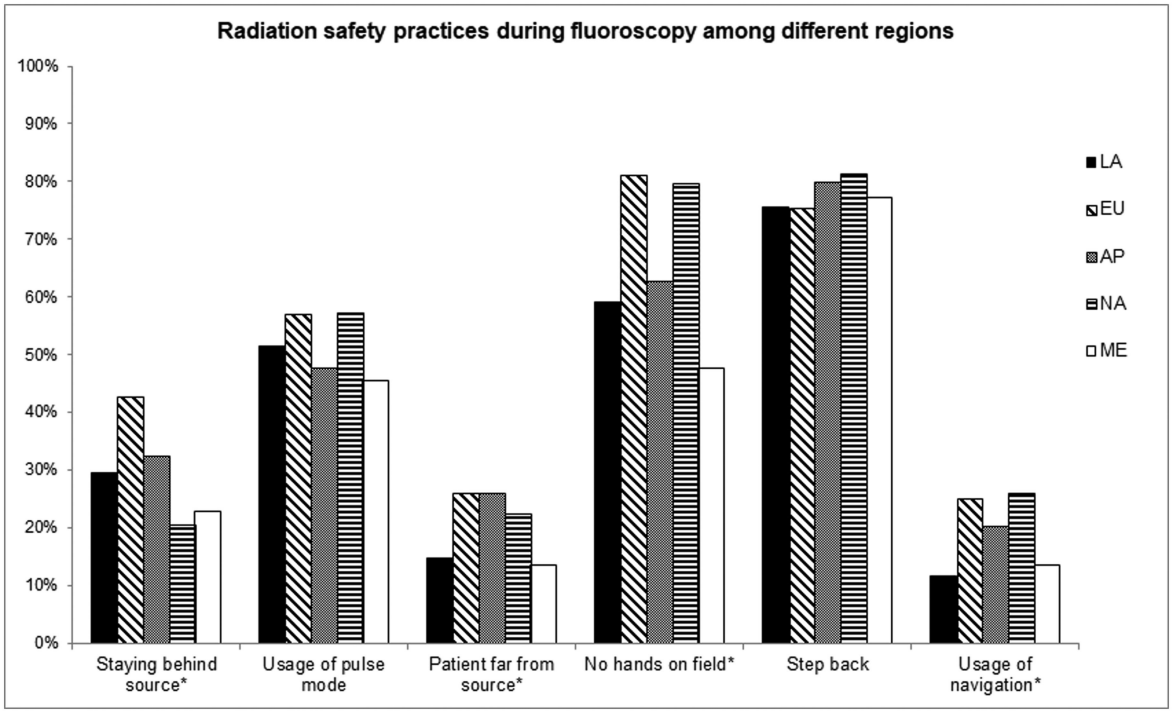

FIGURE 2. *Surgeon's responses from different regions regarding good practices during fluoroscopy. * Significant difference among the groups.*

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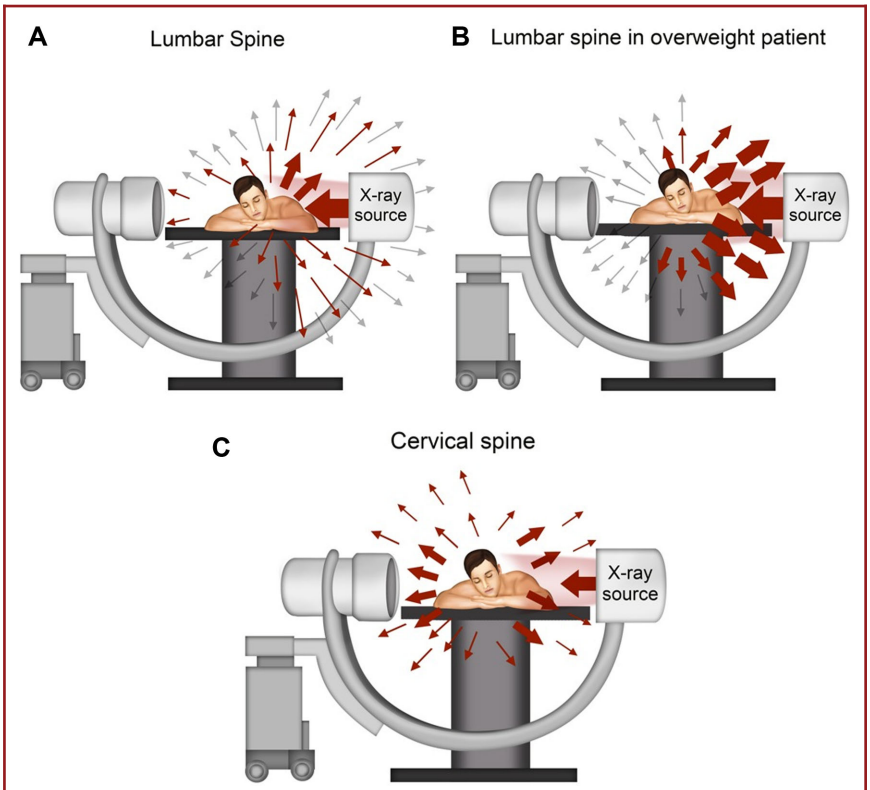

FIGURE 3. *Scattered radiation during lateral fluoroscopy, with the patient in ventral decubitus.* **A,** *The scatter of the X-ray beans is observed toward the source side in a normal-weight patient during lumbar spine lateral fluoroscopy.* **B,** *The wider the patient, the higher the backscattered radiation towards the radiation source, such as on an overweight patient.* **C,** *The opposite is observed during the lateral fluoroscopy of the cervical spine, where the scattered radiation is minimal and more X-ray beams reach the image intensifier.*

Stay as Distant From the Radiation Beam as Possible

Much less radiation is observed when the person stays 70 cm from the radiation source.[13] The reason is due to the inverse square law for radiation: standing twice the distance away from a radiation source results in one-fourth the radiation dose. Taking 1 or 2 steps or more away from the source may be sufficient to minimize exposure to surgeon and staff. Fortunately, this practice was adopted by the majority of the surgeons (77.1%).

Removing the Hands From the Field During Fluoroscopy

Removing the hands from the surgical field during fluoroscopy prevents direct but not scattered radiation exposure. This technique was adopted by 67.2% of the surgeons.

Utilization of Pulse-Mode Instead of Continuous-Mode Fluoroscopy

The pulse-mode fluoroscopy reduces the radiation exposure during fluoroscopy-assisted procedures.[15-17] The present study showed that 52.4% of spine surgeons used pulse-mode in fluoroscopy without a difference between the regions. In addition, the use of collimation is a simple practice that should be adopted in order to reduce scattered radiation.[35]

Rotating the Head Away From the Radiation Beam

Besides wearing lead glasses, a simple way to minimize exposure to the eyes during fluoroscopy is to rotate the head away from the patient and radiation beam.[14]

Knowledge and Attitude From Different Specialties and Level of Experience

Lack of knowledge regarding radiation exposure, independent of the specialty and experience, is described in the literature.[20,21,36] The majority of the neurosurgeons and emergency room doctors (92%) did not know the radiation dose received by a patient during a brain CT.[36] Knowledge regarding radiation was not significantly different when comparing surgeons' level of experience, but experienced surgeons used a dosimeter badge

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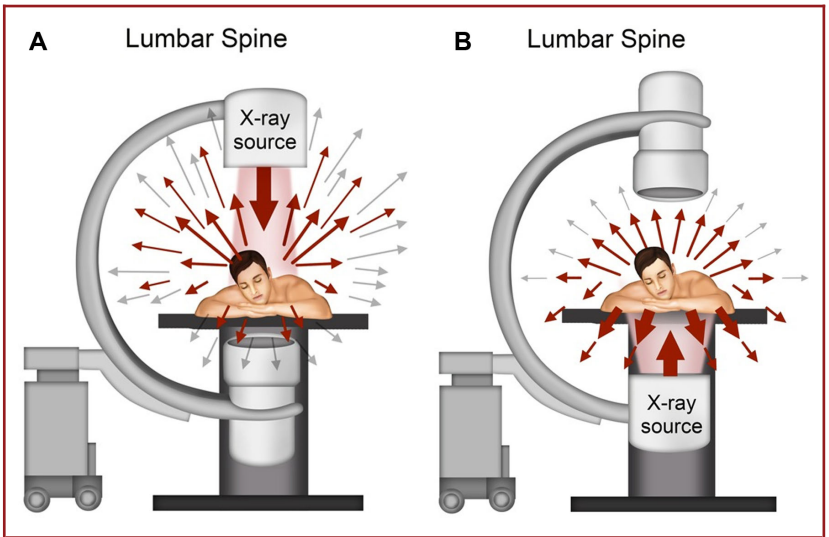

FIGURE 4. *Scattered radiation during anterior–posterior fluoroscopy, with the patient in ventral decubitus.* **A,** *When the X-ray source is positioned above the patient, the radiation spreads upwards in the room.* **B,** *The best practice in terms of surgeon's exposure is when the X-ray source is positioned below the table directing the distribution of the radiation to the floor.*

($P < .05$), lead gloves ($P < .05$), and pulse-mode fluoroscopy ($P = .002$) more often than less experienced surgeons.

Knowledge and Attitude in Different Regions

The literature does not provide data about worldwide knowledge and attitude of spine surgeons regarding radiation exposure. There are some studies, however, that assessed specific regional knowledge of orthopedic surgeons, which was reported to be weak.[19,22,23] Although our results suggest that this should be a worldwide issue, some divergences were observed among the different regions. European surgeons used the dosimeter badge more often than Latin American and Asia-Pacific surgeons ($P < .05$). Respondents from NA answered the best position of the surgeon in relation to the image intensifier (61.6%; $P < .001$) correctly more often than others. Placing the patient as far as possible from the X-ray source was more often adopted by EU and AP surgeons and least often by LA surgeons ($P = .002$). Surgeons from EU and NA used the thyroid shield more often than ME ($P = .001$). Also, surgeons from EU and NA used navigation systems more often than others ($P < .001$) These differences may be explained by different levels of radiation safety teaching and concern among regions. In addition, practices such as wearing lead barriers and using dosimeter badge and navigation systems may be absent due to the low availability of these equipment in some regions.

Strengths and Limitations

To our knowledge, this is the first study to evaluate spine surgeons' knowledge and attitude regarding radiation exposure and safety from a worldwide perspective. Although a small percentage of the eligible surgeons answered the questionnaire, 979 respondents (15.0% of 6524 members) is still a large number and enough to detect that surgeons' knowledge and attitude regarding radiation safety is woefully lacking. The reasons for the lack of best practices regarding radiation safety were not assessed. Studies show that comfort, practicality, availability, or lack of care were among several reasons that surgeons failed to use lead protection.[22,23] Our findings strongly highlight the importance of educating surgeons about the dangers of fluoroscopy and the protocols for maximizing its safe usage.

Future Perspectives

If a doctor routinely prescribed drugs such as narcotics, antibiotics, or chemotherapeutic agents improperly, resulting in harm to the patient, as well as to society, there would be an uproar and that physician might lose his license to practice. Yet, radiation is just as dangerous as any of those drugs and there is no formalized training process or oversight in most countries. AOSpine is preparing teaching material and a protocol to distribute to spine surgeons worldwide to improve education in radiation safety. The educational methods used to deliver the information will be on paper, e-learning program and a computer-based training and simulation system on a C-arm operation and radiation protection. The assessment of the amount of information retained and attitude will be online. We believe that this is a critical topic that has been under-recognized and that only through proper education we can begin to rectify the dangerous conditions that exist in the world today.

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CONCLUSION

Our findings suggest that both patients and surgeons are being unnecessarily exposed to higher radiation doses than if best practices were utilized. Since no radiation is without risk, it is imperative that there be more effective educational programs on radiation safety to improve surgeons' knowledge and attitudes. This is true in every region of the world, including first world regions such as North America and Europe. We call for all training programs and spine surgeon organizations to take action to better educate spine surgeons on this critical topic.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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Acknowledgment

We would like to thanks AOSpine for statistical support.

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