Incidence of X-ray exposure in spinal surgery

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ABSTRACT

Background: Intraoperative radiographic control (IRC) is an increasingly common practice, but it causes certain adverse events for healthcare providers. **Objective:** To measure the use of fluoroscopy in spinal surgery, recognize control measures, evaluate assimilation of protection elements by surgeons, and analyze adverse events for spinal surgeons. **Materials and methods:** A survey of 17 multiple-choice questions was e-mailed to spinal surgeons. **Results:** 55 surveys were answered. More than 60% of surgeons were spinal surgeons. The C-arm is the most widely used machine for final control by pulsating X-rays. Real-time controls are carried out in 31 % of cases. One-piece leaded aprons are the most commonly used method, but it is unknown when they should be replaced. Half of the respondents uses more than one protection element. There were 7 cases of vision changes [*sic*], 5 of thyroid disorders, 3 of dermatitis, and 2 of infertility. Three surgeons required surgery for thyroid nodules, cataracts or neoplasm. **Conclusions:** IRC is a common practice in spinal surgery. One-piece leaded aprons are the most commonly used method and they are often combined with other elements, but it is not known when aprons must be replaced. One in 3 surgeons suffered from the studied conditions, and there were 3 related surgeries. Lack of adequate protection and control is a reality for specialist surgeons, together with a lack of protocols, making this an unregulated issue.

Key words: Spinal surgery; fluoroscopy; adverse event; complications; protection.
Level of evidence: IV

Exposición a los rayos X en cirugías de columna

RESUMEN

Introducción: El control radioscópico intraoperatorio es una práctica cada vez más frecuente, que no está libre de eventos adversos para el personal de la salud. **Objetivos:** Conocer la tasa de uso de radioscopia en la cirugía vertebral, reconocer las medidas de control, evaluar la asimilación del cirujano a los elementos de protección y analizar los eventos adversos en estos profesionales. **Materiales y Métodos:** Se envió, por correo electrónico, a cirujanos espinales, una encuesta de 17 preguntas de opciones múltiples. **Resultados:** Se recibieron 55 encuestas. El 87% se dedicaba a la columna, en más del 60% de sus prácticas. El arco en C es el método más utilizado para el control final, en forma pulsátil. Solo el 31% controla el tiempo real. El delantal plomado de una pieza es el método más utilizado, pero se desconoce cuándo se debe reemplazar. La mitad utiliza más de un elemento. Siete casos de trastornos visuales, 5 patologías tiroideas, 3 dermatitis y 2 casos de infertilidad. Tres cirujanos fueron operados por nódulos tiroideos, cataratas o neoplasia. **Conclusiones:** El control radioscópico intraoperatorio es una práctica frecuente en la cirugía espinal. El delantal plomado de una pieza es el método más utilizado y, muchas veces, se lo combina, pero se desconoce cuándo se deben renovar los plomados. Uno de cada tres cirujanos presentaron las patologías evaluadas y 3, cirugías relacionadas. Así queda en evidencia la protección y el control escasos que existen en los cirujanos especialistas, acompañados de una falta de protocolización que deja a la deriva este control.

Palabras clave: Cirugía espinal; radioscopia; evento adverso; complicaciones; protección.
Nivel de Evidencia: IV

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INTRODUCTION

Fluoroscopy is widely used in surgery, especially in minimally invasive procedures where its key role is to help visualize anatomy. Radiation is known to have obscure and stochastic effects, with known health risks, such as an increased risk of cancer and cataracts.[1] Mastrangelo *et al*. found that cancer incidence was five-fold higher in radiation-exposed health professionals compared to those unexposed.[2] Thomas *et al*. reported cases of fluoroscopy-induced chronic dermatitis both in patients and in health care providers.[3]

Moreover, many spine surgeons have likely exceeded their lifetime radiation dose limits. And as a result of being exposed by 10 years during their practice, this may be the case even for those surgeons whose annual radiation exposure levels comply with the standards of the National Council on Radiation Protection and Measurements.[1] According to a study, 80.4% of orthopedic surgeons use protection elements, and 42.2% acknowledges the use of thyroid shields. The annual maximum limit of dose for the body is 20 mSv and for the hands 500 mSv. However, the limit of doses for non-classified workers (e.g. orthopedic surgeons) is just 30% of those limits (i.e. a hand dose limit of 150 mSv). The radiation limit for the thyroid gland is 300 mSv.[4] Mroz *et al*. studied radiation exposure in kyphoplasty and found that the operator's hand exposure of a single procedure could reach 1.7 mGy and eye exposure could reach 0.3 mGy. This research team concluded that total exposure to hands and eyes could easily exceed occupational exposure limits if the operators use no protection.[5] According to the American Thyroid Association, the thyroid gland is "among the most susceptible sites to radiation-induced cancer".[6] Many authors have emphasized the use of image-guided navigation for spine surgery as a way to decrease radiation exposure and operative time.[7]

We surveyed spinal surgeons to measure the use of fluoroscopy in spinal surgery, assess the use of protection elements, recognize control measures, evaluate assimilation of protection elements by surgeons, and analyze adverse events for spinal surgeons.

MATERIALS AND METHODS

A survey of 17 multiple-choice questions was e-mailed to the members of the Argentine Society for the Study of Spine Pathology (SAPCV). Answers were anonymously sent to the leading study researcher and the data was entered into an Excel spread sheets.

Questions 1 through 5 collected demographics and career-related data (sex, age, education, seniority, and percentage of workload assigned to spine procedures). Questions 6 through 11 collected data on the use and method of fluoroscopy, and protection measures (method, reason for its use, frequency and ways of use, monitoring time, and percentage of use in minimally invasive surgery). Questions 12 through 15 collected data on protection methods (protection elements, ownership, and replacement). Questions 16 through 17 collected data on conditions sustained and surgeries required during the past 10 years.

RESULTS

We received 55 answered surveys, 96% of the responders were men (53/2), 78% were under 50 years old, 93% were orthopedic surgeons (51/4), 78% had less than a 30-year of seniority (Figure 1), and 87% dedicated more than 60% of their practices to spine procedures (Figure 2).

The most commonly used IRC method was C-arm fluoroscopy (95%), followed by radiography (2%) (Figure 3). The most common reason for control was final control (28%), followed by therapeutic procedures (23%) and level location (23%) (Figure 4).

Figure 5 shows the frequency of fluoroscopy use in spine procedures. The machine is used by pulsating X-rays by 98% of the respondents and only 31% carry out real-time controls.

Minimally invasive surgery constitutes less than 25% of the procedures performed by 85% of the respondents, 25-50% for 11%, and 75% only for the remaining 4%.

The one-piece leaded aprons are the used method (39 cases), it was associated with thyroid protection in 23 cases and with standing beyond a 2-meter distance in 16 cases. Combined elements of protection were used in 22 [*sic*] cases and a total lack of protection measures was communicated in 2 cases (Figure 6). Only 3 surgeons own their leaded aprons and 10 own their leaded goggles. In the remaining cases, the protection elements are owned by the medical center, and 83% of the surgeons ignore when they should be replaced.

There were 7 cases of vision changes [*sic*], 5 of thyroid disorders, 3 of dermatitis, and 2 of infertility. It is uncertain if these conditions were associated with the use of fluoroscopy. Three surgeons required surgery for thyroid nodules, cataracts or neoplasm.

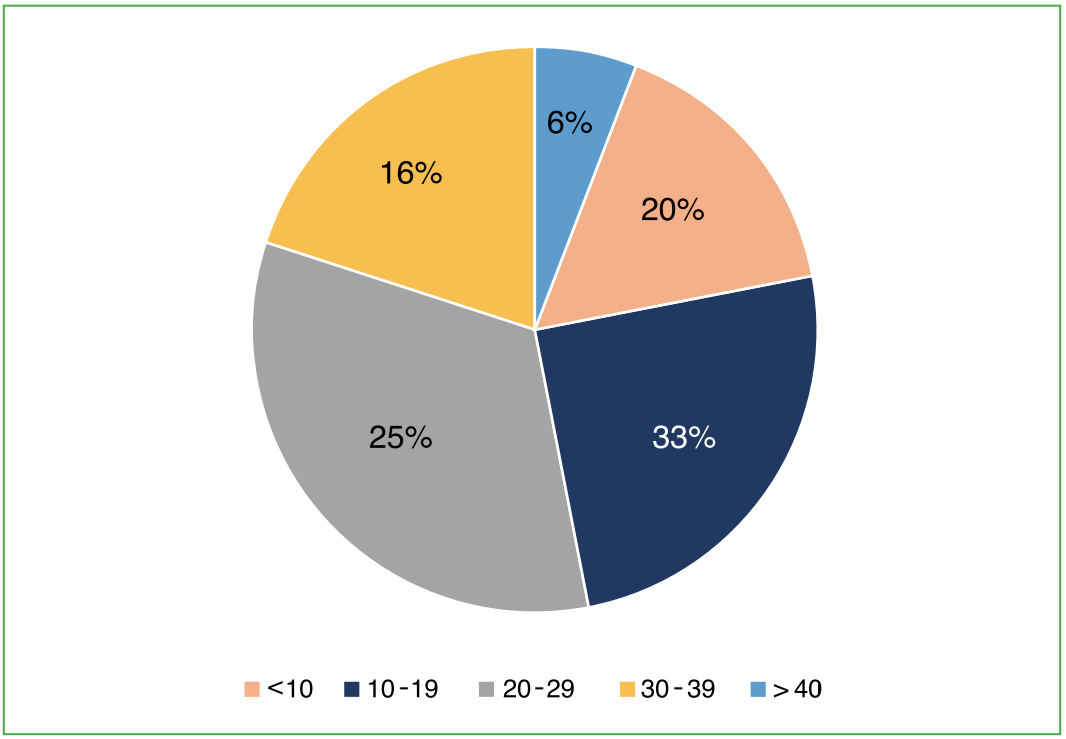
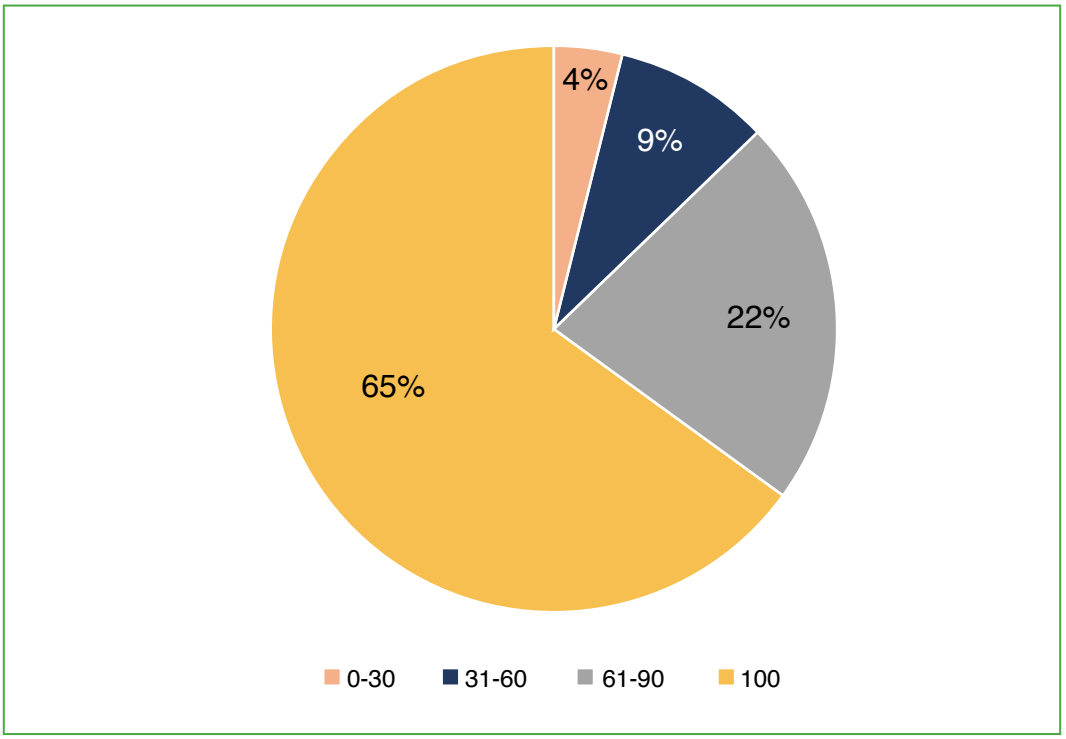


Figure 1. Respondents' seniority.



Figurae2. Respondents' percentage of workload assigned to spine procedures.

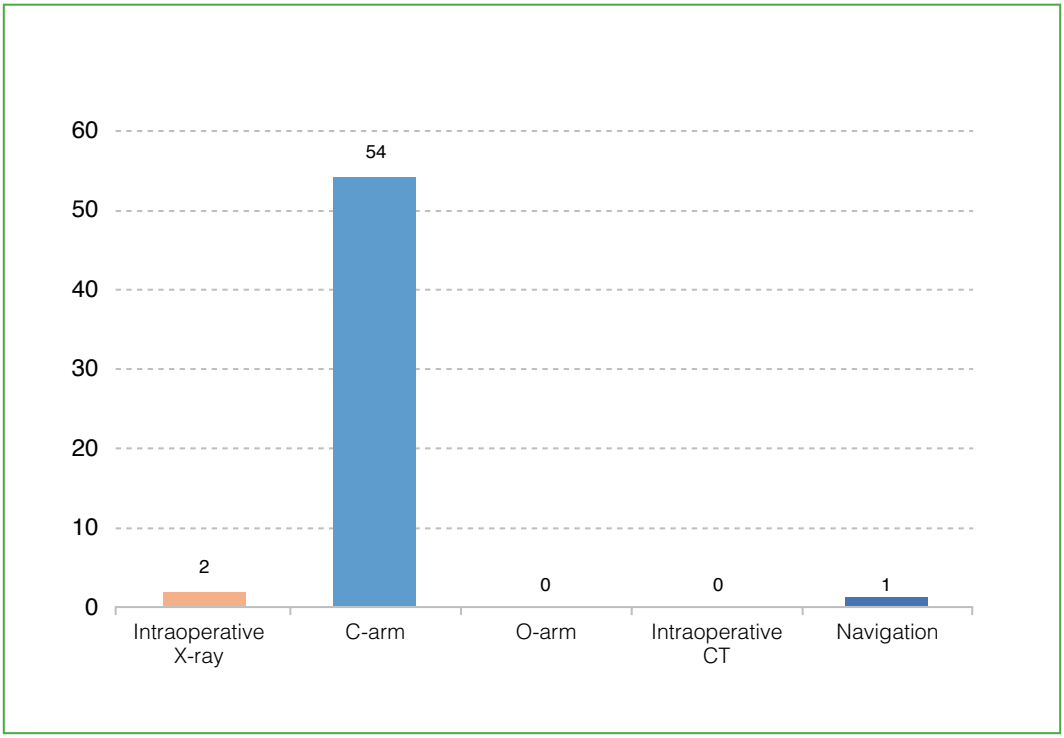


Figure 3. Respondents' imaging diagnosis method used in spine procedures.

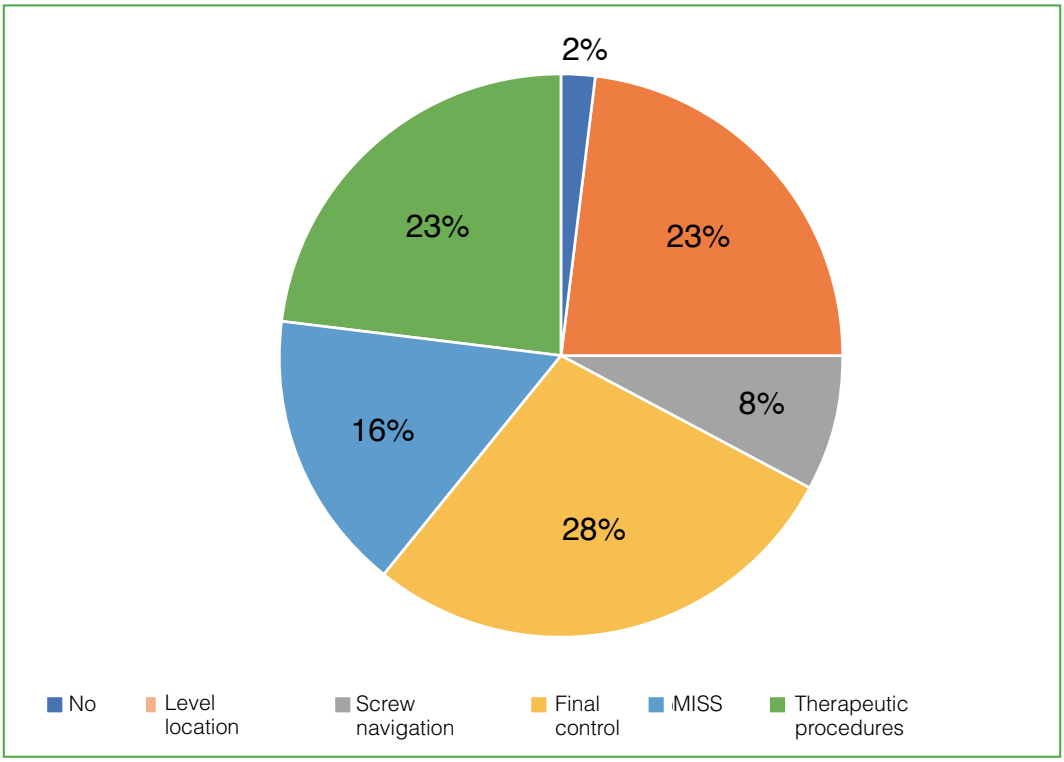


Figure 4. Respondents' reasons for using fluoroscopy in spine procedures.

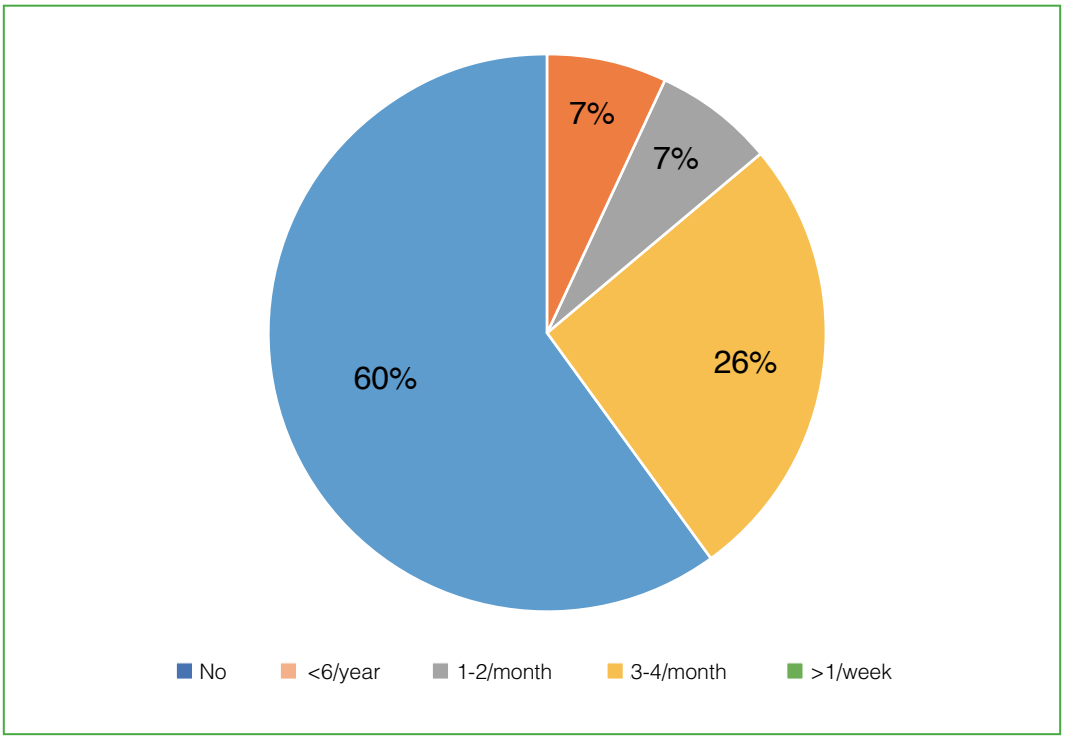


Figure 5. Respondents' fluoroscopy frequency use in spine procedures

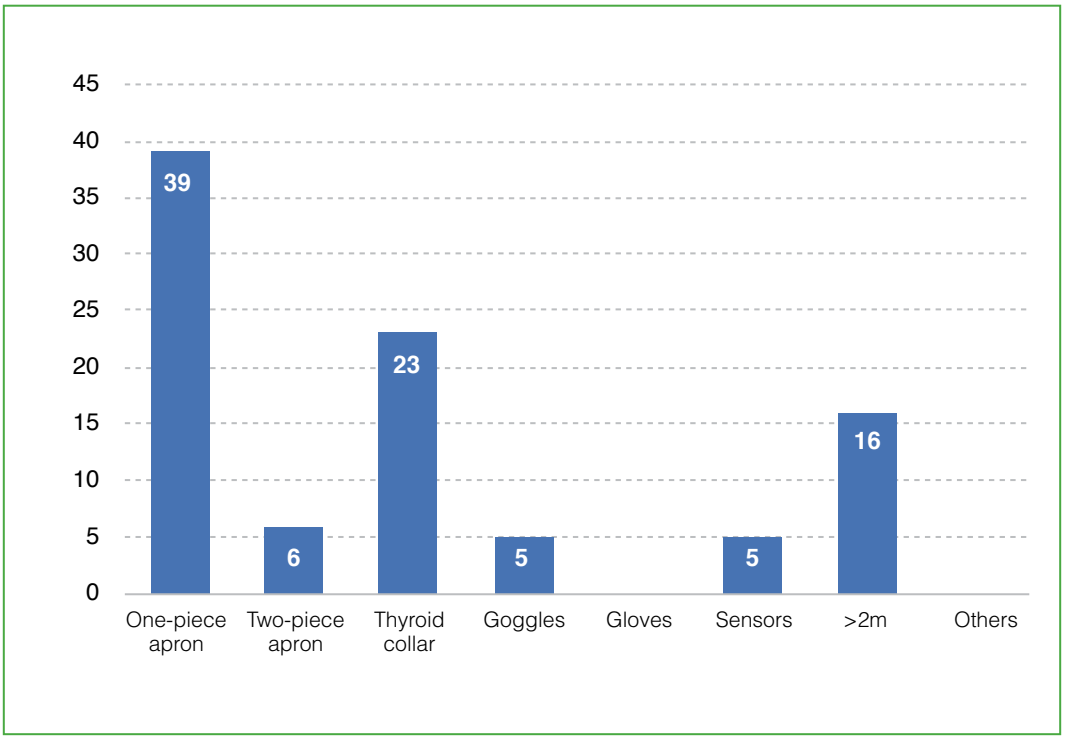


Figure 6. Respondents' protection methods for fluoroscopy in spine procedures.

DISCUSSION

Excessive exposure to radiation is a universally known cause of morbidity. It is known that lumbar spine radiography is the conventional radiographic examination associated with the highest radiation dose.[8] To minimize all related risks and misgivings, it is essential to decrease the received doses *as low as reasonably achievable* (ALARA).[8] However, this problem especially affects surgeons and operating room staff members, thus shown by a survey conducted in the US. The survey included 505 female orthopedic surgeons (AAOS fellows), their prevalence of cancer for all cancers (standardized prevalence ratio 1.85) and for breast cancer (standardized prevalence ratio 2.90) were statistically higher those of the general women population in the US.[9] Spinal surgeons are even more affected by radiation exposure, according to a study that shows that there is increased exposure during the *setup phase of the surgery*, i. e., steps taken before the incision is made (positioning, initial localization, etc.).[1] On average, the total procedure dose was 8.04 rad. The average for the radiation during the setup phase was 1.90 rad.

In our study, we assessed the use of radiation protection elements and the alternatives provided by spine specialist surgeons to decrease exposure. The specialized literature clearly defines the use of protection elements (goggles, leaded vest, thyroid collars, etc.), their durability, when to replace them, and how much absorbed radiation is acceptable in a month and a year.

Some studies have reported alternatives to decrease absorbed radiation. For example, adequate beam collimation has proven that the entire region irradiated outside of the area of diagnostic interest is 1.26 times larger than that of the area of diagnostic interest.[8]

It seems safe to assume that State-of-the-art equipment would entail less radiation than those emitted by old equipment. However, a German study compared two systems, Siremobil Iso-C 3D and Vision FD Vario 3D, and found numerically higher radiation exposures for the Vision FD Vario 3D compared to the Siremobil Iso-C 3D, this last one being older than the other one. Also, as it was expected, thyroid gland exposure is higher in cervical 3D scans.[10] This study also showed that the actual dose the surgeon receives is reduced 16 times by the leaded aprons.[10]

Chinese researchers attempted to reduce exposure risk by using computer-aided rapid prototyping. This method uses a computer surgery simulation with a design and planning scheme which displays the results of the procedure. By performing the digital surgery, it is possible to define the pedicular screw parameters (placement, diameter, and depth direction), avoid neurovascular organs, and ensure a correct placement for the designed screws.[11]

Zhang *et al*. conducted a comparative study to assess the surgical results between minimally invasive posterior decompression combined with percutaneous pedicle screws fixation and posterior open surgery for the treatment of thoracolumbar fractures. The study shows that the first procedure resulted in more radiation exposure and more operative time.[12] Likewise, a transforaminal endoscopic lumbar discectomy is an ultrasound-assisted method that takes significantly less time than a fluoroscopy-assisted percutaneous lumbar discectomy. Therefore, differences of average fluoroscopy time may result in differences in average radiation dose .[13] However, the limitations of the bone structure, the depth of the spinal structures, and the narrow visual field prevent the total replacement from fluoroscopy to ultrasound.[13]

There are approaches that could promote significant safety measures to reduce occupational radiation exposure, including pulsed low-dose diagnostic imaging, healthcare and patient education, technology to reduce radiation exposure, and the use of alternative computer-imaging modalities.[1] Some of them, like the use a of C-arm fluoroscopy machine with an articulated L-arm, resulted in less radiation exposure than the conventional methods.[14] The goal is to develop better-standardized procedures, which will not entirely rely on intraoperative fluoroscopy navigation, better software for surgery panning[15] and better computers for fully computer-guided procedures.[16]

CONCLUSIONS

IRC is a common procedure in spinal surgery, 86% of respondents resort to at least once on a weekly basis.

The one-piece leaded aprons are the used method (39 cases), it was associated with thyroid protection (23 cases) and with standing beyond a 2-meter distance (16 cases). Combined elements of protection were used in 22 [*sic*] cases and a total lack of protection measures was communicated in 2 cases. Most surgeons (86%) ignores when should their leaded clothing be replaced. There were 6 [*sic*] cases of vision changes, 5 of thyroid disorders, 3 of dermatitis, and 2 of infertility. Three surgeons required surgery for thyroid nodules, cataracts or neoplasm.

Therefore, the lack of adequate protection and control is a reality for specialist surgeons, together with a lack of protocols, making this an unregulated issue.

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REFERENCES

1. Reiser EW, Desai R, Byrd SA, Farber H, Chi D, Idler CS, et al. C-arm positioning is a significant source of radiation in spine surgery. *Spine* 2017;42(9):707-10. https://doi.org/10.1097/BRS.0000000000001869
2. Mastrangelo G, Fedeli U, Fadda E, Giovanazzi A, Scoizzato L, Saia B. Increased cancer risk among surgeons in an orthopaedic hospital. *Occupational Medicine* 2005;55:498-500. https://doi/org/10.1093/occmed/kqi048
3. Frazier TH, Richardson JB, Fabre VC, Callen JP. Fluoroscopy-induced chronic radiation skin injury. A disease perhaps often overlooked. *Arch Dermatol* 2007;143(5):637-40. https://doi.org/10.1001/archderm.143.5.637
4. Vanoli F, Gentile L, Iglesias SL, Lobos Centeno E, Diaz MP, Allende Nores C. Exposición a la radiación de los cirujanos en la fijación interna de fracturas de radio distal. *Rev Asoc Argent Ortop Traumatol* 2017;82(4):271-7. http://dx.doi.org/10.15417/674
5. El Tecle NE, El Ahmadieh TY, Patel BM, Lall RR, Bendok BR, Smith ZA. Minimizing radiation exposure in minimally invasive spine surgery. *Neurosurg Clin North Am* 2014;25:247-60. https://dx.doi.org/10.1016/j.nec.2013.12.004
6. Chang LA, Miller DL, Lee Ch, Melo DR, Villoing D, Drozdovitch V, et al. Thyroid radiation dose to patients from diagnostic radiology procedures over eight decades: 1930-2010. *Health Phys* 2017;113(6):458-73. https://doi.org/10.1097/HP.0000000000000723
7. Kim TT, Johnson JP, Pashman R, Drazin D. Clinical study minimally invasive spinal surgery with intraoperative image-guided navigation. *Biomed Res Int* 2016. http://dx.doi.org/10.1155/2016/5716235
8. Karami V, Zabihzadeh M. Beam collimation during lumbar spine radiography: a retrospective study. *J Biomed Phys Eng* 2017;7(2):101-6. PMID: 28580331
9. Chou LB, Chandran S, Harris AH, Tung J, Butler LM. Increased breast cancer prevalence among female orthopedic surgeon. *J Women Health (Larchmt)* 2012;21(6):683-9. https://doi.org/10.1089/jwh.2011.3342
10. Klingler J-H, Sircar R, Scheiwe C, Kogias E, Krüger MT, Scholz C, et al. Comparative study of C-arms for intraoperative 3-dimensional imaging and navigation in minimally invasive spine surgery Part II: Radiation exposure. *Clin Spine Surg* 2017;30(6):E669-E676. https://doi.org/10.1097/BSD.0000000000000187
11. Li X, Zhang Y, Zhang Q, Zhao C, Liu K. Clinical application of a drill guide template for pedicle screw placement in severe scoliosis. *Acta Ortop Bras* 2017;25(2):67-70. https://doi.org/ 10.1590/1413-785220172502138828
12. Zhang W, Li H, Zhou Y, Wang J, Chu T, Zheng W, et al. Minimally invasive posterior decompression combined with percutaneous pedicle screw fixation for the treatment of thoracolumbar fractures with neurological deficits. *Spine (Phila PA 1976)* 2016;41(Suppl 19):B23-B29. https://doi.org/10.1097/BRS.0000000000001814

13. Wu R, Liao X, Xia H. Radiation exposure to the surgeon during ultrasound-assisted transforaminal percutaneous endoscopic lumbar discectomy: a prospective study. *World Neurosurg* 2017;101:658-665. https://doi.org/10.1016/j.wneu.2017.03.050
14. Nascimento A, Defino H, Silva M, Araújo J, Ronaldo LF. Comparison of exposure to radiation during percutaneous transpedicular procedures, using three fluoroscopic techniques. *Coluna/Columna* 2017;16(2):141-4. http://dx.doi.org/10.1590/s1808-185120171602178378
15. Li J, Lin J, Xu J, Meng H, Su N, Fan Z, et al. Novel approach for percutaneous vertebroplasty based on preoperative CT-based 3-Dimensional model design. *World Neurosurg* 2017;105:20-6. https://doi.org/10.1016/j.wneu.2017.05.087
16. Kraus M, von dem Berge PM, Krischak G, Weckbach S. Accuracy of screw placement and radiation dose in navigated dorsal instrumentation of the cervical spine: a prospective cohort study. *Int J Med Robot* 2014;10(2):223-9. https://doi.org/10.1002/rcs.1555