

Radiation dose assessment in patients undergoing interventional pain procedures for lumbar pathology

Evaluación de la dosis de radiación en pacientes sometidos a procedimientos intervencionistas para la patología lumbar

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Funding source: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest: The authors declare that they have no conflicts of interest related to this study.

Fecha de ingreso: 30 de enero de 2026 / Fecha de aceptación: 09 de julio de 2026

ABSTRACT

Purpose: Interventional pain-management procedures have increased in number and complexity in recent years. Consequently, both patients and healthcare staff are receiving higher radiation doses. The aim of this study was to estimate the kerma-area product (PKA) delivered to patients and the effective dose associated with the procedures performed. **Materials and Methods:** Individual doses were measured and estimated using thermoluminescent dosimeters and a NOMEX PTW multimeter. In accordance with international protocols such as IAEA TRS 457 and IAEA TECDOC 1641, PKA was estimated. It was then compared with the reference level suggested by the UK Health Protection Agency (6 Gy•cm², 88 seconds of fluoroscopy). **Results:** The PKA values obtained were below 1 Gy•cm², ranging from 0.17 Gy•cm² to 0.72 Gy•cm² (k = 2), with corresponding fluoroscopy times between 28 and 70 seconds. The effective doses (ranged 0.04 mSv - 0.15 mSv) were estimated using conversion factors suggested by NCRP Report No. 160 and taking into account the recommendations of UNSCEAR 2000. **Conclusions:** PKA values below the established reference levels support the performance of effective and optimised procedures, consistent with the professional judgement of the evaluating expert. Lower PKA values reduce the probability of occurrence of stochastic effects in both patients and healthcare personnel and help prevent the occurrence of tissue reactions. This study represents an initial approach to patient dosimetry in interventional procedures for lumbar pain treatment in the national clinical setting.

Keywords: Fluoroscopy, pain management, in vivo dosimetry, radiation protection, patient safety.

RESUMEN

Propósito: Los procedimientos de manejo del dolor intervencionista han aumentado en número y complejidad en los últimos años. En consecuencia, tanto los pacientes como el personal de salud están recibiendo dosis de radiación más altas. El objetivo de este estudio fue estimar el producto kerma-área (PKA) entregado a los pacientes y la dosis efectiva asociada con los procedimientos realizados. **Materiales y Métodos:** Las dosis individuales se midieron y estimaron utilizando dosímetros termoluminiscentes y un multímetro NOMEX PTW. De acuerdo con los protocolos internacionales como el IAEA TRS 457 y el IAEA TECDOC 1641, se estimó el PKA. Luego se comparó con el nivel de referencia sugerido por la Agencia de Protección de la Salud del Reino Unido (6 Gy•cm², 88 segundos de fluoroscopia). **Resultados:** Los

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ISSN: 0719-6792



valores de PKA obtenidos fueron inferiores a $1 \text{ Gy} \cdot \text{cm}^2$, oscilando entre $0.17 \text{ Gy} \cdot \text{cm}^2$ y $0.72 \text{ Gy} \cdot \text{cm}^2$ ($k = 2$), con tiempos de fluoroscopia correspondientes entre 28 y 70 segundos. Las dosis efectivas (rango de 0.04 mSv - 0.15 mSv) se estimaron utilizando factores de conversión sugeridos por el Informe No. 160 de la NCRP y teniendo en cuenta las recomendaciones de la UNSCEAR 2000. **Conclusiones:** Los valores de PKA por debajo de los niveles de referencia establecidos respaldan la realización de procedimientos efectivos y optimizados, coherentes con el juicio profesional del experto evaluador. Valores de PKA más bajos reducen la probabilidad de ocurrencia de efectos estocásticos tanto en pacientes como en el personal de salud y ayudan a prevenir la aparición de reacciones tisulares. Este estudio representa un enfoque inicial a la dosimetría de pacientes en procedimientos intervencionistas para el tratamiento del dolor lumbar en el entorno clínico nacional.

Palabras clave: Fluoroscopia, manejo del dolor, dosimetría *in vivo*, protección radiológica, seguridad del paciente.

Introduction

Pain is a clinical syndrome associated with a broad spectrum of benign and malignant conditions and represents a major determinant of impaired quality of life. The increasing prevalence of degenerative skeletal disorders, osteoporosis, and oncological diseases has resulted in a growing demand for effective pain management strategies. In many cases, optimal pain control requires a multidisciplinary approach, particularly for patients who show insufficient response to conventional pharmacological or conservative therapies. Within this context, image-guided interventional pain management techniques have emerged as valuable therapeutic options[1].

Over recent decades, interventional radiologists and interventional pain physicians have assumed an increasingly prominent role in the treatment of pain syndromes. This evolution is largely attributable to the ability of interventional techniques to deliver minimally invasive, image-guided treatments directly to the target anatomical region, often resulting in rapid, safe, and clinically effective outcomes[2],[3]. Amongst these conditions, chronic lumbar pain is especially prevalent in the adult population and constitutes a major cause of long-term disability and reduced quality of life.

Consequently, millions of image-guided interventional pain management procedures are performed worldwide each year. Although fluoroscopy-guided techniques provide important benefits, they also raise concerns regarding patient exposure to ionising radiation[4]. During these procedures, patients are exposed to scattered and primary radiation resulting from interactions between the X-ray beam and body tissues. While reported dose levels for fluoroscopy-guided pain procedures are generally considered acceptable, uncertainties related to the health effects of low-dose radiation exposure persist. Therefore, rigorous application of the optimisation principle of radiation protection as expressed by the ALARA criterion ("as low as reasonably achievable") remains essential in clinical practice[5],[6],[7].

In addition to optimisation, justification constitutes a fundamental principle of radiological protection in medical exposures involving ionising radiation. The inappropriate, excessive, or non-optimised use of fluoroscopic and other radiological procedures may result in avoidable radiation exposure and increased healthcare costs. Although the true magnitude of the risk associated with unjustified medical exposures remains uncertain, ensuring that interventional procedures are properly justified and optimised is crucial for minimising unnecessary radiation doses to patients and healthcare personnel. The availability of reliable dosimetric data is therefore an important

component in supporting informed decision-making and improving radiation protection strategies in interventional practice[8],[9],[10],[11],[12],[13].

Within this framework, the aim of the present study is to estimate the kerma-area product (PKA) and the effective dose received during routine interventional pain management procedures. The dosimetric information obtained provides an additional tool to support the justification and optimisation of these procedures.

Materials and Methods

Definitions

The kerma-area product (PKA) measures the total radiation energy incident on a patient during a fluoroscopy procedure, calculated as the radiation's air kerma (energy per unit mass) multiplied by the beam's cross-sectional area ($\text{Gy} \cdot \text{cm}^2$). It is an indicator of the total energy delivered, used for assessing overall radiation risk (stochastic effects) and monitoring dose levels, though it does not directly reflect organ doses or skin reactions, which depend on body region and filtration[14].

The effective dose (E) is a radiation protection quantity intended to represent the overall stochastic health risk to a reference person from exposure to ionising radiation. It is calculated as the sum of equivalent doses to individual tissues and organs, each multiplied by a tissue-weighting factor that reflects the relative radiosensitivity of that tissue; it is expressed in Sievert (Sv)[15]. The effective dose allows comparison of different diagnostic or occupational exposures on a common risk-related scale, but should not be used for patient-specific risk prediction or epidemiological dose reconstruction, as stated in the discussion section of this manuscript.

Study design

This was an observational, descriptive study conducted in patients undergoing fluoroscopy-guided interventional procedures for lumbar pain management.

Study population: The participants' pool consisted of patients who underwent these procedures at Hospital Zonal Bariloche, San Carlos de Bariloche, Argentina, during the second half of 2021 and who provided informed consent to participate in this study.

Inclusion criteria: Adult patients involved in interventional techniques for pain treatment in lumbar pathology who provided

ed written informed consent to participate in the project.

Exclusion criteria: Patients involved in pain treatment techniques in lumbar pathology other than interventional procedures, or those who underwent these procedures but declined to participate or did not provide informed consent for inclusion in this project.

Sample size: The sample size was constrained by the feasibility of performing measurements at the hospital under pandemic conditions. Nevertheless, despite these constraints, a recruitment rate of approximately two patients per week was achieved, which was considered sufficient given the standardised nature of the procedures and the reproducibility of the procedural steps. This resulted in a total sample of 24 patients: 16 females (median age: 44 years old (range: 30 to 77 years old); mean weight: $78.6 \text{ kg} \pm 16.2 \text{ kg}$) and eight males (median age: 53 years old (range: 40 to 68 years old); mean weight: $86.8 \text{ kg} \pm 11.4 \text{ kg}$). No statistically significant sex-related differences were found.

Dose assessment

A dosimetry survey was carried out using thermoluminescent dosimeters (TLDs) to estimate the doses received by patients during interventional procedures for the treatment of lumbar pain. The dosimeters were calibrated using a ^{137}Cs (cesium-137) radioactive source, and energy correction factors were subsequently applied[16]. In addition, a PTW NOMEX multimetric was used in the survey, with the capability to determine parameters such as dose, tube voltage (maximum and mean), exposure time (total and per pulse), amongst others.

Nine irradiations were performed on an adult phantom to estimate the magnitude of the kerma-area product (PKA) during a standard diagnostic procedure. From the measurement of air kerma at the entrance surface, the entrance surface dose (ESD), the PKA, and the effective dose were estimated.

In accordance with the definition of PKA[14], this quantity was calculated by multiplying the air kerma measured at the centre of the X-ray beam plane by the area of the X-ray field, expressed in $\text{Gy}\cdot\text{cm}^2$. The phantom used had the standard dimensions required to simulate the thorax of an adult individual and consisted of a water filled PMMA (Poly(methyl meth-

acrylate)) structure. The fluoroscopic system employed was a Siemens Siremobil unit.

The ESD was calculated using equation 1 as suggested in the literature[14]:

$$ESD = f(E) \cdot B(A,E) \cdot K_{e,a} \quad (1)$$

where:

$f(E)$: is the energy-dependent conversion factor that converts air kerma to absorbed dose in the skin.

$B(A,E)$: is the backscatter factor, which accounts for radiation backscattered from the patient and contributing to the ESD. It depends on the radiation field area and the bremsstrahlung spectrum. Typical values range from 1.1 to 1.4.

$K_{e,a}$: is the air kerma.

Air kerma values were measured at the surface of the phantom and on the patients' skin using the mean of the reading obtained from the dosimeters (each dosimeter consisting of three TLDs), which were calibrated in terms of air kerma. The dosimeters were positioned on the patient as shown in Figure 1. In addition, the number of exposures, exposure time, tube voltage, and tube current were recorded.

The effective dose was calculated from the PKA by applying a conversion coefficient of $0.21 \text{ mSv}\cdot\text{mGy}^{-1}\cdot\text{cm}^{-2}$, as recommended in the literature for this type of procedure[17],[18]. A PKA value of $6 \text{ Gy}\cdot\text{cm}^2$ corresponding to a fluoroscopy time of 88 seconds was adopted as the reference level[19].

Results

Table 1 presents the measurements performed using an adult patient phantom, TLDs, and the PTW NOMEX system, together with the calculated quantities, as well as the number of exposures and the fluoroscopy time for each measurement. The PKA values obtained for all measurements are below the adopted reference level ($6 \text{ Gy}\cdot\text{cm}^2$). Uncertainty assessment was carried out as stated in the literature[20].

Table 1. Measured and calculated quantities for a patient phantom.

Results are expressed with a relative expanded uncertainty of $k = 2$ [20].						
Meas	# shoots	Time [s]	K_{aire} [mGy]	ESD [mGy]	PKA [$\text{Gy}\cdot\text{cm}^2$]	E [mSv]
1	22	70	5.50	6.18	0.59	0.12
2	25	79	6.76	7.60	0.72	0.15
3	13	47	1.56	1.76	0.17	0.04
4	13	47	2.22	2.50	0.24	0.05
5	13	47	1.93	2.17	0.21	0.04
6	13	47	1.71	1.92	0.18	0.04
7	11	35	4.75	5.34	0.58	0.11
8	9	28	3.69	4.14	0.70	0.08
9	11	35	2.57	2.89	0.68	0.06

K_{air} : air kerma; ESD: entrance surface dose; PKA: air kerma-area product; E: effective dose. The "time" column indicates the fluoroscopy time.

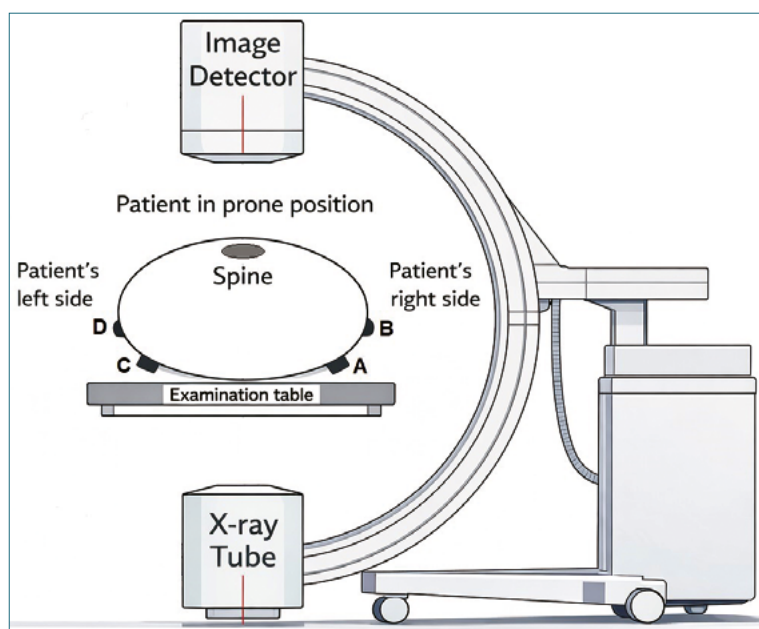


Figure 1. Scheme of the patient's cross-sectional view. Letters A, B, C and D represent the arrangement of TLDs on the patient's skin surface. Irradiation field diameter: 11 cm. Irradiated area: 95.03 cm². TLD correction factor[20]: 1.06

In addition, dosimetry was performed for 24 patients at four positions, as indicated in the schematic shown in Figure 1, with the dosimeters positioned so as not to interfere with the interventional procedure. Table 2 presents the air kerma values measured at the different positions and for the type of procedure performed.

Discussion

Dose management is a key aspect of fluoroscopy-guided interventional procedures for the treatment of lumbar pain, particularly in the context of the increasing number of interventions performed and the cumulative nature of radiation exposure. For anaesthesiologists and pain physicians, fluoroscopy is an indispensable tool that improves procedural accuracy and patient safety by facilitating correct needle placement and anatomical localisation. Nevertheless, its use entails exposure to ionising radiation, which may become clinically relevant in prolonged or technically demanding procedures. Although radiation doses per procedure are generally moderate, suboptimal technique, limited operator experience, or inadequate equipment settings may result in unnecessary patient exposure, highlighting the importance of appropriate training and adherence to radiation protection principles in interventional pain practice[21].

Patient radiation dose during interventional pain procedures shows considerable variability, influenced by factors such as the imaging modality employed, procedural complexity, patient anatomy, and operator-dependent practices, including fluoroscopy time, beam angulation, and collimation. From a clinical perspective, this variability underscores the need for systematic and practical dose monitoring strategies that can be integrated into routine anaesthesiology practice without interfering with procedural workflow. The use of surrogate dosimetric quantities, such as air kerma, kerma-area product (PKA), and fluoroscopy time, allows clinicians to monitor radiation exposure,

identify high-dose procedures, and support optimisation efforts aimed at reducing patient dose while maintaining procedural efficacy[22],[23].

Dose estimates based on indirect metrics are subject to inherent uncertainties related to patient size and anatomy, beam geometry, field overlap, tube angulation, backscatter, calibration of dose indicators, and system-specific assumptions. In clinical interventional practice, these uncertainties are generally addressed implicitly and qualitatively rather than through formal uncertainty propagation, as suggested in the literature[20]. This approach reflects the primary role of surrogate dose quantities in anaesthesiology: to support dose awareness, guide optimisation strategies, and define trigger levels for follow-up, rather than to provide precise patient-specific dosimetric estimates.

Within this context, effective dose constitutes a useful radiation protection quantity for interventional pain practice. Although it is not intended for individual patient risk estimation, effective dose enables comparison of the relative radiation burden associated with different imaging techniques, procedural protocols, or institutional practices. In lumbar interventional pain procedures, it has proven particularly valuable for comparing fluoroscopy-guided and CT-guided approaches and for supporting justification and optimisation decisions. When used in conjunction with procedure-specific quantities such as PKA, effective dose contributes to a coherent dose management framework that promotes safer clinical practice and reinforces radiological protection principles in anaesthesiology and pain management.

Conclusions

Patient dosimetry should be a fundamental component of medical procedures involving ionising radiation, with the aim of maximising clinical benefits while minimising the associated risks, in particular the probability of future stochastic effects

Table 2. Air kerma values measured in 24 patients at the positions indicated in Figure 1 (0.00 indicates that the measured values is below the recording threshold of 0.1 mGy). Results are expressed with a relative expanded uncertainty of $k = 2$ [20]

Patient	Air kerma [mGy]; position				# shoots	Procedure
	A	B	C	D		
1	2.85	-	1.60	-	56	CESI
2	1.42	-	1.12	-	31	SIIAI L. ZAIAI L5-S1 L
3	1.08	0.90	0.38	-	32	SIIAI L
4	-	0.00	-	-	53	ZAIAI L
5	-	-	-	-	20	Incomplete
6	0.37	0.00	0.25	6.08	54	TFSI L5/S1 L + CESI
7	0.22	0.69	1.58	0.28	42	TFSI L5/S1 R + CESI
8	0.75	0.00	0.25	0.00	39	ZAIAI L5-S1 L4-L5 L
9	4.86	0.00	0.49	2.58	47	SIIAI L. ZAIAI L5-S1 L
10	0.28	0.00	0.47	0.00	33	ZAIAI L5-S1 L4-L5 R + SIIAI R
11	0.58	0.00	0.57	15.65	59	TFSI L5/S1 R + CESI
12	2.75	0.18	0.67	0.24	43	ZAIAI L5-S1 L4-L5 R + SIIAI R
13	0.45	0.00	0.58	2.98	36	ZAIAI L5-S1 L4-L5 L
14	0.48	0.37	0.67	2.23	51	TFSI L3/L4 R + CESI
15	1.52	0.17	0.14	1.78	26	TFSI L5/S1 R
16	0.48	0.00	1.08	6.80	70	TFSI L4/L5 L
17	0.15	0.00	5.28	0.21	33	CESI
18	1.79	0.30	0.83	10.60	48	Intradiscal platelet-rich plasma L5 + L4.
19	0.17	0.00	0.39	0.13	27	Concordance proof L5-S1 L4-L5 L3-L4
20	1.34	0.26	0.64	0.38	110	TFSI L4-L5 L.
21	0.00	0.00	0.18	0.00	51	Concordance proof L5-S1 L4-L5 L3-L4
22	2.35	0.14	-	1.04	26	SIIAI R. ZAIAI L5-S1 R
23	4.82	0.00	-	1.41	36	CESI
24	1.66	0.00	-	-	32	ZAIAI L5-S1 L4-L5 L

CESI: Caudal epidural injection; SIIAI: Sacroiliac intra-articular injection; ZAIAI: Zygapophyseal intra-articular injection; TFSI: Transforaminal injection.

resulting from radiation exposure.

The patient phantom dosimetry performed in this study shows that all recorded values of the kerma-area product (PKA) are below the adopted reference level. This finding indicates, in principle, that it is possible to carry out successful and optimised procedures while reducing the likelihood of radiation-induced effects in patients. The interventional procedures were performed and their results analysed by a local expert. However, national diagnostic reference levels (DRLs) have not yet been established. Their development would be highly desirable to ensure standards tailored to the local context, given their dependence on the technology employed and on socio-economic and demographic factors.

The present study represents an initial step in the local dosimetric assessment of patients, contributing to increased awareness of the importance of patient dosimetry. Furthermore, from a radiological protection perspective, it provides a first picture of the current situation of interventional procedures for the treatment of lumbar pathology at a national level and serves as a starting point for future improvements.

Ethical approval

This study was reviewed and approved by the Ethics Committee and Commission for the Evaluation of Human Health Research Projects (CEEPISH) of the Ministry of Health of Rio Negro Province, Argentina (Resolution No. 5451/21 MS). Written informed consent was obtained from all participants prior to inclusion in the study.

References

1. Rauch M, Hattingen E. Interventional pain treatment in radiology: an overview of practical approaches. Clin Imaging. 2025;125:110530. doi: 10.1016/j.clinimag.2025.110530. PMID: 40499286.
2. Bauones S, Cazzato RL, Dalili D, Koch G, Garnon J, Gantzer J et al. Precision pain management in interventional radiology. Clin Radiol. 2023;78(4):270-8. doi: 10.1016/j.crad.2022.09.135. PMID: 36931782.

3. Bittman RW, Friedberg EB, Fleishon HB, Prologo JD. Global approach to the patient with pain in interventional radiology. *Semin Intervent Radiol*. 2018;35(4):342-9.
4. Pavlovich Zhitny V, Do K, Kawana E, Do J, Wajda MC, Gualtieri RT, et al. Radiation exposure in interventional pain management physicians: a systematic review of the current literature. *Pain Physician*. 2024;27:E17-35. PMID: 38285025.
5. Botwin KP, Thomas S, Gruber RD. Radiation exposure of the spinal interventionalist performing fluoroscopically guided lumbar transforaminal epidural steroid injections. *Arch Phys Med Rehabil*. 2002;83:697-701. doi: 10.1053/apmr.2002.32439. PMID: 11994810.
6. Hendee WR, Edwards FM. ALARA and an integrated approach to radiation protection. *Semin Nucl Med*. 1986;16:142-50.
7. Valentin J. Avoidance of radiation injuries from medical interventional procedures. *Ann ICRP*. 2000;30(7):1-67.
8. Lee CI, Haims AH, Monico EP, Brink JA, Forman HP. Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. *Radiology*. 2004;231:393-8. doi: 10.1148/radiol.2312030767. PMID: 15031431.
9. Hadly JL, Agola J, Wong P. Potential impact of the American College of Radiology Appropriateness Criteria on CT for trauma. *AJR Am J Roentgenol*. 2006;186:937-42.
10. Brenner DJ, Hall EJ. Computed tomography - an increasing source of radiation exposure. *N Engl J Med*. 2007;357:2277-84.
11. Oikarinen H, Meriläinen S, Pääkkö E, Karttunen A, Nieminen MT, Tervonen O. Unjustified CT examinations in young patients. *Eur Radiol*. 2009;19:1161-5.
12. Rehani MM, Frush DP, Berris T, Einstein AJ. Patient radiation exposure tracking: worldwide programs and needs - results from the first IAEA survey. *Eur J Radiol*. 2012;81:968-76. doi: 10.1016/j.ejrad.2012.07.004. PMID: 22840382.
13. Seuri R, Rehani M, Kortenesniemi M, et al. Tracking radiological procedures and dose: experience from Finland. *AJR Am J Roentgenol*. 2013;200(4):771-5. doi: 10.2214/ajr.12.10112. PMID: 23521446.
14. International Atomic Energy Agency. Patient dose optimization in fluoroscopically guided interventional procedures. IAEA-TEC-DOC-1641. Vienna: IAEA; 2010.
15. International Commission on Radiological Protection. The 2007 recommendations of the International Commission on Radiological Protection. ICRP Publication 103. *Ann ICRP*. 2007;37(2-4). PMID: 14389685.
16. Scarnichia E. Discriminación de energía en dosimetría personal. Bariloche: Centro Atómico Bariloche; 1996.
17. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States. NCRP Report No. 160. Bethesda, MD: NCRP; 2009.
18. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. UNSCEAR 2000 Report, Vol I. New York: United Nations; 2000.
19. Hart D, Hillier MC, Shrimpton PC. Doses to patients from radiographic and fluoroscopic X-ray imaging procedures in the UK - 2010 review. HPA-CRCE-034. Chilton. Health Protection Agency; 2010.
20. International Atomic Energy Agency. Dosimetry in diagnostic radiology: an international code of practice. IAEA Technical Reports Series No. 457. Vienna: IAEA; 2007.
21. Rehani MM, Ciraj-Bjelac O, Vaño E, Miller DL, Walsh S, Giordano BD, Persliden J. Radiological protection in fluoroscopically guided procedures outside the imaging department. *Ann ICRP*. 2010;40(6):1-102. doi: 10.1016/j.icrp.2012.03.001. PMID: 22732420.
22. Schmid G, Schmitz A, Borchardt D, Ewen K, von Rothenburg T, Koester O, Jergas M. Effective dose of CT- and fluoroscopically-guided perineural/epidural injections of the lumbar spine: a comparative study. *Cardiovasc Intervent Radiol*. 2006;29(1):84-91. doi: 10.1007/s00270-004-0355-3. PMID: 16228853.
23. Wagner AL. CT fluoroscopically-guided epidural injections: technique and results. *AJNR Am J Neuroradiol*. 2004;25:1821-3. doi: 10.3174/ajnr.a7178. PMID: 34083261.