Retrospective Study

Radiation Doses for Different Approaches of Fluoroscopy-Guided Epidural Injections: An Observational Clinical Study

Rekib Sacaklidir, MD, Ekim Can Ozturk, MD, Savas Sencan, MD, and Osman Hakan Gunduz, MD

From: Division of Pain Medicine, Department of Physical Medicine and Rehabilitation, Marmara University, İstanbul, Turkey

Address Correspondence:
Rekib Sacaklidir, MD
Marmara Üniversitesi Pendik Eğitim ve Araştırma Hastanesi
Fevzi Çakmak, Muhsin Yazıcıoğlu Cd No:10, 34899 Pendik/İstanbul
E-mail: rakipsacakli@hotmail.com

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Background: Although fluoroscopy-guided interventional therapies have declined in recent years, radiation exposure remains a critical issue for both patients and medical staff. Radiation exposure varies according to the physicians' experience, procedure time, patients' body mass index (BMI), imaging techniques, and the type of procedure performed.

Objective: The purpose of this study is to report procedure times and calculate the radiation doses for 4 different approaches of fluoroscopy-guided epidural injections per procedure and BMI to provide radiations doses for potential use in future dose reduction strategies.

Study Design: Retrospective, observational study.

Setting: A university hospital, pain management center.

Methods: A retrospective evaluation was performed of patients who received epidural steroid injections between January 2015 and December 2020 in a university hospital interventional pain management center. This observational study was conducted with patients aged ≥ 18 who underwent 3,711 epidural injections including cervical interlaminar, lumbar interlaminar, lumbar transforaminal, and caudal approaches. If more than one level or bilateral injections were performed, total dose and times were divided by the number of sites injected to attain procedure time and mean dose per injection. Provided doses for each patient were also divided by patients' BMI to obtain dose per BMI.

Results: The highest radiation dose per procedure was found in caudal epidural injection with 0.218 mGy·m^2, and the lowest dose was found in cervical interlaminar epidural injection with 0.057 mGy·m^2. The radiation dose per procedure was 0.123 mGy·m^2 for lumbar transforaminal and 0.191 mGy·m^2 for lumbar interlaminar epidural injection. The shortest procedure time was determined in transforaminal (37.3 seconds) injections, and the longest was in lumbar interlaminar (46.7 seconds) injections. Caudal epidural injection also had the highest radiation dose per BMI which was 0.00749, and cervical interlaminar epidural injection had the lowest radiation dose per BMI, which was 0.00214.

Limitations: Firstly, injections were performed by first- or second-year fellows in pain medicine. Moreover, patient-related factors (previous surgery, scoliosis, etc.) affecting radiation exposure were ignored.

Conclusions: Radiation dose levels and procedure times of 4 approaches of epidural injections were obtained from 3,711 procedures performed in a university hospital pain medicine clinic. BMI of patients was taken into account with the dose levels of injections given per BMI. Multicenter research with standardized techniques will assure more reliable reference levels, which will guide pain physicians to self-assess their own levels of radiation exposure.

Key words: Spine, epidural injections, radiation, radiation exposure, fluoroscopy, prevention, device safety

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Although fluoroscopy-guided interventional therapies have declined in recent years (1), radiation exposure remains a critical issue for both patients and medical staff (2). Ionizing radiation has been linked with deleterious side effects such as cataracts, skin rash, dermal necrosis, and cancer (3). Radiation exposure varies according to the physicians' experience, patients' body mass index (BMI), imaging techniques (such as magnification), and the type of procedure performed. As low as reasonably achievable (ALARA) principle is recommended to minimize the risk of acute and estimated effects of ionizing radiation (4).

There are many studies in the literature on spinal procedures (1,5-9). Manchikanti L et al found a 6.7% decrease in interventional techniques use between 2009 and 2018 (1). While there was an 89.2% increase in epidural injection between 2000-2009, declining utilization of epidural injections occurred in all categories with an annual change of 2.5% and an overall decrease of 20.7% from 2009 to 2018 (9). However, the use of facet joint interventions increased by 1.9% from 2009 to 2018 (8). On the other hand, for safety Cohen SL et al analyzed the radiation doses of 6,234 patients consisting of 9 different spinal procedures and types and made recommendations for radiation reduction (6). David C Miller et al, in their study on radiation safety for interventional spine procedures, stated that any radiation doses pose a risk to the patient and healthcare team (5).

Epidural steroid injection (ESI) is one of the most frequently performed fluoroscopy-guided spinal procedures (9). Fluoroscopic imaging ensures the injected drug reaches epidural space and lowers the risk of intravenous leakage and damaging neural structures (10). Radiation dose differs with the type and number of epidural injections performed; establishing reference levels for each approach helps to reduce exposure since they guide as a quality standard for physicians. As far as we know, there is only one study aiming to determine reference levels of different spinal injections, in which patients' body habitus was omitted (6). In different studies, it has been shown that the radiation dose exposed increases significantly as BMI increases. Therefore, BMI should be considered when calculating estimated radiation exposures for various epidural injections (11,12).

The purpose of this study is to report procedure times and calculate the radiation doses for 4 different approaches of fluoroscopy-guided epidural injections per procedure and BMI to provide radiations doses for potential use in future dose reduction strategies.

Methods

After approval of the institutional ethics committee (05.02.2021-Ethics number: 09.2021.192), a retrospective evaluation was performed of patients who received epidural steroid injections between January 2015 and December 2020 in a tertiary hospital pain management center. A total of 7,036 interventional procedures registered in the computer system was scanned. This observational study was conducted with 2,889 patients who underwent 3,711 epidural injections. Inclusion criteria were aged ≥ 18 years of age and a cervical interlaminar, lumbar interlaminar, lumbar transforaminal, and/or caudal approach. Patients without available body mass index (BMI) at the time of the procedure and without cumulative radiation dose obtained from the C-arm report were excluded. A flow diagram was made according to exclusion and inclusion criteria (Fig. 1).

Procedures

All procedures were performed by pain medicine fellows in the same fluoroscopy unit (GE healthcare OEC 9900 Elite) with intermittent imaging and under guidance of interventional pain medicine specialists having at least 5 years of experience. Linear and circular collimation were used to minimize radiation exposure for each injection regarding the ALARA principle.

Data Collection

Cumulative radiation exposure and fluoroscopy time (in seconds) for each procedure was derived from the C-arm report, which was calculated by the software of the device after obtaining the last image. If more than one level or bilateral injections were performed (especially for a transforaminal approach), total dose and fluoroscopy time were divided by the number of sites injected to attain the mean dose and time per injection. Provided doses for each patient were also divided by patients' BMI to obtain dose per BMI. Doses were given as milligray square meters ($mGy \cdot m^2$) units.

Statistical Analysis

In our study, all continuous variables (age, height, weight, BMI, numeric rating scale [NRS] score) were found to be suitable for normal distribution using the Shapiro-Wilk test except radiation dose per injection. A bootstrap, which is a nonparametric test to find estimated confidence intervals, was used to calculate dose per injection quartiles and confidence intervals. The radiation values and fluoroscopy times were found by calculating the midpoint of the 75th percentile and the upper point of the 75th percentile based on previous studies (6). Statistical analysis was performed using SPSS version 22 (SPSS Inc., Chicago, IL, USA). A *P* value of < 0.05 was considered statistically significant.

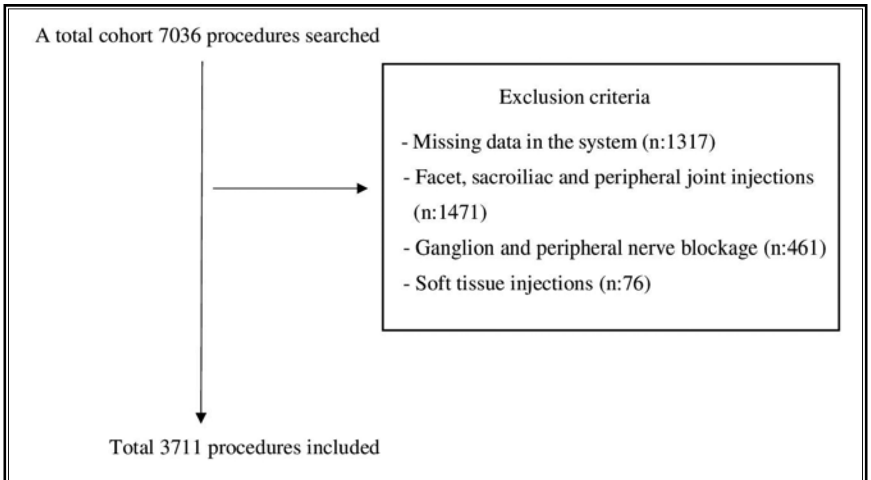

Fig. 1. *Patient flow diagram.*

Results

Demographic data such as height, weight, age, and gender of all patients were collected. 41.6% of the patients were male, and 58.4% were female. While the mean age of the patients was 53.01, the BMI was found 27.90. Of the 3,711 procedures performed, 2,907 (78.3%) were transforaminal, 433 (11.6%) were interlaminar (cervical or lumbar), and 371 (9.9%) were caudal epidural injections (Table 1).

Table 1. *Baseline Characteristics (n = 3711).*

Variable value	Mean (SD) or %
Age (years)	53.01 ± 15.16
BMI (kg/m²)	27.90 ± 4.94
Gender	
Male	1203 (41.6 %)
Female	1684 (58.4 %)
Procedure	
Lumbar transforaminal	2907 (78.3 %)
Cervical interlaminar	189 (5.1 %)
Lumbar interlaminar	244 (6.5 %)
Lumbar Caudal	371 (9.9 %)

BMI = body mass index; SD = standard deviation.

The radiation dose, procedure times, and radiation dose per BMI with the 10th, 25th, 50th, 75th, and 95th percentile estimates for all procedures are listed in Table 2. Radiation dose and radiation dose per BMI for four different fluoroscopy-guided epidural injections are provided in Table 3.

The highest radiation dose per procedure was found in caudal epidural injection with 0.218 mGy·m^2, and the lowest dose was in cervical interlaminar epidural injection with 0.057 mGy·m^2. The radiation dose per procedure was 0.123 mGy·m^2 for lumbar transforaminal and 0.191 mGy·m^2 for lumbar interlaminar epidural injection (Table 3). Among the procedures, the shortest time for the procedure was determined in the transforaminal injection, while the longest duration was determined as the interlaminar injection (Table 3). Caudal epidural injection had also the highest radiation dose per BMI which was 0.00749 mGy and cervical interlaminar epidural injection had the lowest radiation dose per BMI which was 0.00214 mGy. The radiation doses per BMI for lumbar transforaminal and lumbar interlaminar injections were 0.00412 mGy and 0.00626 mGy, respectively.

Discussion

There has been a remarkable decrement in the utilization of epidural steroid injections (ESIs) for chronic spinal pain over the past decades (9). Nevertheless, ESI has shown superiority to conservative treatment in short and intermediate-term pain relief, which makes it a preferable and repeatable minimally invasive treatment option (13). Transforaminal, interlaminar, and caudal approaches are offered to deliver steroids or local anesthetics to the epidural area (14). Fluoroscopy allows the visualization of bony landmarks and still stands as the standard guidance technology for accurate needle placement, especially for interlaminar and transforaminal routes (15).

According to these results, the lowest amount of radiation exposure was found during the cervical interlaminar approach as expected due to the thinner area that radiation had passed through, whereas the highest level of exposure occurred during the caudal approach. Tendency to use a larger area while lateral imaging of sacral hiatus and presumable high ratio of

Table 2. *Dose per injection, procedure time, and radiation dose per BMI*.

Radiation Dose								
Procedure	Number of studies	Mean dose	Standard deviation	10th percentile with 95% CI	25th percentile with 95% CI	50th percentile with 95% CI	75th percentile with 95% CI	95th percentile with 95% CI
Lumbar Transforaminal	2907	0.103	0.087	0.039 (0.037-0.401)	0.055 (0.053-0.057)	0.082 (0.079-0.085)	0.121 (0.118-0.125)	0.237 (0.219-0.253
Cervical Interlaminar	189	0.055	0.070	0.018 (0.016-0.020)	0.025 (0.022-0.027)	0.035 (0.032-0.039)	0.053 (0.047-0.061)	0.168 (0.120-0.234)
Lumbar Interlaminar	244	0.145	0.125	0.047 (0.038-0.057)	0.072 (0.066-0.078)	0.110 (0.099-0.123)	0.182 (0.164-0.200)	0.340 (0.289-0.396)
Caudal Epidural	371	0.167	0.123	0.048 (0.033-0.060)	0.087 (0.079-0.099)	0.136 (0.124-0.148)	0.209 (0.195-0.228)	0.425 (0.342-0.471)
Radiation dose per BMI								
Procedure	Number of studies	Mean dose	Standard deviation	10th percentile with 95% CI	25th percentile with 95% CI	50th percentile with 95% CI	75th percentile with 95% CI	95th percentile with 95% CI
Lumbar Transforaminal	2907	0.00356	0.00290	0.00152 (0.00145-0.00159)	0.00208 (0.00202-0.00215)	0.00292 (0.00283-0.00301)	0.00401 (0.00398-0.00422)	0.00762 (0.00699-0.00832)
Cervical Interlaminar	189	0.00196	0.00236	0.00070 (0.00060-0.00076)	0.00092 (0.00084-0.00099)	0.00128 (0.00120-0.00140)	0.00196 (0.00165-0.00232)	0.00589 (0.00434-0.00901)
Lumbar Interlaminar	244	0.00478	0.00396	0.00167 (0.00145-0.00205)	0.00257 (0.00236-0.00277)	0.00383 (0.00349-0.00418)	0.00583 (0.00524-0.00670)	0.01060 (0.00917-0.01229)
Caudal Epidural	371	0.00556	0.00375	0.00176 (0.00116-0.00217)	0.00319 (0.00286-0.00341)	0.00472 (0.00440-0.00504)	0.00720 (0.00660-0.00778)	0.01260 (0.01177-0.01401)
Procedure Time (s)								
Procedure	Number of studies	Meantime	Standard deviation	10th percentile with 95% CI	25th percentile with 95% CI	50th percentile with 95% CI	75th percentile with 95% CI	95th percentile with 95% CI
Lumbar Transforaminal	2907	30.3	14.4	15.3 (15.0-17.0)	20.0 (18.0-23.0)	27.0 (25.5-29.0)	35.7 (32.0-39.0)	58.4 (49.7-74.1)
Cervical Interlaminar	189	36.3	14.3	23 (20.0-24.0)	25.5 (24.0-27.0)	30.5 (30.0-32.0)	41.0 (40.0-46.0)	60.0 (60.0-75.0)
Lumbar Interlaminar	244	41.9	25.3	23.1 (23.0-24.0)	29.0 (25.0-30.5)	34.5 (33.0-35.0)	43.0 (42.8-48.0)	106.0 (68.0-142.0)
Caudal Epidural	371	39.8	36.0	17.0 (16.5-18.0)	25.0 (21.0-26.0)	32.0 (32.0-34.0)	41.0 (40.0-42.0)	90.0 (66.0-147.0)

BMI = body mass index.

patients with a history of back surgery/lumbar stabilization selected for this approach might be reasonable explanations. In the study of Cohen SL et al (6), while the shortest procedure time was found in the caudal injection, in our study, it was found in the transforaminal injection. In our clinic fellows, who have just started their education, firstly perform caudal injection among the epidural procedures. Therefore, the caudal injection time may have been found to be longer. As a result, the prolongation of the caudal procedure may also have caused the radiation dose to be high. The following year's ultrasound guidance, which showed high feasibility and safety for caudal epidural access, might precede fluoroscopic guidance for caudal epidural injections as a part of cumulative dose reduction strategies (16).

Long-term exposure to even low doses of radiation is now believed to have harmful effects; hence, mitigating exposure to physicians performing interventional techniques is of utmost importance. Radiation may affect the cutaneous, hematological, cerebrovascular systems and, if severe, may lead to multi-organ failure. As the radiation dose increases, it can have effects ranging from mild changes in blood counts to immunosuppression and bleeding, followed by irreparable bone marrow destruction. At very high doses, there is central nervous system (CNS) failure with apnea and cardiovascular collapse (17). Wearing lead aprons, maximizing the distance from the radioactive source, minimizing exposure time, avoiding magnification, and increasing the use of collimation are the main strategies to reduce radiation exposure with respect to ALARA principle (4,18).

Aforementioned recommendations are often oversight; besides, physicians need reference level standards to assure quality controls. There is a paucity of data regarding reference dose standards for epidural injections, and available research has been focused on comparing radiation exposure for computed tomography or fluoroscopy-guided injections or conducted with relatively small sample sizes without available reference levels (19-21). Our study is inspired by the paper of Cohen et al which assessed 6.234 spinal injections and provided reference radiation doses for 11 different interventional procedures. In fact, this study neglected the BMI of patients while calculating preliminary reference levels, which was also mentioned as a limitation (6). Radiation dose and procedure time during fluoroscopy-guided spinal injections are known to be positively correlated with patients' BMI. As a result, to attain a more precise approximation, radiation doses should be adjusted with BMI, or doses per BMI should be provided for each procedure (22).

This research offers estimated levels of radiation doses, procedure time per injection, and BMI for fluoroscopy-guided cervical interlaminar, lumbar interlaminar, lumbar transforaminal, and caudal epidural injections. Procedures were performed under intermittent imaging instead of continuous image acquisition, and they were all done by pain medicine residents. An experienced pain medicine specialist supervised the vast majority of injections. Our radiation doses are far lower than those of Cohen et al (6), which might be explained by the usage of collimation and intermittent imaging or the differences in fluoroscopy units.

Table 3. *Fluoroscopy radiation doses (mGy·m²) and time level by procedure.*

Procedure	Reference dose level	Radiation dose per BMI	Reference time level (s)
Lumbar Transforaminal	0.123	0.00412	37.3
Cervical Interlaminar	0.057	0.00214	44.5
Lumbar Interlaminar	0.191	0.00626	46.7
Caudal Epidural	0.218	0.00749	41.5

BMI = body mass index.

In recent studies that are comparing transforaminal epidural steroid injections (TFESE) and interlaminar epidural steroid injections (ILESE), it is generally seen that both processes have similar efficacy (23-25). Makkar JK et al (24) found no difference in efficacy between parasagittal interlaminar and transforaminal epidural steroid injections. Choi EJ et al (26) also demonstrated similar results for both procedures at 3-month follow-up. In our study, less radiation exposure was shown in lumbar TFESE compared to the lumbar interlaminar procedure. Since the efficiencies of the 2 procedures are similar and the radiation doses are low in lumbar TFESE, it may be more logical to prefer TFESE in procedures.

Limitations

This study has a number of limitations. Firstly, injections were performed by first or second-year fellows in pain medicine. Although they were instructed by experienced interventional pain medicine specialists, it might have increased estimated levels of radiation exposure. Secondly, procedures were all done with the same fluoroscopy unit, which complicates the generalization of our results. We also could not track the exact percentage of injections conducted with radiation lowering strategies, albeit we implemented collimation in the wide majority of injections and avoided the use of magnification. Moreover, related factors (previous surgery, scoliosis, etc.) affecting radiation exposure were ignored.

Despite reflecting results provided from a single center, our radiation dose levels are strengthened with BMI adjustment with a considerable number of procedures, and we assume that our results will serve physicians to optimize radiation exposure during epidural injections.

Conclusion

Radiation dose levels and procedure time of 4 approaches of epidural injections were obtained from 3,711 injections performed in a university hospital pain medicine clinic. The BMI of patients was taken into account with the dose levels of injections given per BMI. Multicenter research with standardized techniques will assure more reliable reference levels, which will guide pain physicians to self-assess their own levels of radiation exposure.

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