Retrospective Study

Assessment of Radiation Exposure with Mandatory Two Fluoroscopic Views for Epidural Procedures

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Background: Various regulations and practice patterns develop on the basis of Local Coverage Determination (LCD), which are variably perceived as guidelines and/or mandated polices/regulations. LCDs developed in 2021 and effective since December 2021 mandated a minimum of two views for final needle placement with contrast injection which includes both anteroposterior (AP) and lateral or oblique view.

Radiation safety has been a major concern for pain physicians and multiple tools have been developed to reduce radiation dose, along with improvement in technologies to limit radiation exposure while performing fluoroscopically guided interventional procedures, with implementation of principles of As Low As Reasonably Achievable (ALARA).

The mandated two views of epidural injections have caused concern among some physicians, because of the potential of increased exposure to ionizing radiation, despite application of various principles to minimize radiation exposure. Others, including policymakers are of the opinion that it reduces potential abuse and improves safety.

Objective: To assess variations in the performance of epidural procedures prior to the implementation of the new LCD compared with after the implementation of the new LCD by comparing time and dosage for all types of epidural procedures.

Study Design: A retrospective, case controlled, comparative evaluation of radiation exposure during epidural procedures in interventional pain management.

Setting: An interventional pain management practice and a specialty referral center in a private practice setting in the United States.

Methods: The study was performed using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) criteria. The main outcome measure was radiation exposure time measured in seconds and dose measured in mGy-kG2 (milligray to kilogray squared per procedure).

Results: Changes in exposure and dose varied by procedural type and location. Exposure time in seconds increased overall by 21%, whereas radiation dose mGy-kG increased 133%. Fluoroscopy time increased most for lumbar interlaminar epidural injections of 43%, followed by 29% for cervical interlaminar epidural injections, 20% for caudal epidural injections, and 14% for lumbar transforaminal epidural injections. In contrast, highest increases were observed in the radiation dose mGy of 191% for caudal epidural injections, followed by 173% for lumbar interlaminar epidural injections, 113% for lumbar transforaminal epidural injections, and the lowest being cervical interlaminar epidural injections of 94%.

This study also shows lesser increases for cervical interlaminar epidural injections because an oblique view is utilized rather than a lateral view resulting in a radiation dosage increase of 94% compared to overall increase of 133%, whereas the duration of time of 29% was higher than the overall combined duration of all procedures which only increased by 21%.

Limitations: A retrospective evaluation utilizing the experience of a single physician.

Conclusion: The results of this study showed significant increases in radiation exposure time and dosage; however, increase of dosage was overall 21% median Interquartile Range (IQR) compared to 133% of radiation dose median IQR. In addition, the results also showed variations for procedure, overall showing highest increases for lumbar interlaminar epidural injections for time (43%) and caudal epidural injections for dosage (191%).

Key words: Spinal interventional procedures, cervical epidural injections, lumbar epidural injections, caudal epidural injections, lumbar transforaminal epidural injections, radiation exposure time, radiation dose

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National health expenditures are projected to have grown 4.3% in 2022, slower than the nominal gross domestic product (GDP) of 9.2%, leading to a decrease in the projected health spending share of GDP from 18.3% in 2021 to 17.4% in 2022 (1). However, overall healthcare costs of $4.4 trillion in 2022 are expected to increase $4.67 trillion in 2023, $4.9 trillion in 2024, and $7.17 trillion in 2031. The projected growth of national health expenditures is 5.4% on average per year. These numbers are staggering and have become a major concern to all, despite health spending falling for the first time in 60 years (2,3). COVID-19 global pandemic has affected the economy and health care since 2020 (4-6). U.S. spending on personal and public health care from 1996 to 2016 (7,8) showed the highest spending outlay of $134.5 billion in 2016 for back and neck pain with a 53.5% increase from 2013 of $87.6 billion. Further multiple evaluations of health care utilization patterns have shown significant increases in expenditure in almost all categories. The utilization patterns of interventional pain techniques showed a deceleration of utilization patterns and costs since 2009 (4,9-15), except for spinal cord stimulation implants which bucked the trend with increasing utilization (16). The major declines were observed for epidural procedures, specifically with the COVID-19 effect from 2019 to 2020, with a rate of decline of 19% and an annual decline from 2010 to 2019 of 3.1% (4,9).

As part of the policy changes to reduce utilization and potentially improve quality of care and safety, Medicare has developed multiple Local Coverage Determinations (LCDs) covering epidurals, facet joint interventions, and sacroiliac joint interventions (17-23). Further, multiple systematic reviews, i.e., several fold more than available randomized trials, have been published, along with the development of multiple guidelines (24-33).

C-arm fluoroscopy is the most commonly used imaging modality during the performance of spinal interventions. C-arm fluoroscopy may expose patients and medical staff to radiation (34-39). Multiple variables may influence radiation exposure time which include the type of view (anteroposterior (AP) versus lateral oblique), body mass index (BMI) (40-45), distance maintained from the x-ray tube, quality of the instrument, intermittent versus continuous fluoroscopy, and multiple precautions undertaken to reduce radiation exposure.

Several factors affect the exposure of the physician to scattered radiation, including the time, distance, backscattered radiation, collimation, and mode (46). During AP fluoroscopy it is easier to avoid scattered radiation by positioning the x-ray tube beneath the operating table and by physicians standing as far away as possible from the x-ray tube during the fluoroscopy (47-52). However, for lateral fluoroscopy even though the same principles apply, scattered radiation is impacting providers much prevalent. The scattered radiation on the side of the x-ray tube is 2-3 times higher than the side of the image intensifier (53). Consequently, physicians may stand on the side of the image intensifier or stay at least more than 1 meter away from the x-ray tube (54). Further, scattered radiation impacting the provider is generally higher with steep oblique positions, similar to lateral positions (55). With continuous fluoroscopy the safety of protective radiation gloves is also questioned which may increase the risk (56).

Historically, many physicians have performed epidural procedures with a single fluoroscopic view with injection of contrast unless there were issues related to the final positioning of the needle and circumstances of training, or difficult entry into the space. The new LCD (7-19) mandated that two views be documented with final position of the needle utilizing the injection of the contrast. This approach is expected to increase radiation exposure time and dosage. In fact, an evaluation of comparison of radiation exposure to physicians between AP and lateral real-time fluoroscopy when performing lumbar transforaminal epidural steroid injections by Yoo et al (39) showed increased dose levels with lateral real-time fluoroscopy compared to real-time AP fluoroscopy alone.

While this regulation is expected to increase radiation exposure time, it is also expected to improve procedural quality and safety.

Consequently, we have undertaken this evaluation assessing fluoroscopy timing and dosages before and after implementation of the new mandated two view fluoroscopy with assessment of perceived improvement of quality and safety even though absolute parameters were not available to measure these aspects.

Methods

This study was conducted utilizing an Institutional Review Board (IRB) exemption issued by Western Institutional Review Board (WIRB) Work Order #1-1294799-1 D4-Exemption-Manchikanti (04-16-2020). The study was conducted utilizing the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (57), methodologic quality assessment in interventional pain management guidance (58), and previously performed retrospective cohort studies (59,60).

Study Design

Utilizing a retrospective cohort, the study design was that of a comparative evaluation of fluoroscopic exposure time and dose in performing epidural injections prior to and after implementation of new LCDs.

Setting

The setting for the study was in an interventional pain management practice, a specialty referral center, in a private practice setting in the United States.

Objective

The objective of this retrospective study was to determine radiation exposure by means of time and dosage.

Patients

Data was collected from an interventional pain management practice undergoing epidural injections by a single physician to diminish variability.

Inclusion Criteria

All patients undergoing epidural injections in the lumbosacral and cervicothoracic regions. The types of epidurals included caudal, lumbar interlaminar, thoracic interlaminar, cervical interlaminar, and lumbar transforaminal epidural injections.

Exclusion criteria were lack of availability of appropriate data and if the number of procedures performed was less than 50 in each group.

Interventions

The intervention in this study was fluoroscopy which is part of performing epidural procedures. All patients signed appropriate consent understanding the risks and benefits of epidural injections, along with the use of fluoroscopy in performing these procedures with a contrast injection.

Data Source and Management

A retrospective review of consecutive fluoroscopic injections between August 2018 and December 2022 was performed by querying electronic medical record software prospectively collected clinical database. All patients who received an epidural injection by a single interventional pain physician with board certifications in pain medicine from the American Board of Anesthesiology (ABA), American Board of Pain Medicine (ABPM), and the American Board of Interventional Pain Physicians (ABIPP) were screened. Demographic data were obtained, including age, gender, height, and weight from the medical records. Fluoroscopy time was reported in seconds, and the radiation dose (technically a dose area product [DAP]) was reported in milligray to kilogray (mGy/kg^2) for all these procedures. Milligray (mGy) is a unit of absorbed radiation equal to one thousandth of a gray, or 0.1 rad. For bilateral transforaminal injections the total radiation dose and fluoroscopy time were halved to create a calculated dose and time for each injection and divided by number of levels. 81% of transforaminals were performed at two levels.

The patients were categorized into 2 groups: Group I consisted of all encounters undergoing epidural procedures prior to the implementation of the new LCD on December 5, 2021, and Group II consisted of encounters after December 5, 2021.

Statistical Analysis

In this study, the data collected on Microsoft Access was subjected to statistical analysis using SPSS version 22. The original data was initially described in terms of the median Interquartile Range (IQR). Nonparametric tests, specifically Mann-Whitney U tests for two groups and Kruskal-Wallis tests for more than two groups, were utilized. To address the issue of multiple comparisons, the Bonferroni correction was applied, and a significance level of 0.05 was adopted for all hypothesis testing. Additionally, parametric analysis was performed after log transformation of the data, employing either ANOVA or t-tests. The results for radiation time and radiation dose were presented as the anti-log of the mean and standard deviation.

Results

Figure 1 is the schematic presentation of flow of patients receiving epidural injections. Among a total of 16,961 encounters, interventional procedures were identified from August 2018 to December 2022. Of these, patients without epidural injections and those receiving multiple procedures were excluded. Further, thoracic epidural injections were also excluded due to their low frequency. Consequently, a total of 5,298 encounters with single epidural injection were performed between August 2018 and December 2022 by a single interventional physician (after excluding 5,710 non-epidural injections encounters, 5,893 encounters with multiple procedures, and 58 thoracic epidural injections). Encounters with multiple procedures with epidural injections were excluded due to the fact that radiation dosages were not available by procedure. The 5,298 encounters consisted of 884 cervical epidural injections, 1,112 lumbar interlaminar epidural injections, 370 caudal epidural injections and 2,922 transforaminal epidural injections. Of the transforaminal epidural injections, 66% (1,937/2,922) were performed at two levels, and 33% (974/2,922) bilaterally. All encounters prior to December 5, 2021, were assigned to Group 1, with encounters on or after that date assigned to Group 2.

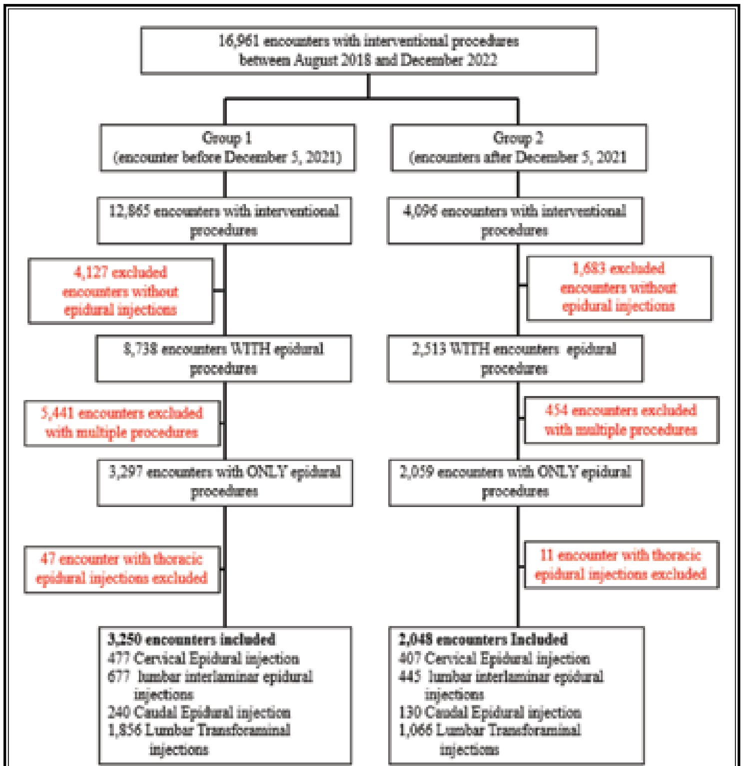

Fig. 1. *Schematic presentation of patient flow and inclusion in analysis.*

Demographic Characteristics

Table 1 shows the demographic characteristics with no significant difference between groups except for gender.

Table 2 and Fig. 2 present the fluoroscopy exposure duration and radiation dose for each procedure in both groups. The combined median fluoroscopy time was 7.0 seconds in Group I and 8.5 seconds in Group II, indicating an increase of 21%. When examining individual procedures, all procedures showed increases when compared to the baseline values, the highest increases were observed for lumbar interlaminar epidural of 43% followed by cervical interlaminar epidural of 29%, caudal epidural injections 20% and transforaminal epidurals 14%.

Additionally, Table 2 and Fig. 3 display the median radiation dose measured as mGy/kg^2.

The results of radiation dose are vastly different from the duration of exposure in seconds. Overall, mean radiation dose was 1.63 mGy-kg^2, which increased to 3.80 mGy-kg^2, a 133% increase when comparing 7 seconds to 8.5 seconds, with a 21% increase. Further, the highest increases were observed for caudal epidural injections from 1.5 mGy-kG to 4.40 mGy-kG for 191% increase, followed by lumbar interlaminar epidural injections from 2.40 mGy-kG to 6.56 mGy-kG for a 173% increase. In contrast, for cervical interlaminar epidural injections, it was 0.83 mGy-kg to 1.61 mGy-kg for a 94% increase.

Variables

Table 3 displays the fluoroscopy exposure duration and radiation dose for each procedure categorized by group and gender. The results indicate that there were no significant differences in fluoroscopy exposure duration and radiation dose within the

Table 1. *Demographic characteristics.*

		Group 1 (3,250)	Group II (2,048)	Total (5,298)	*P* value
Age	Mean + SD	56.1 ± 11.45	56.8 ± 11.12	56.4 ± 11.33	0.033
	< 45	17.4% (564)	15.7% (322)	16.7% (886)	0.182
	45-60	43.4% (1411)	43.0% (880)	43.2% (2291)	
	≥ 60	39.2% (1275)	41.3% (846)	40.0% (2121)	
Gender	Female	59.6% (1,938)	66.2% (1,356)	62.2% (3,294)	0.001
	Male	40.4% (1,312)	33.8% (692)	37.8% (2,004)	
Race	White	86.1% (2,789)	87.0% (1,774)	86.5% (4,563)	0.364
	African American & Others	13.9% (450)	13.0% (265)	13.5% (715)	
Body Mass Index (BMI)	Mean + SD	31.9 ± 8.03	32.0 ± 8.06	32.0 ± 8.04	0.540
	Underweight (< 18.5)	1.8% (57)	1.1% (23)	1.5% (80)	0.056
	Normal weight (18.5-25)	16.7% (543)	18.8% (385)	17.5% (928)	
	Pre-obesity (25-30)	29.0% (944)	26.3% (538)	28.0% (1482)	
	Obesity class I (30-35)	21.3% (691)	21.9% (449)	21.5% (1140)	
	Obesity class II (35-40)	16.0% (519)	16.8% (345)	16.3% (864)	
	Obesity class III (≥ 40)	15.3% (496)	15.0% (308)	15.2% (804)	

Table 2. *Mean fluoroscopy time (seconds) and radiation dose (mGy) by procedure before and after new local coverage determination.*

		Group I	Group II	Change in Mean/ Median Values	Percent Increase	*P* value	Total
Fluoroscopy time (seconds)							
Cervical interlaminar epidural injection	Mean ± SD (n)	6.75 ± 1.65 (477)	9.59 ± 1.63 (407)	2.84	42%	0.001	7.94 ± 1.69 (884)
	Median (IQR)	7.0 (5.0 – 9.0)	9.0 (7.0 – 13.0)	2.0	29%	0.001	8.0 (6.0 – 11.0)
Lumbar interlaminar epidural injection	Mean ± SD (n)	7.56 ± 1.75 (677)	10.20 ± 1.47 (445)	2.64	35%	0.001	8.52 ± 1.68 (1122)
	Median (IQR)	7.0 (5.0 - 11.0)	10.0 (8.0 - 13.0)	3.0	43%	0.001	9.0 (6.0 - 12.0)
Caudal Epidural Injections	Mean ± SD (n)	5.01 ± 2.22 (240)	6.24 ± 1.87 (130)	1.23	25%	0.001	5.41 ± 2.11 (370)
	Median (IQR)	5.0 (3.0 - 9.0)	6.0 (4.0 - 9.0)	1.0	20%	0.001	5.0 (3.0 - 9.0)
Lumbar transforaminal epidural Injections	Mean ± SD (n)	7.48 ± 1.65 (1856)	7.99 ± 1.53 (1066)	0.51	7%	0.001	7.66 ± 1.61 (2922)
	Median (IQR)	7.0 (5.5 - 10.0)	8.0 (6.0 - 10.0)	1.0	14%	0.001	7.5 (5.5 - 10.0)
All Combined	Mean ± SD (n)	7.17 ± 1.74 (3250)	8.60 ± 1.59 (2048)	1.43	20%	0.001	7.69 ± 1.69 (5298)
	Median (IQR)	7.0 (5.0 - 10.0)	8.5 (6.5 - 11.0)	1.5	21%	0.001	8.0 (5.5 - 11.0)
Radiation dose (mGy)							
Cervical interlaminar epidural injection	Mean ± SD (n)	0.90 ± 2.03	1.66 ± 2.11	0.76	84%	0.001	1.20 ± 2.20
	Median (IQR)	0.83 (0.55 – 1.38)	1.61 (1.00 – 2.57)	0.78	94%	0.001	1.14 (0.66 – 1.94)
Lumbar interlaminar epidural injection	Mean ± SD (n)	2.75 ± 3.06	6.28 ± 2.10	3.53	128%	0.001	3.81 ± 2.90
	Median (IQR)	2.40 (1.09 - 6.95)	6.56 (3.77 -10.90)	4.16	173%	0.001	4.28 (1.71 - 8.89)
Caudal Epidural Injections	Mean ± SD (n)	1.96 ± 3.83	4.18 ± 2.39	2.22	113%	0.001	2.56 ± 3.49
	Median (IQR)	1.51 (0.68 - 5.80)	4.40 (2.63 - 7.10)	2.89	191%	0.001	2.95 (0.89 - 6.40)
Lumbar transforaminal epidural Injections	Mean ± SD (n)	2.18 ± 2.88	4.03 ± 2.15	1.85	85%	0.001	2.73 ± 2.73
	Median (IQR)	1.86 (0.95 - 4.73)	3.96 (2.33 - 6.82)	2.1	113%	0.001	2.79 (1.23 - 5.74)
All Combined	Mean ± SD (n)	1.99 ± 3.02	3.73 ± 2.41	1.74	87%	0.001	2.54 ± 2.91
	Median (IQR)	1.63 (0.85 - 4.52)	3.80 (2.00 - 7.09)	2.17	133%	0.001	2.47 (1.10 - 5.70)

* Significant difference ($P < 0.05$) from group 1
IQR = interquartile range; (n) = number of episodes

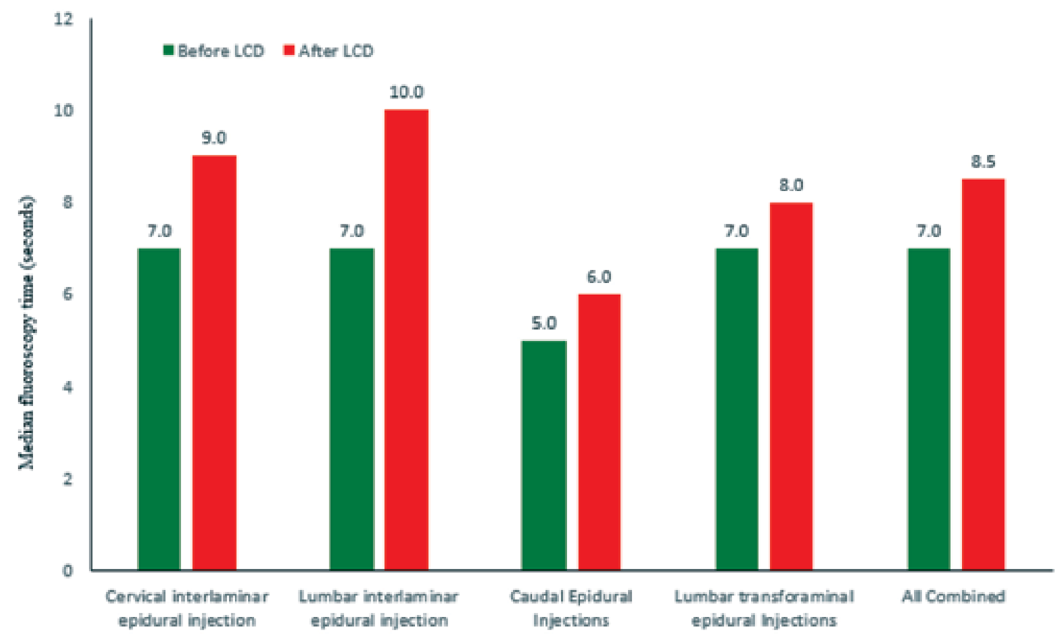

Fig. 2. *Median fluoroscopy time (seconds) by procedure before and after new local coverage determination.*

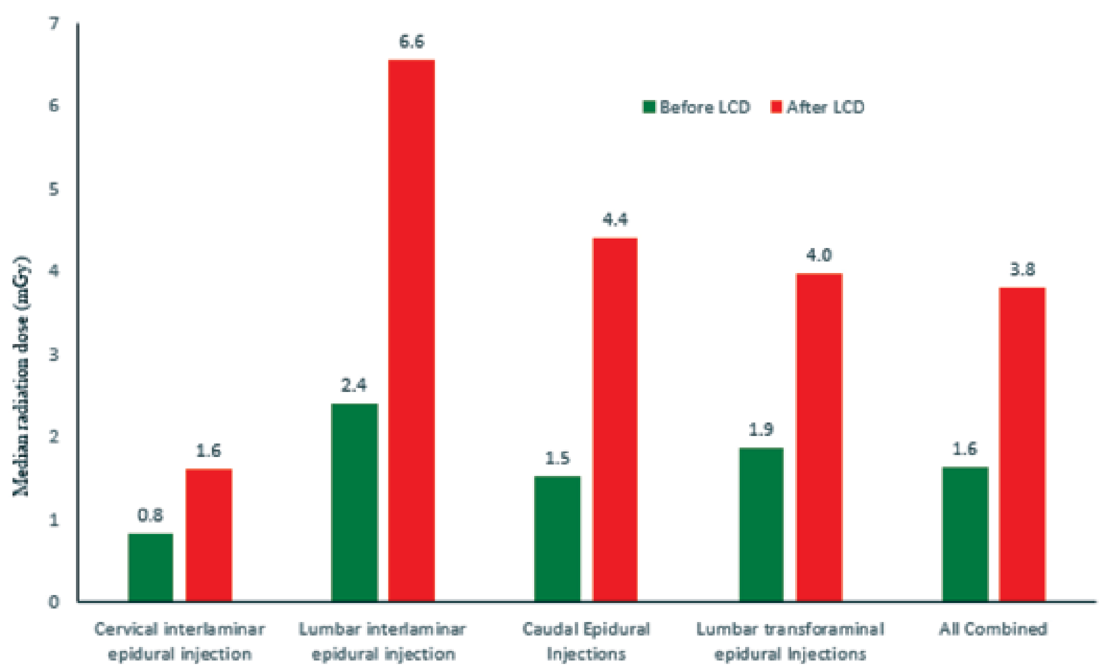

Fig 3. *Median radiation dose (mGy) by procedure before and after new local coverage determination.*

Table 3. *Mean radiation time and doses by gender and group.*

	Gender					
	Group 1			Group 2		
	Female	Male	*p* value	Female	Male	*p* value
Radiation Time (seconds)						
Cervical interlaminar epidural injection	6.61 ± 1.66 (298)	6.92 ± 1.66 (179)	0.353	9.33 ± 1.55 (262)	9.77 ± 1.74 (145)	.351
	7.0 (5.0 - 9.0)	7.0 (5.0 - 9.0)	0.296	9.0 (7.0 - 13.0)	9.0 (7.0 - 14.0)	0.399
Lumbar interlaminar epidural injection	7.59 ± 1.74 (452)	7.59 ± 1.78 (225)	0.980	10.23 ± 1.48 (346)	10.23 ± 1.51 (99)	0.921
	7.0 (5.0 - 11.0)	8.0 (5.0 - 11.0)	0.746	10.0 (8.0 - 13.0)	10.0 (8.0 - 13.0)	0.753
Caudal Epidural Injections	5.13 ± 2.24 (161)	4.79 ± 2.19 (79)	0.456	6.31 ± 1.91 (86)	6.17 ± 1.78 (44)	.0804
	5.0 (3.0 - 9.0)	4.0 (3.0 - 8.0)	0.513	6.0 (4.0 - 10.0)	6.0 (4.0 - 9.0)	0.748
Lumbar transforaminal epidural Injections	7.41 ± 1.66 (1027)	7.41 ± 1.66 (829)	0.883	7.94 ± 1.51 (662)	8.13 ± 1.55 (404)	0.505
	7.0 (5.5 - 10.0)	7.0 (5.5 - 10.5)	0.672	8.0 (6.0 - 10.0)	8.0 (6.3 - 10.0)	0.873
All Procedures	7.08 ± 1.74 (1938)	7.24 ± 1.74 (1312)	0.514	8.71 ± 1.58 (1356)	8.51 ± 1.62 (692)	0.725
	7.0 (5.0 - 10.0)	7.0 (5.0 - 10.0)	0.426	8.5 (6.5 - 11.0)	8.0 (6.5 - 11.0)	0.310
Radiation Dose (mGy/kg^2)						
Cervical interlaminar epidural injection	0.88 ± 2.04	0.96 ± 2.00	0.188	1.62 ± 2.14	1.74 ± 2.04	0.414
	0.8 (0.5 - 1.3)	0.9 (0.6 - 1.5)	0.146	1.6 (1.0 - 2.5)	1.6 (1.0 - 2.6)	0.395
Lumbar interlaminar epidural injection	2.73 ± 2.04	2.77 ± 2.93	0.878	6.17 ± 2.14	6.76 ± 1.91	0.219
	2.4 (1.1 - 6.7)	2.4 (1.1 - 7.3)	0.811	6.4 (3.6 - 11.0)	7.1 (4.3 - 10.2)	0.301
Caudal Epidural Injections	2.01 ± 2.04	1.88 ± 3.70	0.734	4.27 ± 2.45	4.07 ± 2.24	0.764
	1.5 (0.7 - 5.8)	1.8 (0.7 - 5.7)	0.823	4.5 (2.6 - 7.6)	3.6 (2.4 - 6.4)	0.473
Lumbar transforaminal epidural Injections	2.16 ± 2.04	2.21 ± 2.86	0.656	4.07 ± 2.14	3.98 ± 2.19	0.622
	1.9 (0.9 - 4.6)	1.9 (1.0 - 4.8)	0.650	4.1 (2.3 - 6.9)	3.8 (2.3 - 6.6)	0.556
All Procedures	2.00 ± 3.09	2.04 ± 2.95	0.491	3.80 ± 2.45	3.63 ± 2.34	0.227
	1.6 (0.8 - 4.5)	1.7 (0.9 - 4.5)	0.328	3.9 (2.0 - 7.3)	3.6 (2.0 - 6.5)	0.164

groups by genders. These findings remained consistent when comparing the results of parametric tests to non-parametric tests.

Since there were no variables identified in relation to age, race, and BMI, these variables were not studied and will be separately reported. Meanwhile, there were significant differences between male and female in Group I and Group II, consequently, these differences were calculated. Table 3 shows mean radiation time and doses by gender, by group. There were no significant differences observed based on gender, either with radiation time or radiation dose in comparison of the 2 groups.

Discussion

This comparative, retrospective, cohort study shows clear patterns of increase in time and duration of fluoroscopic exposure and increase in dose. There was also significant variation and differences between time and dose increases. Fluoroscopic time increases did not parallel with increases in dose. Dose increases were higher based on the applied view, AP alone, AP and oblique or AP and lateral. Thus, it shows highest increases for lumbar interlaminar epidural injections, as a majority of the times these were performed with a single view, whereas, for cervical interlaminar epidural injections there was only a mild increase in dosage, whereas it was the highest increase in the exposure time based on an oblique view was utilized instead of lateral view (Table 1). Thus, overall, there is an increase in exposure time as well as dosage based on the policy requirement of two views. Nevertheless, the policy enjoys the perception based on non-duration/exposure factors of increasing quality among all personnel involved by gathering opinions among physicians, technologists, and nursing staff. Further, these doses are considered very low compared to traditional image-guided procedures in general and other publications.

This study, the first of its nature, compares the mandated two views with others, whereas previous studies have looked at various aspects of fluoroscopy and measures to improve safety. One study by Yoo et al

(39) showed significant increases of cumulative radiation exposure at all the measurement sites for transforaminal epidural injections while performing them with real-time fluoroscopy in a lateral view.

Radiation safety for pain physicians includes understanding the principles of As Low As Reasonably Achievable (ALARA) and principles of reducing radiation exposure. Principles of reducing radiation exposure include exposure time, distance, shielding, protective measures including lead aprons and glasses, thyroid shields, and radiation reducing gloves. Methods also include collimation with a pulsed mode.

Radiation exposure is defined as the quantity of x-ray or gamma radiation required to produce an amount of ionization in air at standard temperature and pressure. When patients and physicians are exposed to radiation, some of this will be absorbed into the body described as radiation absorbed dose. Cumulative dose equivalent (DE) is used in radiation safety to measure biologic harmfulness and is defined as sievert (Sv) (47). Real-time fluoroscopy utilizes excessive radiation, and some have mandated this as a requirement to avoid adverse events (48,61,62); however, advantages of continuous fluoroscopy outweigh the risks has not been proven (63-66).

Further, the recommendations made by the Multi-Society Pain Workgroup (MPW) (62), and opposed by others (63,64), were not approved as a guideline for mandatory purposes by the U.S. Food and Drug Administration (FDA) (67). These variables have been well described in the literature (46-56).

Most radiation exposure to physicians is due to secondary radiation from leakage and scattered radiation. Leakage radiation is radiation that escapes from the shielding of the x-ray tube, and the radiation exposure rate can be reduced to 0.1% at a distance of 1 meter from the x-ray tube. Thus, leakage radiation is small and not a significant concern (68). Scattered radiation has lower energy than primary energy and deflected radiation occurs with increasing proportionally from primary radiation that has interacted with objects such as patients, floor, or the x-ray tube on its path and comes from any direction, which is critical for radiation exposure to physicians (46,47,55,56).

Collimation and pulsed sequence also assist in reducing radiation exposure. In our study, all of the protective measures were utilized, and intermittent fluoroscopy was performed. As it is shown in this study, even though with cervical epidural injections the time increased 2 seconds or 29% with increase of dose of 0.78 mGy-kG or 94% compared to lumbar interlaminar epidural injections where the time increased 3 seconds or 43% and dose increased 4.16 mGy-kG or 173%. Dramatic increases were observed with dosage for caudal epidural injections with 20% increase in time, but 191% increase with dose.

Cohen et al (35) evaluated 6,234 fluoroscopically guided spinal injections, in a retrospective analysis. There were multiple variables with 9 different types of procedures by multiple physicians. They provided reference levels of cumulative radiation dose in mGy and exposure time in seconds for fluoroscopically guided spinal interventional procedures for lumbar transforaminal of 13 mGy (30 seconds), caudal epidural 12 mGy (23 seconds), and interlaminar epidural 13 mGy (39 seconds). As shown in Table 2 in the present study, for lumbar transforaminal in Group II, it was 3.96 mGy (8 seconds), for caudal epidural 4.40 mGy (6 seconds), and for interlaminar epidural 6.56 mGy (10 seconds), which were significantly lower in our study than reported by Cohen et al (35).

Braun et al (36) conducted a randomized, double-blind controlled trial of radiation exposure in lumbar transforaminal epidural steroid injections utilizing pulsed fluoroscopy. They studied 231 cases by randomly assigning to either continuous mode fluoroscopy (high-dose), pulsed fluoroscopy with 8 pulses per second (medium-dose) or pulsed fluoroscopy with one pulse per second (low-dose). Their results showed that the mean radiation effective dose microSievert (μSv) was 121 in the high-dose group, 57.9 in the medium-dose group, and 34.8 in the low-dose group with significant differences among the groups. Thus, it is crucial that protective measures are utilized to limit radiation exposure. In our study, pulse and collimation were routinely applied.

Badawy et al (37) studied radiation exposure to staff during fluoroscopic endoscopic procedures, concluding that the magnitude of radiation exposure will accumulate over the staffs' working life. In the study, they obtained radiation exposure measurements at varying locations with different shielding set-ups surrounding a mobile c-arm fluoroscopy unit while imaging a patient equivalent phantom at different heights. Heat maps were generated for various conditions to provide visual guidelines for radiation protection. The use of appropriate radiation protection may result in reduced exposure, as per the authors, to the staff by up to 98%.

The study by Yoo et al (39) is the most relevant for this assessment. Similar to our study, they evaluated radiation exposure to physicians between AP and lateral real-time fluoroscopy when performing lumbar transforaminal epidural steroid injections. However, the differences between their study and ours is that we did not include continuous fluoroscopy and we also studied all types of epidural injections. Consequently, they experienced high fluoroscopy time of 0.27 ± 0.12 minutes or 16.2 ± 7.2 seconds in both groups with no significant difference between AP fluoroscopy compared to lateral fluoroscopy, both of them being administered with real-time continuous fluoroscopy. They also did not use collimation and pulsed mode describing certain disadvantages to these measures. However, they concluded that cumulative radiation exposure at all the measurement sites was lower for AP real-time fluoroscopy compared with lateral real-time fluoroscopy when performing lumbar transforaminal epidural steroid injections, except for outside of the groin. This data is of the most important consideration in utilizing multiple views of continuous fluoroscopy utilizing protective measures with fluoroscopy, protective maneuvers, and protective shielding. In this study, cumulative DE in mSv (milliSievert) was 4 times higher for inside the chest and 8 times higher inside the thyroid. They also emphasized the fact that distance from the x-ray tube was one of the major factors affecting the radiation exposure of physicians which can be easily corrected by physician behavior.

Multiple authors have described the impact of BMI on fluoroscopy time (40-45). The effect of age and racial distributions will be described in another report.

Park et al (34) extensively described radiation safety for pain physicians. They described 3 main causes of radiation exposure with primary x-ray beam; scattered x-ray, leakage from x-rays, and factors affecting the amount of scattered x-rays which included thickness of the area, x-ray generator location, and radiation exposure allowance which included annual maximum permissible dosage, and the use of a dosimeter. Further, they described principles of reducing radiation exposure in detail which included principles of ALARA with time, distance, shielding, fluoroscopy mode, collimation, and education. Among the principles of reducing radiation exposure, they extensively discussed time, distance, shielding, and the importance of personal protective devices and distance.

In conclusion, this study shows there are significant differences in time and dose usage of fluoroscopy when comparing two-view fluoroscopy to a single view. However, as it is mandated by guidelines and medical policies, it also has become a standard of practice and a comfort and safety measure for all involved. Further, results of our study show lesser exposure compared to real-time fluoroscopy and avoidance of collimation and pulsed fluoroscopy.

Conclusion

Based on the results of this study, lateral views increase the radiation time and dosage, whereas 30° oblique does not have so much effect on the increase of radiation dosage despite a significant increase in the duration of the time. All appropriate protective measures are essential including intermittent fluoroscopy and using continuous fluoroscopy only, when necessary, with modern advances and the drugs utilized as injectate. The perceived quality and safety appear to be improving with these regulations.

Author Contributions

The study was designed by LM and VP.

Statistical analysis was performed by VP.

All authors contributed to preparation of the manuscript, reviewed, and approved the content with final version.

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