

## SPINE SECTION

### Original Research Article

# The Impact of Body Mass Index on Fluoroscopy Time During Lumbar Epidural Steroid Injection; A Multicenter Cohort Study

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### Abstract

**Objective.** This study aimed to assess the relationship between BMI and fluoroscopy time during lumbar epidural steroid injections (LESIs) performed for lumbosacral radicular pain.

**Design.** Multicenter retrospective cohort study.

**Setting.** Three academic, outpatient pain treatment centers.

**Subjects.** Patients who underwent fluoroscopically guided LESI.

**Methods.** Mean and standard deviation (SD) fluoroscopy time were compared between patients with normal (18.5–24.9 kg/m<sup>2</sup>), overweight (25.0–29.9 kg/m<sup>2</sup>), and obese (≥30.0 kg/m<sup>2</sup>) BMI. Statistical significance was set at  $P=0.01$  due to multiple comparisons.

**Results.** A total of 2,930 procedure encounters were included, consisting of 598 interlaminar LESIs and 2,332 transforaminal LESIs. Fluoroscopy time was significantly longer in the obese patients compared to normal and overweight patients during interlaminar LESI ( $P<0.01$ ). Fluoroscopy time was significantly longer with each increasing BMI category in during transforaminal LESI ( $P<0.01$ ). These relationships remained when a trainee was involved ( $P<0.01$ ;  $P<0.01$ ), during repeat injections ( $P<0.01$ ;  $P<0.01$ ), and during bilateral transforaminal LESIs ( $P<0.01$ ). While longer fluoroscopy times were required in high BMI categories during L5-S1 transforaminal LESI ( $P<0.01$ ), there was no relationship between fluoroscopy time and BMI during L4-L5 and S1 transforaminal LESI ( $P=0.02$ ;  $P=0.13$ ). Fluoroscopy time during interlaminar LESI compared to transforaminal LESI was significantly lower within all BMI categories (all  $P<0.01$ ).

**Conclusions.** The findings of this study indicate that fluoroscopy time is increased during interlaminar LESIs and during L5-S1 transforaminal LESIs in patients who are obese. These relationships are not affected by injection number, performance of bilateral injections, or trainee involvement. Further study is needed to determine if this increase in fluoroscopy time is indicative of a clinically significant associated increase in radiation dose.

**Key Words.** Lumbar; Epidural; Interlaminar; Transforaminal; Injections; Obesity; Overweight; Body Mass Index; Fluoroscopy; Radiation

## Introduction

Lumbar epidural steroid injections are commonly performed for low back pain with radicular symptoms [1]. Particularly in patients with an acute to subacute disc herniation with radicular pain, epidural steroid injection can be helpful for improving pain and function, as well as preventing spinal surgery [2–10]. The safe and effective performance of epidural steroid injections requires the use of fluoroscopic guidance [11–13].

While common co-morbidities in individuals who are candidates for epidural steroid injections include cardiovascular disease, asthma, headache/migraine, osteoporosis, and mood disorders [14–18], obesity is perhaps the most common [17]. High body mass index (BMI) introduces challenges in obtaining medical imaging, resulting in the need for increased radiation exposure in some cases [19,20]. Radiation during interventional procedures has potential health implications for both patients and healthcare providers, particularly given the cumulative effect of radiation exposure [21–23]. The short-term risk to patients is radiation-induced skin damage, which can result from acute radiation doses greater than or equal to 2Gy. Reports of skin changes on the hands, injuries to the lens of the eye, and cataracts in operators and assistants underscore the risk to care providers [24,25]. Although cancer is uncommon, malignancy associated with radiation exposure in adults may include leukemia and breast cancer [25,26].

Though a range of interventional and surgical procedures have been associated with longer fluoroscopy times and greater radiation exposure with increasing BMI [27–30], few studies have analyzed this relationship during spine injections for pain management [31–35]. The present study aimed to define the relationship between BMI and fluoroscopy time during lumbar epidural steroid injections (LESIs) performed for lumbosacral radicular pain. Relationships specific to interlaminar and transforaminal LESI approaches, repeat injections, bilateral transforaminal LESIs, and procedures in which a trainee was involved were additionally investigated.

## Methods

### Study Sites

This was a multicenter retrospective cohort study, approved by the Northwestern University Institution Review Board. Electronic medical records were queried at three urban academic, outpatient spine/pain treatment centers using current procedural terminology codes for both interlaminar and transforaminal LESIs in order to identify eligible patients for analysis. The Rehabilitation Institute of Chicago (RIC) Sports and Spine Rehabilitation Center (SSRC), the RIC Sports and Spine Center at River Forest (SSCRF), and the Northwestern Memorial Faculty Foundation (NMFF)

Anesthesiology Pain Medicine Center. The RIC SSRC and the RIC SSCRf are both managed under the umbrella institution of RIC (affiliated with, but not a part of, the Northwestern University hospital system). There was attending physician and trainee overlap between these two sites, but less than 25%. The NMFF Anesthesiology Pain Medicine Center is a separate clinical practice that is part of a distinct institution (Northwestern University) with no overlap of attending physicians or trainees at either of the two RIC clinical sites.

### Procedures

At all three study sites, LESIs were performed in the following manner: Patients were positioned prone on a fluoroscopy table and the lumbosacral region was prepped with chlorhexidine and draped in a standard sterile manner. The skin and subcutaneous tissues were anesthetized with 1% preservative-free lidocaine. A sterile, 3.5- or 6.0-inch, 17- or 20-gauge Tuohy needle for interlaminar LESIs, or a sterile, 2.5- or 7.0-inch, 22- or 25-gauge spinal needle for transforaminal LESIs was positioned using fluoroscopic guidance. For interlaminar LESIs, the needle was advanced at the midline space between the lamina of the lumbar vertebrae. A paramedian approach was taken when radicular symptoms were clearly unilateral and the attending physician elected to perform an interlaminar LESI rather than a transforaminal LESI. For transforaminal LESIs, the subpedicular approach was used [13].

During both interlaminar and transforaminal LESI, appropriate needle placement in the epidural space was confirmed in both anterior-posterior and lateral fluoroscopic views following negative aspiration and injection of approximately 1.5–2 mL of contrast through microbore tubing, with live-fluoroscopy observation in the anterior-posterior view. One to three milliliters of corticosteroid were injected depending on attending preference, which included triamcinolone acetonide (40mg/mL), methylprednisolone acetate (40mg/mL), or dexamethasone (4mg/mL or 10mg/mL) diluted in 1.0–3.0 mL of various combinations of 1% lidocaine or 0.9% normal saline. This injectate was administered through microbore tubing. For bilateral transforaminal LESIs, the steps after skin prep and draping were repeated. The route of entry to the epidural space (interlaminar vs. transforaminal) was at the attending's discretion. Digital subtraction technology was used at the discretion of the attending physician, when the presence of vascular contrast pattern was possible but not certain during observation of contrast injection under live fluoroscopy. In this cohort, digital subtraction technology was not used during interlaminar LESIs, and rarely (<1% of the time) during transforaminal LESIs. More commonly, the spinal needle was repositioned in cases when the presence of a vascular flow pattern was not clear.

An attending physician supervised and/or personally performed all of the LESI procedures. A total of 23 attending physicians, with a range of five to 38 years

of clinical experience, performed LESIs. All were board-certified in Physical Medicine and Rehabilitation (PM&R) or Anesthesiology, with subspecialty board-certification in either Pain Medicine or Sports Medicine. Trainees in an ACGME-accredited PM&R residency, Anesthesiology residency, Sports Medicine fellowship, or Multidisciplinary Pain Medicine fellowship participated in the LESI procedure.

### **Data Collection**

Consecutive patients treated at the two RIC sites between April, 2007 and October, 2014 and the NMFF site between January, 2014 and February, 2015 were included in the study if they met the following inclusion criteria: [1] received a fluoroscopically guided LESI; [2] had a documented fluoroscopy time from the procedure; [3] had documented height and weight measurements in the electronic medical record within six months of the encounter. Patients who underwent a LESI that did not meet these criteria were excluded from the analysis.

At all three study sites, fluoroscopy times were recorded directly from the fluoroscope and transposed into the electronic medical record. In addition to collecting fluoroscopy time by electronic medical record review, the following demographic and procedural characteristics were recorded from each individual procedure encounter: age, sex, BMI, needle length used, type and level of injection, trainee involvement, trainee duration of training, and in the case of transforaminal LESIs the unilateral side of injection or performance of a bilateral procedure. In the case of bilateral transforaminal LESIs, the total fluoroscopy time was divided by two in order to estimate the fluoroscopy time per injection.

Data were stratified into three BMI categories: normal (BMI 18.5–24.9 kg/m<sup>2</sup>), overweight (BMI 25.0–29.9 kg/m<sup>2</sup>), and obese (BMI ≥30.0 kg/m<sup>2</sup>). The mean fluoroscopy time required per injection was compared among these three BMI categories. In order to identify relationships within subgroups of patients who received LESIs, results were further stratified by [1] the route of injection (interlaminar vs. transforaminal), [2] injection number (first vs. repeat), [3] level of injection (i.e., L1-L2, L2-L3, etc), [4] trainee involvement (yes vs. no), [5] new trainee involvement (defined as July or August; i.e., the start of the new academic year) and, for transforaminal LESIs, [6] bilateral injections (yes vs. no).

### **Statistical Analysis**

A statistical software package was used to analyze the data (PSPP, Version 0.8.4; Gnu Project, Boston, MA). The distributional form of the data was checked using summary statistics and graphical displays. Groups were compared with analysis of variance testing for continuous variables and  $\chi^2$  tests for categorical variables. A Bonferroni correction was used given multiple

comparisons so that the level of significance was reduced to 0.01.

### **Results**

A total of 3,140 procedure encounters were identified; 210 procedures were excluded from further analysis due to missing BMI or fluoroscopy time data. The resulting data included a total of 2,930 procedure encounters, consisting of 598 interlaminar LESIs and 2,332 transforaminal LESIs. Demographic and procedural characteristics of the study population, separated by interlaminar and transforaminal LESI, are shown in [Tables 1](#) and [2](#), respectively. Comparison of fluoroscopy time in various BMI classes as well as relevant subgroup analyses are shown for both interlaminar LESIs and transforaminal LESIs in [Tables 3](#) and [4](#), respectively. Fluoroscopy time plotted by BMI with the level of injection indicated for each individual injection is shown for both interlaminar and transforaminal LESIs in [Figures 1](#) and [2](#). Interlaminar LESIs were only performed at the NMFF study site. Of the procedures performed at the NMFF study site, fluoroscopy time during interlaminar LESI compared to transforaminal LESI was significantly lower within all BMI categories (all  $P < 0.01$ ).

#### **Interlaminar LESI**

Patients who underwent interlaminar LESI had a mean age of 61 years (SD 16), with 63% being female, and the overall average fluoroscopy time was 17.4 seconds (9.8). The mean BMI in the normal weight, overweight, and obese interlaminar LESI groups was 22 kg/m<sup>2</sup> (SD 2), 27 kg/m<sup>2</sup> (SD 1.5), and 36 kg/m<sup>2</sup> (SD 6.2), respectively. There was a significant difference in the mean fluoroscopy time recorded between these BMI classes during interlaminar LESI ( $P < 0.01$ ), with obese patients requiring the longest fluoroscopy times. Trainees were involved in 86% of interlaminar LESI procedures, and this involvement was not associated with a significant difference in fluoroscopy time between BMI classes ( $P = 0.02$ ).

#### **Transforaminal LESI**

Patients who underwent transforaminal LESI had a mean age of 57 years (SD 16), with 53% being female, and the overall average fluoroscopy time was 22.2 seconds (13.5). The mean BMI in the normal weight, overweight, and obese transforaminal LESI groups was 22 kg/m<sup>2</sup> (SD 1.9), 27 kg/m<sup>2</sup> (SD 1.3), and 34 kg/m<sup>2</sup> (SD 4.3), respectively. There was a significant difference in the mean fluoroscopy time recorded between these BMI classes ( $P < 0.01$ ), with obese patients requiring the longest fluoroscopy times. Trainees were involved in 68% of transforaminal LESI procedures, and this involvement was associated with significantly longer fluoroscopy time in increasing BMI classes ( $P < 0.01$ ). While longer fluoroscopy times were required in obese patients during L5-S1 transforaminal LESI ( $P < 0.01$ ) there was no significant relationship between fluoroscopy time and BMI

**Table 1** Subject characteristics and procedure details for fluoroscopically guided interlaminar lumbar epidural steroid injections; stratified by normal body mass index (BMI 18.5–24.9 kg/m<sup>2</sup>), overweight (BMI 25.0–29.9 kg/m<sup>2</sup>), and obese (BMI ≥30.0 kg/m<sup>2</sup>)

Variable	All procedures n = 598	Normal weight n = 184	Overweight n = 163	Obese n = 251	Normal weight vs. overweight vs. obese P value
Age, y; mean (SD)	61 (16)	61 (17)	61 (16)	60 (14)	0.54
Gender, n (%)					
Female	374 (63%)	131 (80%)	86 (53%)	157 (63%)	<0.01
Male	224 (37%)	53 (20%)	77 (47%)	94 (37%)	
BMI, kg/m <sup>2</sup> ; mean (SD)	30 (7.4)	22 (2.0)	27 (1.5)	36 (6.2)	<0.01
Trainee involvement	516 (86%)	159 (86%)	136 (83%)	221 (88%)	0.41
Repeat injection	299 (50%)	90 (49%)	77 (47%)	132 (53%)	0.53
Level of injection					
L1-L2	9 (1%)	5 (3%)	2 (1%)	2 (1%)	0.25
L2-L3	19 (3%)	4 (2%)	6 (4%)	9 (4%)	0.65
L3-L4	53 (8%)	19 (10%)	13 (8%)	21 (8%)	0.70
L4-L5	224 (37%)	67 (37%)	61 (37%)	96 (38%)	0.93
L5-S1	293 (49%)	89 (48%)	81 (50%)	123 (49%)	0.97
Length of needle, inches					
3.5	541 (91%)	182 (100%)	159 (99%)	197 (79%)	<0.01
6.0	54 (9%)	0 (0%)	2 (1%)	52 (21%)	

n = number of procedure encounters; SD = standard deviation.

during L4-L5 or S1 transforaminal LESI ( $P=0.02$ ,  $P=0.13$ ).

No serious adverse events occurred.

## Discussion

The results of this study demonstrated that fluoroscopy time is significantly longer in obese patients compared to normal and overweight patients during interlaminar LESIs, while fluoroscopy time increases significantly with each progressively larger BMI category during transforaminal LESIs. These relationships were not affected by involvement of either a “new” (July/August) or “seasoned” (September–June) trainee in the procedure, by the performance of a repeat as opposed to first-time injection, or by the performance of a bilateral procedure in the case of transforaminal LESIs. When transforaminal LESIs were stratified by level, the above described relationship remained for L5-S1 level but not for L4-L5 and S1 level LESIs.

These results confirm prior smaller studies suggesting a relationship between BMI and fluoroscopy time with regard to lumbar epidural steroid injections [31–33]. The present data represents the largest sample to date with nearly 3,000 injections, gathered from multiple centers, and thus may be considered a more accurate estimate of typical fluoroscopy times during LESI in academic interventional practice.

Smuck et al. (total  $n=209$ ) reported fluoroscopy time data from a combination of zygapophyseal joint injections, medial branch nerve blocks, and transforaminal epidural steroid injections. These authors used a two-group comparison between normal weight (BMI 18.5–24.9 kg/m<sup>2</sup>) and overweight (BMI ≥25.0 kg/m<sup>2</sup>) individuals, which demonstrated a significant increase in fluoroscopy time during procedures with a mean of 3 additional seconds per injection in the overweight group [31]. There was no sub-analysis by injection type, so while the majority of these injections were transforaminal LESIs ( $n=113$ ), it is not known if this relationship would have remained true when excluding the extra-axial injections investigated in this study. In another study conducted by Hanu-Cernat et al. ( $n=127$ ), a weak correlation between weight (though not BMI) and fluoroscopy dose per unit area was demonstrated for a mix of spinal injections including lumbar medial branch blocks, caudal and interlaminar epidurals, intra-articular facet injections, sacroiliac joint injections, and lumbar radiofrequency ablation of the medial branch nerves [32]. Similar to Smuck et al.’s study, these authors did not stratify data by injection type, so the relationship between weight and fluoroscopy time specifically for LESI cannot be inferred from the data provided, particularly given that only 17 of the procedures included were LESIs. The present study, therefore, provides more definitive evidence that fluoroscopy time is increased in patients with greater body habitus during LESI. This is likely due to a combination of a greater depth of tissue

**Table 2** Patient characteristics and procedure details for fluoroscopically guided lumbar transforaminal epidural steroid injections; stratified by normal body mass index (BMI 18.5–24.9 kg/m<sup>2</sup>), overweight (BMI 25.0–29.9 kg/m<sup>2</sup>), and obese (BMI ≥30.0 kg/m<sup>2</sup>)

Variable	All procedures n = 2332	Normal weight n = 775	Overweight n = 866	Obese n = 691	Normal weight vs. overweight vs. obese P value
Age, y; mean (SD)	57 (16)	57 (17)	58 (16)	57 (14)	0.12
Gender, n (%)					
Female	1246 (53%)	461 (60%)	420 (49%)	365 (53%)	<b>&lt;0.01</b>
Male	1086 (47%)	314 (40%)	446 (51%)	326 (47%)	
BMI, kg/m <sup>2</sup> ; mean (SD)	28 (5.5)	22 (1.9)	27 (1.3)	34 (4.3)	<b>&lt;0.01</b>
Trainee involvement	1576 (68%)	506 (65%)	592 (68%)	478 (69%)	0.24
Repeat injection	811 (38%)	237 (34%)	325 (41%)	249 (40%)	<b>0.01</b>
Side of injection					
Left	861 (41%)	301 (43%)	328 (41%)	232 (38%)	0.15
Right	1063 (50%)	332 (48%)	407 (51%)	322 (52%)	
Bilateral	186 (9%)	64 (9%)	60 (8%)	62 (10%)	
Foraminal level of injection					
L1-L2	6 (<1%)	2 (<1%)	3 (<1%)	1 (<1%)	0.74
L2-L3	42 (2%)	6 (<1%)	18 (2%)	18 (2%)	<b>0.02</b>
L3-L4	182 (8%)	59 (7%)	56 (6%)	67 (9%)	0.06
L4-L5	548 (23%)	194 (24%)	201 (22%)	149 (21%)	0.16
L5-S1	1301 (53%)	425 (53%)	494 (61%)	380 (53%)	0.60
S1	343 (14%)	119 (15%)	122 (14%)	102 (14%)	0.77
Length of needle, inches					
2.5	3 (<1%)	3 (<1%)	0 (0%)	0 (0%)	<b>&lt;0.01</b>
3.5	1380 (59%)	604 (78%)	565 (65%)	211 (31%)	
5.0	879 (38%)	164 (21%)	286 (33%)	429 (62%)	
7.0	37 (2%)	0 (0%)	6 (1%)	37 (5%)	

n = number of procedure encounters; SD = standard deviation.

**Table 3** Fluoroscopy time during lumbar interlaminar epidural steroid injection for normal body mass index (BMI 18.5 - 24.9 kg/m<sup>2</sup>), overweight (BMI 25.0–29.9 kg/m<sup>2</sup>), and obese (BMI ≥30.0 kg/m<sup>2</sup>) individuals

Variable	n	Fluoroscopy time per injection, s; mean (SD) normal weight	Fluoroscopy time per injection, s; mean (SD) overweight	Fluoroscopy time per injection, s; mean (SD) obese	P value
All injections	598	16 (9.6)	16 (8.6)	19 (10)	<b>&lt;0.01</b>
Repeat injections	299	15 (0.8)	14 (0.6)	18 (0.7)	<b>&lt;0.01</b>
Level of injection					
L4-L5	224	17 (11)	17 (10)	20 (10)	0.04
L5-S1	293	15 (8)	15 (8)	18 (10)	0.06
Trainee involvement	516	17 (9.8)	17 (9.1)	19 (10)	0.02
New trainee involvement	90	20 (14)	15 (5.2)	21 (13)	0.16

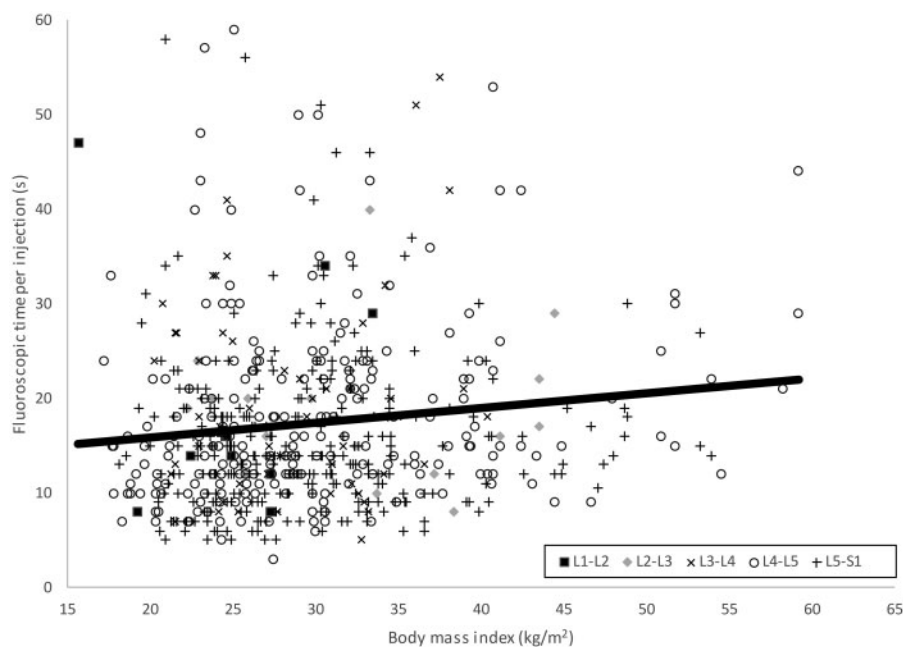
n = number of procedure encounters; SD = standard deviation; new trainee = injection performed with trainee in July or August.



**Table 4** Fluoroscopy time during lumbar transforaminal epidural steroid injection for normal body mass index (BMI 18.5–24.9 kg/m<sup>2</sup>), overweight (BMI 25.0–29.9 kg/m<sup>2</sup>), and obese (BMI ≥30.0 kg/m<sup>2</sup>) individuals

Variable	n	Fluoroscopy time per injection, s; mean (SD) normal BMI	Fluoroscopy time per injection, s; mean (SD) overweight	Fluoroscopy time per injection, s; mean (SD) obese	P value
All injections	2332	24 (16)	26 (23)	29 (17)	<0.01
Repeat injections	878	22 (12)	26 (15)	26 (12)	<0.01
Bilateral Injections	186	21 (10)	25 (13)	29 (17)	<0.01
Level of injection					
L4-L5	548	24 (16)	24 (13)	28 (16)	0.02
L5-S1	1301	23 (11)	26 (23)	29 (16)	<0.01
S1	343	26 (22)	30 (32)	33 (25)	0.13
Trainee involvement	1577	23 (15)	26 (21)	29 (16)	<0.01
New trainee involvement	206	26 (22)	24 (14)	30 (20)	0.10

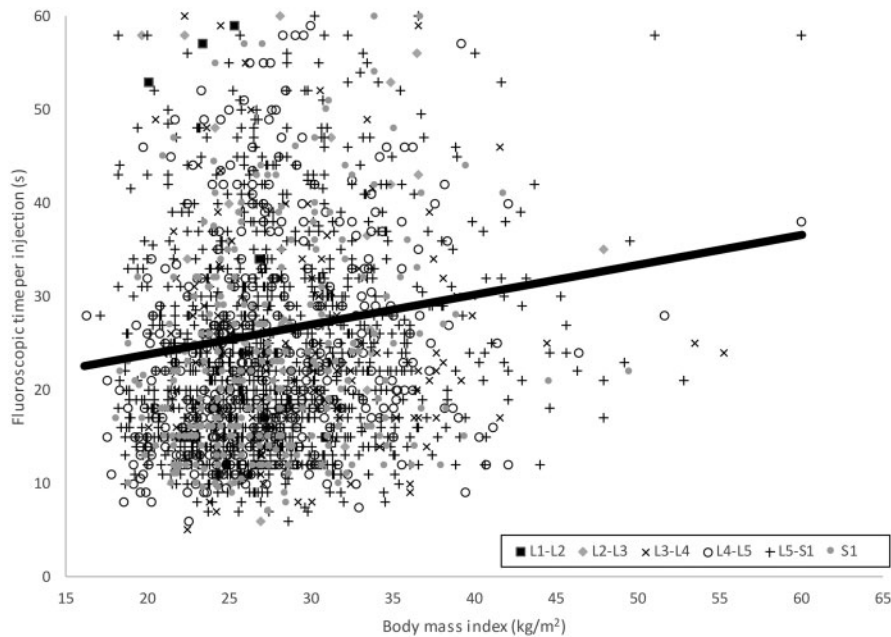
n = number of procedure encounters; SD = standard deviation; new trainee = injection performed with trainee in July or August. Bilateral injection fluoroscopy time = total time fluoroscopy time for both sides divided by two.

**Figure 1** Fluoroscopy time for each patient receiving an interlaminar epidural steroid injection, based on the patient's body mass index. Each level of injection is identified separately. A best-fit line is shown.

traversed to get to the epidural space of patients with increased BMI and reduced radiographic image quality in patients with higher BMI, which provides additional challenge to accurately traversing this additional tissue depth [19,20,36].

Interestingly, when specifically analyzing the fluoroscopy time-BMI relationship stratified by level of transforaminal

LESI, the observation of longer fluoroscopy time with increasing BMI category remained significant only for L5-S1 level injections. While our review of the anatomy literature revealed no prior evidence of greater tissue depth from skin to L5-S1 level epidural access via the transforaminal approach [35], anecdotally, this appears true, and is supported by post-hoc analysis; in the present cohort, 5.0- or 7.0-inch compared to 3.5-inch



**Figure 2** Fluoroscopy time for each patient receiving a transforaminal epidural steroid injection, based on the patient's body mass index. Each level of injection is identified separately. A best-fit line is shown.

needles were used far more commonly during transforaminal access of the epidural space at the L5-S1 level compared to the L4-L5 and S1 level ( $P < 0.01$ ). This may in part be due to the need for a more cranial needle entry in order to avoid the iliac crest in many patients, which is less of an obstacle for injections at other levels, and thus a less direct route to the epidural space when using an oblique view and co-axial needle technique. Alternatively, it is possible that radiology technicians experience increased difficulty obtaining an appropriate target view for an L5-S1 level transforaminal LESI compared to other levels, and thus require more fluoroscopic imaging time prior to needle entry.

The present data demonstrated that, regardless of BMI category, interlaminar LESI was associated with shorter fluoroscopy time than transforaminal LESI. To speculate, it is possible that providers use less fluoroscopy during interlaminar LESI due to the use of loss-of-resistance technique in combination with confirmatory fluoroscopic guidance, which is not used during transforaminal LESI. Aside from establishing the initial trajectory and confirmation of an epidural contrast pattern under fluoroscopic viewing, providers may check fewer serial fluoroscopic images during needle advancement given the tactile feedback of the loss-of-resistance technique. It is also possible that entry into the interlaminar epidural space compared to the transforaminal epidural space presents less technical challenge; at the most common level of injection in the present study, L5-S1, the neural foramina space is the most narrow in the lumbar spine, and this diameter is further reduced by 20% when the lumbar spine is in a position of extension [37–39], such

as is the case when a patient lays prone on a fluoroscopy table.

Investigation of the effect of trainee involvement on the relationship between fluoroscopy time and BMI yielded unexpected results. For transforaminal LESIs, the presence of a trainee resulted in a shorter duration of fluoroscopy time by 1-3 seconds in all three BMI categories when compared to attending-only injections. To speculate, this may be related to the fact that at the two RIC sites, the most experienced attending physicians work with trainees, while inexperienced attending physicians do not, so the longer fluoroscopy times during attending-only injections may be a reflection of experienced versus inexperienced attending physician operator skill, as the experienced attending physician may often take over an injection from a trainee during supervised procedures. A final theory is that trainees are not permitted to be involved with the more technically difficult and time-intensive patients, at the judgment of the attending physician, thus falsely elevating the fluoroscopic times when trainees are not present.

While the results of this study do provide a powerful estimate of fluoroscopy time and BMI relationship associated with both interlaminar and transforaminal LESIs in an academic practice setting, further study is needed to define the impact of BMI on radiation dose during these procedures. It is likely that there is an even greater increase in radiation exposure beyond the relative increase in fluoroscopy time with increasing BMI category; x-ray output, scatter, and absorption all increase with greater tissue depth between the skin and

neuraxis [40]. Specific quantification of this theoretical increase in radiation dose would be useful given the implications of cumulative exposure with regards to malignancy for both patients and healthcare workers involved with these procedures [21–26]. In particular, clinicians and support staff who treat largely obese populations in certain regions of the country and regularly perform LESIs may incur a significantly greater magnitude of radiation exposure than those in regions with a smaller proportion of obese patients.

Regardless of relative exposure, appropriate radiation safety protocols during fluoroscopically guided spinal injections have been shown to reduce effective exposure to both patients and clinicians. The use of lead aprons, lead barriers, lead table drapes, image collimation, avoidance of image magnification, increasing the camera aperture or electronic gain on the video amplifier rather than increasing current to improve image brightness, the use of pulsed imaging, and increasing distance between the patient and the image intensifier are all methods of decreasing radiation exposure to patients and/or clinicians and staff [41–47].

The feasibility of ultrasound guidance during interlaminar LESI, a technique that does not require radiation exposure, has been investigated [48–50]. While this method does not appear to compromise the procedure time or the number of needle insertion attempts and needle passes [51], this technique has not been investigated in a large enough study sample to determine whether rates of dural puncture, vascular injection, and neurovascular injury are greater compared to interlaminar LESI using fluoroscopic guidance. Further, there is no reported use of ultrasound guidance for transforaminal LESI; this technique as an alternative to fluoroscopic guidance would potentially be even more hazardous than interlaminar LESI, given that arterial injection with possible resulting spinal cord infarction during transforaminal LESI would be challenging to detect without the use of radio-opaque contrast dye. While the use of ultrasound guidance allows avoidance of radiation exposure, the additional risks associated with an improperly placed needle and/or steroid injectate likely outweigh potential benefit, and are currently not recommended by society guidelines [13].

Finally, the limitations of this study must be highlighted to allow appropriate interpretation of the presented data. Heterogeneity of physician and radiology technician experience and training background is represented in this study. While this increases generalizability, the present results may not be accurate for experienced physicians working without trainees in a non-academic setting. Additionally, specific injection and fluoroscopy techniques, as described in the methods section, were used in all patients included in the present dataset. Providers may find different results if common alternative techniques are used, such as the infraneural approach during transforaminal LESI or the contralateral oblique fluoroscopic view during interlaminar LESI. The frequency

of use of digital subtraction angiography was not consistently recorded in the electronic medical record; thus, we could not analyze how the use of this technology might impact fluoroscopy time in patients of different BMI categories. The practice pattern at all centers in this study was rare use of digital subtraction angiography during transforaminal ESIs (<2% of the time) and no use during interlaminar ESIs. When vascular flow was suspected, the needle was typically repositioned. However, in other practice settings, digital subtraction technology may be used more frequently; this may affect fluoroscopy time, and certainly is known to significantly increase radiation dose [51]. Further study is needed to define how patterns and quantity of use of digital subtraction angiography are affected by body habitus. As previously suggested, true radiation dose exposure cannot be accurately extrapolated from fluoroscopy time. While estimates are possible, definitive large-scale study is needed to define the relationship between radiation exposure and BMI during LESI. Finally, this retrospective investigation carries the usual risk of bias associated with such studies, though it is minimized by review of consecutive procedure encounters with only 7% missing data.

## Conclusions

The findings of this study indicate that fluoroscopy time is increased during interlaminar LESIs and during L5-S1 transforaminal LESIs in patients who are obese. These relationships are not affected by injection number, performance of bilateral injections, or trainee involvement. Further study is needed to determine if this increase in fluoroscopy time is indicative of a clinically significant associated increase in radiation dose.

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