Pain Physician 2024; 27:341-348 • ISSN 1533-3159

Retrospective Study

Comparing the Effectiveness and Safety of Dexamethasone, Methylprednisolone and Betamethasone in Lumbar Transforaminal Epidural Steroid Injections

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Disclaimer: There was no external funding in the preparation of this article.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Article received: 09-16-2023
Revised article received: 01-22-2024
Accepted for publication: 02-08-2024

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Background: Particulate steroids are thought to exert their effects for long durations at injection sites. However, these types of steroids carry higher risks when used in epidural steroid injections. Catastrophic spinal cord complications, including sudden-onset paraplegia, have been reported due to intravascular particulate steroid preparations that cause embolisms and occlusion of blood vessels, resulting in spinal cord infarctions. Clinicians, therefore, recommend nonparticulate steroids to mitigate these adverse events. To our knowledge, this is the first retrospective study that addresses the effectiveness and safety of methylprednisolone, dexamethasone, and betamethasone when used in transforaminal epidural steroid injections (TFESIs) for the treatment of lumbar radiculopathy.

Objectives: The primary goal of this study was to compare the proportion of patients who received injections of particulate steroids and required zero repeat injections within 12 months of their initial injection to the proportion of patients who received injections of nonparticulate steroids and also required zero repeat injections, as well as to compare the number of patients in the particulate cohort who required one or more repeat injections within 12 months of their initial injection to the number of patients in the nonparticulate cohort who required the same. The secondary goal was to evaluate the proportion of patients ultimately requiring surgery.

Study Design: This is a single-center, IRB-approved, retrospective study evaluating the safety and effectiveness of nonparticulate as compared to particulate steroid medications when used in TFESIs as minimally invasive treatments for chronic lumbar radiculopathy.

Setting: This study captured data (n = 1717) over a 4-year time frame (01/15/2018 to 01/15/2022).

Methods: The following data were collected from each patient's chart: age, gender, BMI, race, date of initial injection, number of repeat injections at the same lumbosacral level and on the same side within 12 months of the initial injection, and lumbar surgery date (if applicable). Inclusion criteria included: 1) having chronic low back pain of radicular etiology; 2) being at least 18 years old; 3) having experienced the failure of conservative therapy after 12 weeks (including physical therapy and/or medications); 4) having positive physical exam findings supporting nerve impingement (straight leg raise, slump test); and 5) showing lumbar MRI evidence of nerve impingement from disc herniation. Exclusion criteria included: 1) having received prior lumbar surgery at any level (L1-S1); 2) having been given prior TFESIs fewer than 6 months prior to initial injection; 3) having contracted a systemic infection at the proposed injection site; 4) undergoing active cancer treatment; and 5) having gotten any other spine injections.

Results: A significantly greater proportion of patients in the nonparticulate steroid cohort received 0 repeat injections (87.5% vs 71.4%, $P < 0.001$). The particulate steroid cohort demonstrated a significantly greater proportion of patients who received repeat injections within 12 months after the initial injections (12.5% vs 29.6%, $P < 0.001$). There were no significant differences among patients requiring surgery between the 2 cohorts. Other outcome measures included the identification of risk factors significantly associated with repeat injections. There was a statistically

significant weak positive correlation between age and repeat injections (Pearson corr = 0.102; $P < 0.001$) and a weak negative correlation between ethnicity/race and repeat injections (point-biserial corr = -0.093; $P < 0.001$). No adverse events were reported.

Limitations: Not all clinicians included in this study used each of the 3 steroid types, and all clinicians used either particulate or nonparticulate steroids exclusively.

Conclusions: Our study demonstrates that the clinical outcomes associated with TFESIs of nonparticulate steroids are superior to those associated with TFESIs of particulate steroids when either variety of medication is used to treat lumbar radiculopathy. This is the first study to include a clinically useful predictive model using information on laterality, age, and steroid type.

Key words: Interventional spine, epidural steroid injections, pain medicine

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Lower back pain (LBP) is one of the most common medical complaints in the United States (US), with an estimated $200 billion spent annually on its management (1). Treatment for LBP and related spine disorders represents an extensive medical problem. Chronic LBP contributes to long-term disability and morbidity and therefore substantial health care and societal costs (1). A global review of LBP's prevalence in the general adult population has shown a lifetime prevalence of approximately 40% (2). Lumbar radiculopathy is one of the most common causes of LBP, with an estimated prevalence of 3-5% among both men and women worldwide (3).

Lumbar radiculopathy is caused by the compression or irritation of a nerve root as it exits the neural foramen. Radiculopathy can arise from many causes, including spondylosis, disc herniation, foraminal stenosis, trauma, tumors, infections, or vascular conditions. Symptoms are commonly characterized as LBP that radiates into the lower extremities in a dermatomal pattern with accompanying numbness, paresthesia, weakness, and loss of reflexes, although the absence of these symptoms does not preclude the diagnosis (2). Age is the primary significant risk factor for developing lumbar radiculopathy (3). Epidemiologically, men have been seen to exhibit a higher risk for the condition, although women with physically demanding careers are also at increased risk (3). Other risk factors include driving occupations, frequent lifting of heavy weights and with twisting motions, trauma, above-average height, smoking, obesity, sedentary lifestyles, multiple pregnancies, history of back pain, and chronic cough (3).

An epidural steroid injection (ESI) is a nonsurgical interventional procedure used commonly in patients with subacute or chronic lumbar radiculopathy who have not responded to conservative treatment consisting of physical therapy and nonopioid pharmacotherapy (4). The literature has reported strong evidence supporting the use of lumbar transforaminal ESIs (TFESIs) for discogenic radicular pain (5-7).

Despite the evidence for the effectiveness of TFESI procedures, they have also presented safety concerns. A systematic review reported that rates of minor complications after lumbar TFESIs were between 2.4 and 9.6%. Those major complications included spinal abscesses, spinal cord infarcts, and epidural hematomas (8). Some patients with spinal cord infarcts had permanent neurological deficits, while the other patients' neurological functioning recovered after surgical or medical intervention (8). The needles that enter during injections can cause direct blood vessel injuries, which may result in epidural hematomas. The risk is higher in patients who take anticoagulants. Other causes of hematomas are increased pressure in the epidural space and injury to the Batson venous plexus, which encircles the spinal cord (9).

It has been hypothesized that there may be several reasons why patients undergoing lumbar TFESIs suffer spinal cord infarctions, including the embolization of particulate steroids, needle-induced vasospasm, compression from an epidural hematoma or abscess, and the mechanical disruption of radiculomedullary arteries (8). Some spinal cord infarctions are thought to occur due to particulate steroid preparations' occlusion of the small-caliber arteries that perfuse to the nerve roots and spinal cord. It has been proposed that the greater the size of the particle, the greater the risk of obstruction in radicular arteries (10). These radicular arteries are branches of the intercostal and lumbar arteries located within each neural foramen throughout the spine, which supply

blood to the nerve root. The larger-diameter radicular arteries are called the radiculomedullary arteries, the largest of which is known as the artery of Adamkiewicz. The artery of Adamkiewicz supplies the lower two-thirds of the spinal cord via the anterior spinal artery. This vessel shows a considerable amount of anatomic variance, typically arising between T6-L2 and sometimes even from S2 (10). Although particulate steroids have been used commonly and shown to be efficacious in TFESIs, rare cases have reported catastrophic spinal cord complications such as sudden-onset paraplegia and other neurological deficits. Therefore, clinicians are more in favor of using nonparticulate steroids to mitigate major adverse effects. One case reported that after a lumbar TFESI, a patient had suffered a spinal cord injury (SCI) that was presumed to be secondary due to the inadvertent intraarterial injection of particulate steroids, causing thrombosis and spasm in the L2 segmental artery. In this case, the particulate steroid preparation occluded the artery of Adamkiewicz and resulted in the infarction of the anterior spinal artery, causing the SCI. Catheter-directed spinal angiography imaging demonstrated widespread alteration in the appearance of the branches of the L2 segmental artery, which further supported the etiology of vessel occlusion causing infarctions (9). Other cases have reported paraplegia immediately following lumbar TFESIs of particulate steroids (10-12). The etiology of those SCIs was thought to be related to the patients' abnormally low arteries of Adamkiewicz. In those case reports, the etiology of the patients' paraplegia was thought to be either injury to the artery of Adamkiewicz or the injection of particulate matter that might have resulted in vessel occlusion and subsequent infarction of the anterior spinal artery. Nonparticulate steroids carry lower risk because their particle sizes are significantly smaller than the diameter of the radicular arteries and would therefore be less likely to occlude the artery of Adamkiewicz and consequently cause an SCI (10-12). To our knowledge, only one case has reported a conus medullaris infarction that occurred after a right lumbar TFESI that used a nonparticulate steroid (dexamethasone), which led to an SCI and the onset of lower-extremity weakness, numbness, and incontinence (13). To mitigate the risks associated with TFESIs, clinicians have carefully considered different corticosteroids (nonparticulate and particulate steroids) based on their safety profiles and effectiveness. Particulate steroids such as betamethasone acetate or methylprednisolone acetate are insoluble in water and must undergo hydrolysis, theoretically allowing them to last longer at injection sites (14). Nonparticulate steroids like dexamethasone sodium phosphate are water-soluble, which lets them achieve a rapid onset of action with a short duration (14). Compared to the particulate steroid solutions, dexamethasone sodium phosphate has particles that are significantly smaller than red blood cells and have the lowest density and the least tendency to aggregate. These characteristics should significantly reduce the risk of embolic infarctions or prevent them from occurring after intra-arterial injections (14).

Although multiple systematic reviews do not present a robust consensus on whether particulate or nonparticulate steroids are more efficacious, studies have reported an association between particulate steroids and significant decreases in patient-reported pain (15). Several studies address particulate steroids' safety and effectiveness because they have traditionally been the steroids of choice. The results of a prospective study that compared methylprednisolone TFESIs' effectiveness to dexamethasone TFESIs' when both were used for treating lumbar radicular pain demonstrated equal immediate and short-term pain relief in both groups of patients involved. However, the methylprednisolone group showed superior long-term pain and functional benefits at 6 months (16). Despite the findings of this literature, the comparative effectiveness and safety of nonparticulate steroids versus particulate steroids as treatments for radicular lumbar pain remains a contentious topic.

Objectives

While other studies have documented patient-reported pain relief in the immediate post-injection period as the primary endpoint, this study aims to objectively measure an ESI's effectiveness by comparing each cohort's proportion of patients who required 0 injections after their first to those who required one or more repeat injections 12 months afterward, evaluating the proportion of patients in each cohort who required surgery, and identifying significant risk factors associated with repeat injections.

Study Design

This is a single-center, retrospective chart review evaluating the safety and effectiveness of nonparticulate versus particulate steroid medications when each type of preparation is used in TFESIs as a minimally invasive treatment for chronic lumbar radiculopathy.

Setting

This study was approved by the Institutional Re-

view Board of the University of Miami (approval No. 20220122). Data were captured over a 4-year time frame (01/15/2018 to 01/15/2022).

Methods

The following data were collected from each patient's chart: age, gender, BMI, race, date of initial injection, number of repeat injections at the same lumbosacral level and on the same side within 12 months of the initial injection, and lumbar surgery date (if applicable). The dosages of particulate methylprednisolone and betamethasone steroids were 40 mg and 6 mg, and the dosage of the nonparticulate dexamethasone steroid was 10 mg. The 3 procedural physicians in this study determined whether the patients would benefit from repeat injections or not. The physicians based their clinical judgements on patients' responses to the initial injections and symptoms at follow-up visits. Each repeat injection was considered a true repeat injection if it was repeated on the same side and at the same level in the lumbar spine (L1-L5). A total of 3,388 patient charts were included and captured in a 4-year time frame based on the billing procedure code (64483) used for ESIs. One thousand seven hundred and seventeen patients were excluded from the study based on the exclusion criteria. Of the 1,671 patients included in this study, 801 patients were in the betamethasone particulate sub-cohort, and 752 patients were in the methylprednisolone (Depo-Medrol) particulate sub-cohort. There were 118 patients in the dexamethasone (Decadron) nonparticulate steroid sub-cohort (Fig. 1). The primary outcome measure for this study was to compare the proportion of patients in each cohort (particulate versus nonparticulate) who required 0 repeat injections to those who needed one or more repeat injections within 12 months of their initial injection. The secondary outcome measure was to evaluate the proportion of patients ultimately requiring surgery within 4 years. Our third outcome measure was to identify the risk factors significantly associated with repeat injections.

The inclusion criteria included: 1) having chronic low back pain of radicular etiology; 2) being at least 18 years old; 3) having experienced the failure of conservative therapy (including physical therapy and/or medications) after 12 weeks; 4) showing positive physical exam findings that support nerve impingement (straight leg raise, slump test); and 5) having lumbar MRI evidence of nerve impingement from disc herniations. The exclusion criteria included: 1) having received prior lumbar surgery at any level (L1-S1); 2) having been given TFESIs fewer than 6 months prior to the initial injection; 3) having a systemic infection at the proposed injection site; 4) undergoing active chemotherapy or radiation treatment; and 5) having gotten any other injections, such as facet injections, sacroiliac joint injections, medial branch nerve blocks, or interlaminar ESIs. The aforementioned inclusion and exclusion study design is described in Fig. 1.

Association of risk factors was performed using Pearson's correlation coefficient. Demographics were represented as the median, means, interquartile ranges, and SDs. Correlation between laterality and repeat injections was performed using a point-biserial correlation coefficient. An ANOVA was employed to compare the results between the averages of the laterality. Paired t-tests were used to statistically compare the proportions of patients who required repeat injections or surgery to those who did not need repeat injections or surgery. A logistic regression model fitted our study's data to use them as a tool for predicting statistically significant associations between patients receiving a repeat injection within 12 months of the initial injection, based on the steroid used (particulate or nonparticulate) and patient age. A new binary variable called repeat inject bin, which discretized whether patients received a repeat injection or not, was created. Here, 0 represents individuals who did not receive repeat injections, and one represents that they did, regardless of the quantity, as depicted in Fig. 2 as Model 1.

When the binary version of the number of repeat injections is used, the effect size for this study's comparison of particulate and nonparticulate steroids is estimated as 0.31. Because the effect size is 0.31, the power of this study is estimated to be 0.72.

Results

The median age of the study sample was 60.62 (interquartile range [IQR] = 51.29-70.63). The median BMI was 28.12 (IQR = 25.06-31.94). There was an unequal proportion of female (53%) and male patients (47%; P = 0.039). The highest proportion of ethnicities was Hispanic at 52.9%, followed by white (33.8%), black (11.3%), other (1.1%), and Asian/Pacific Islander (0.9%) (Table 1).

Overall, 72.4% of patients did not receive repeat injections, and 27.6% received one or more repeat injections over 12 months. When these results are stratified by steroid type, they reveal that of the patients who required zero repeat injections, a statistically sig-

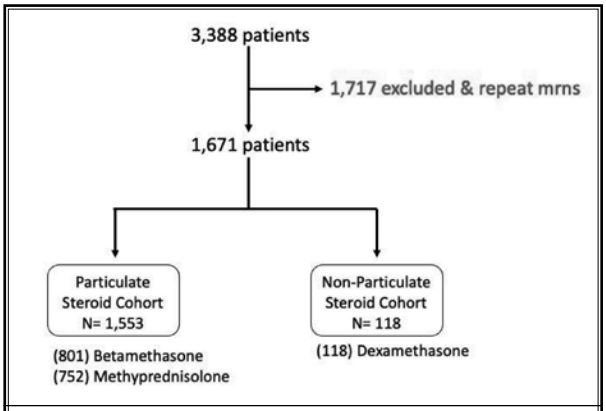

Fig. 1. *Study design.*

Model 1:

Repeat Injections = -1.479 + (-0.792 * Steroid binary) + (0.009 * Age)

Fig. 2. *Model 1.*

nificantly higher proportion of those patients were given the nonparticulate steroid preparation rather than the particulate steroid preparation (87.5% vs 71.4%, $P < 0.001$). The proportion of patients who required one or more repeat injections was statistically significantly lower in the nonparticulate steroid group than in the particulate steroid group (12.5% vs 29.6%, $P < 0.001$). These results are depicted in Table 2.

The proportion of patients requiring surgery was 5.2% (n = 3956) of the sample, as depicted in Table 3. No reported adverse events, such as spinal cord infarctions, vasovagal episodes, allergic reactions, spinal hematomas, or headaches were documented. Further stratification by steroid cohort (particulate versus nonparticulate) shows no statistically significant differences among the 2 cohorts who underwent surgery.

We observed weak correlations between the risk factors and repeat injections. There was a significant weak positive correlation between age and repeat injections (Pearson corr= 0.102; $P < 0.001$) and a significant weak negative correlation between ethnicity/race and repeat injections (point-biserial corr = -0.093; $P < 0.001$). We noticed a weak nonsignificant positive correlation between gender and repeat injections (point-biserial corr = 044; $P = 0.127$) and a weak nonsignificant positive correlation between BMI and repeat injections (Pearson corr = 0.015; $P = 0.599$). There was no correlation between laterality and repeat injections (point-biserial corr = -0.005; $P = 0.861$). as demonstrated in Table 4. The greatest proportion of repeat injections was located at L5-S1 (0.414 ± 0.660 [676]), as depicted in Table 5.

There were 3 stratifications for laterality: left (L), right (R), and bilateral (BL). For L, the proportion was 35.2%, and the average number of repeat injections was 0.385 ± 0.708. For R, the proportion was 35%, and the average number of repeat injections was 0.290 ± 0.579. Lastly, for BL, the proportion was 29.8%, and the average number of repeat injections was 0.299 ± 0.669. Our results demonstrated no statistically significant

Table 1. *General demographics (n = 1219).*

Age	
median (IQR)	60.62 (51.29-70.63)
BMI (n = 1211)	
median (IQR)	28.12 (25.06-31.94)
mean ± SD	28.92 ± 5.53
Gender* (n = 1217)	% (n)
Female	53 (645)
Male	47 (572)
Ethnicity/Race (n = 1216)	% (n)
White	33.8 (411)
Black	11.3 (138)
Hispanic	52.9 (643)
Asian/Pacific Islander	0.9 (11)
Other	1.1 (13)

*Denotes statistical significance using a 2-sample proportion test.
Table 1. General demographics of the patients included in this study.

Table 2. *Number of repeat injections.*

	Total, % (n)	No. of Repeat Injections % (n)	
		0	0
Particulate steroids combined	93.8 (1138)	71.4 (813)	29.6 (325)
Betamethasone	47.3 (571)	71.6 (409)	28.4 (162)
Methylprednisolone	46.6 (567)	71.3 (404)	28.7 (163)
Nonparticulate steroid			
Dexamethasone	6.2 (72)	87.5 (63)	12.5 (9)

Table 3. *Number of patients requiring surgery (n = 1082).*

Yes	5.2 (56)
No	94.8 (1026)

differences among the averages of the laterality (F = 0.031; *P* = 0.861), as seen in Table 6.

In Fig. 2 above, Model 1 is a logistic regression model fitted to these data, which found statistically significant relationships between whether a repeat injection was administered to the patient and whether the steroid used was particulate or nonparticulate (*P* = 0.018), as well as between repeat injections and age (*P* = 0.040). Specifically, if a nonparticulate steroid was used, the patient's log odds of receiving a repeat injection decreased by 1.479 ± 0.284. For every one-unit increase in age, the log odds of receiving a repeat injection increased by 0.009 ± 0.005. Other risk factors, including gender, BMI, and laterality were not statistically significant in the model.

Discussion

To our knowledge, this retrospective study is the first that has evaluated the effectiveness and safety of methylprednisolone, betamethasone, and dexamethasone by based on the number of repeat injections required per steroid cohort. This is also the first study to include a predictive logistic regression model that incorporates information on laterality, age, and steroid type, which can be used as a clinical tool to guide management and clinical decision-making when counseling patients. Our study supports that nonparticulate steroid use is superior to and safer than particulate steroid use. The results of our study showed that between the 2 cohorts of patients, the proportion who required zero repeat injections was higher in the nonparticulate group than in the particulate group and that a lower proportion of patients required one or more repeat injections if they received the nonparticulate steroid (both *P* values < 0.001).

For many lumbar radiculopathy patients who have been failed by conservative management, a TFESI is an effective nonsurgical treatment option. Steroids used in TFESIs come in particulate and nonparticulate varieties, and which type is more efficacious and safer to use has been the subject of study and debate.

Although the more effective steroid type for treating radicular lumbar pain remains highly debated, the studies evaluating particulate and nonparticulate steroids have demonstrated mixed results. Furthermore, there is a gap in the current research on whether methylprednisolone, dexamethasone, or betamethasone will produce superior clinical outcomes in patients with radicular lumbar back pain when utilized in TFESIs. A literature search has yielded no previously published retrospective cohort study outlining the safety and effectiveness of each of these 3 steroids in TFESIs meant to treat lumbar radiculopathy.

In a randomized double-blind controlled trial comparing the effectiveness of particulate steroids to nonparticulate steroids in lumbar TFESIs for lumbosacral radicular pain, the results demonstrated dexamethasone and betamethasone were associated with similar degrees of pain relief and functional improvement at 3 months after the injections. Because of its safety profile, dexamethasone may be considered physicians' first choice among TFESI ingredients when treating lumbar radiculopathy. The aforementioned study was underpowered due to a smaller sample size and because it followed patients for no longer than 6 months post-injection (16). Our study adds upon this knowledge by following patients until 12 months after their injections and evaluating effectiveness objectively by comparing the numbers of repeat injections instead of comparing pain and function outcome measures. This research supports our findings and provides more evidence that supports advocating for the exclusive use of nonparticulate steroids to mitigate unnecessary repeat injections, increased patient visits, and increased

Table 4. *Association between risk factors and repeat injections.*

	Correlation
Gender	0.044
Age	0.102*
Ethnicity/Race	-0.098*
BMI	0.015
Laterality	0.005

*Denotes a statistically significant correlation.

Table 5. *Spine level and number of repeat injections, mean ± SD (n).*

L1-L2	0 (2)
L2-L3	0.178 ± 0.476 (28)
L3-L4	0.139 ± 0.383 (79)
L4-L5	0.320 ± 0.660 (425)
L5-S1	0.414 ± 0.660 (676)

Table 6. *Laterality and repeat injections (n = 1211).*

	% (n)	mean ± SD
Left	35.2 (426)	0.385 ± 0.708
Right	35 (424)	0.290 ± 0.579
Bilateral	29.8 (361)	0.399 ± 0.669

costs for and potentially higher risks to patients. Our study demonstrated that nonparticulate steroids were associated with a significantly lower need for repeat injections and could therefore be linked to more favorable patient outcomes. Nonparticulate steroids were also favored in patient outcomes due to an associated greater reduction in pain, which was demonstrated in a 2016 systematic review and meta-analysis, in which the nonparticulate group had a larger proportion of patients who experienced pain relief exceeding 50% than did the particulate group (17).

In contrast, there were 2 studies published demonstrating superiority in particulate steroids based on pain scores evaluated at variable time points from one week to 3 months post-injection (18). The study was limited to comparing pain scores, which can vary and are not the most reliable measure of evaluating effectiveness. Additionally, the same study had a short follow-up (i.e., 3 months post-injection). This follow-up time is not a true reflection of long-term patient outcomes and has less utility in clinical practice. Although nonparticulate steroids have not traditionally been the choice of steroid for an ESI, rare major adverse effects have been reported with particulate steroids and are possibly attributable to a particulate steroid's insolubility. There were no adverse events reported in either steroid cohort of our study.

An analysis of the spinal levels that received the injections and the number of repeat injections demonstrated that highest mean of repeat injections was in L5-S1 (0.414 ± 0.678, n = 676), as shown in Table 5. Our results are consistent with the literature, since L4-L5 and L5-S1 have been reported as the most common sites for lumbar radiculopathy (19). As for the association of risk factors with repeat injections, we found only significant weak positive correlations for age and significant weak negative correlations for ethnicity/race. No significant correlations were found for BMI, gender, or laterality. These results have not been widely reported in the literature, and our findings offer some correction to a previous paucity of data. There was no correlation between the laterality of the injection and repeat injections.

Limitations

Among the 3 clinicians who performed injections in this study, there was inter-physician variability in background training, years of experience, steroid preference, and clinical practices. One clinician was double board-certified in physical medicine and rehabilitation and pain medicine, and the other 2 clinicians were single board-certified in physical medicine and rehabilitation and did not participate in a dedicated fellowship training year in pain medicine. This variability may have served as a possible confounding factor because clinical practices may differ according to physicians' training, experience, and adherence to guidelines. Not all clinicians included in this study used each of the 3 steroid types, and each physician used exclusively either particulate or nonparticulate steroids, which could have been another potential confounding factor. The uneven sample size among the particulate steroid cohort and nonparticulate steroid cohort made achieving a large effect size difficult, therefore limiting the power of this study. As mentioned earlier, when we used the binary version of the number of repeat injections, the effect size for this study comparing particulate and nonparticulate steroids was estimated to be 0.31, a small effect size. This could be due to the highly uneven sample sizes between the group of patients who received particulate steroids and the group of those who received nonparticulate steroids. One factor that might have been responsible for the small effect size among the steroid cohort sample sizes was that only one of the 3 proceduralists preferred using nonparticulate over particulate steroids, so most of the patients in this study received the particulate steroid cohort. This retrospective study did not consider which oral medications patients were taking before or after the injections, which may suggest that those taking more potent pain medications could have required a lower number of repeat injections. Moreover, this study intentionally avoided evaluating patient-reported pain scores as a metric for the steroids' effectiveness due to the significant variability and inconsistent documentation of VAS pain scores during patient visits and among the 3 proceduralists included. To compare outcomes consistently, we evaluated the steroids' effectiveness through the assessment of repeated injections and whether patients required them or not. This study did not specifically evaluate the interlaminar injection approach, another procedural approach that may be considered in future studies.

Conclusion

This study was able to objectively evaluate the effectiveness of steroids used in TFESIs by evaluating the number of repeat injections as opposed to pain or functional outcome scores, which can be inconsistent in a retrospective study. The results of this study also

suggest that these injections did effectively alleviate symptoms in the majority of the patients, an effect that might have also ultimately delayed surgery at least a year after the injections.

Our study supports the use of nonparticulate steroids in TFESIs for the treatment of lumbar radiculopathy because they have a demonstrated association with a requirement for fewer repeated injections than the particulate steroids. This evidence indicates that using nonparticulate steroids may mitigate the unnecessary risks associated with administering TFESIs to treat lumbar radiculopathy. Given the unequally sized groups, the low effect size, and a retrospective nature of our study, large randomized trials are needed to conclusively determine nonparticulate steroids' effectiveness compared to particulate steroids' when used in lumbar radiculopathy TFESIs.

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