Randomized Trial

Comparison of Effect and Contrast Spreading in Transforaminal Epidural Injection Using the Retrodiscal Versus Subpedicular Approach: A Prospective, Randomized Trial

Hyun Seung Jin, MD[1], Geon Hyeong Bae, MD[2], Eun Joo Choi, MD, PhD[2], Joon Woo Lee, MD, PhD[3], and Pyung Bok Lee, MD, PhD[2]

From: [1]The Comfortable Pain Clinic, Korea; [2]Department of Anesthesiology and pain medicine, Seoul National University Bundang Hospital, Korea; [3]Department of Radiology, Seoul National University Bundang Hospital, Korea

Address Correspondence: Pyung-Bok Lee, MD, PhD Department of Anesthesiology and Pain Medicine, Seoul National University Bundang Hospital 82, Gumi-ro 173 Beon-gil, Bundang-gu Seongnam 13620, Korea E-mail: painfree@snubh.org

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Background: Lumbar transforaminal epidural injection (TFEI) effectively decreases low back pain and radicular pain in herniated intervertebral disc (HIVD) and spinal stenosis (SS). The precise delivery of drugs to the target is important for pain control and minimizing complications.

Objectives: We aimed to evaluate the efficacy and complications of the subpedicular (SP) and retrodiscal (RD) approaches by analysis of contrast spread patterns into the pathologic target on the basis of a newly established specific criterion. We also investigated whether the severity of patients' spinal disease influenced this pattern.

Study Design: A prospective, randomized, observational study.

Setting: Interventional pain management center at a university-affiliated hospital.

Methods: Among patients who showed lumbar spinal stenosis or HIVD at the L4/5 level, participants were randomly assigned to undergo TFEI with the SP approach (SP group) or RD approach (RD group). Pain relief in terms of the visual analog scale (VAS) score and complications such as intravascular or intradiscal uptake were also analyzed. The contrast image was analyzed as the contrast media was injected, starting from 0.5 mL up to 3.0 mL. The spread patterns of contrast media were graded into 4 categories, which were newly defined in this study.

Results: Both groups demonstrated a significant decrease in pain relief (P value < 0.01) at 2 and 4 weeks after the procedures, but no significant difference was found between the 2 groups. In the intergroup analysis between the RD and SP groups, with a 1.5-mL contrast media injection, more patients in the RD group (17.2%) showed a grade 3 spread than those in the SP group (8.2%). In the subgroup analysis, the RD group showed superior spread (more grade 3 and 4) with 1.5-, 2-, and 2.5-mL contrast media injections (P values = 0.02, 0.03, and 0.04) in severe central stenosis, and 1.5- and 2-mL contrast media injections (P values = 0.01, 0.02) in severe foraminal stenosis.

Limitations: The follow-up period was only 4 weeks after TFESI, and higher contrast injection was used for procedures.

Conclusions: The RD approach for TFEI showed a better contrast spreading pattern than the SP approach, especially in patients with severe central and foraminal spinal stenosis. The RD approach might be more beneficial for patients with severe central and foraminal spinal stenosis in the short-term follow-up.

Key words: Contrast media, epidural injection, epidural space, intervertebral disc herniation, radiating pain, spinal stenosis

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Lumbar epidural steroid injection (ESI) is a widely performed procedure that can effectively decrease low back pain and radicular pain in herniated intervertebral disc (HIVD) and spinal stenosis (SS) (1,2). The main goal of ESI is drug delivery to the target and amelioration of local inflammation. Precise drug delivery to the target can ensure effective pain control with minimal complications.

On the basis of the final location of the needle tip, the approach methods for ESIs can be categorized as interlaminar, caudal, and transforaminal, of which transforaminal epidural injection (TFEI) allows direct injectate delivery to the site of pathology, such as the compressed nerve roots in the anterior epidural space (3,4). TFEI can be subdivided into subpedicular (SP), retroneural, and retrodiscal (RD) methods depending on the final target of the advancing needle (Fig. 1). Among these, the SP approach, which is the most popular approach, allows more precise drug delivery to the target lesion since the needle tip is advanced directly toward the ventrolateral space trajectory of the spinal foramen, where most lesions are usually present. The SP approach thus shows improved target specificity and yields better clinical efficacy than the interlaminar approach (5). The injection needle in the SP approach is advanced into the "safe triangle" formed below the inferior aspect of the pedicle and superolateral to the exiting spinal nerve, as described by Bogduk (Fig. 1) (6). This target is traditionally known to be safe from neural or discal injury (7-9). However, some studies have shown that the radicular artery passes through the safe triangle in the thoracolumbar levels and that the needle could irritate or penetrate the vessels and nerve root. Thus, the safe triangle may not be as safe as assumed previously (10,11). Moreover, drug delivery may be suboptimal with this approach. For cases involving severe disc-level adhesions, inferior disc migration, or subarticular stenosis, the SP approach may show limitations in drug delivery through the compressed barrier toward the retrodiscal space and the above the traversing nerve root, which may be the main lesion (12).

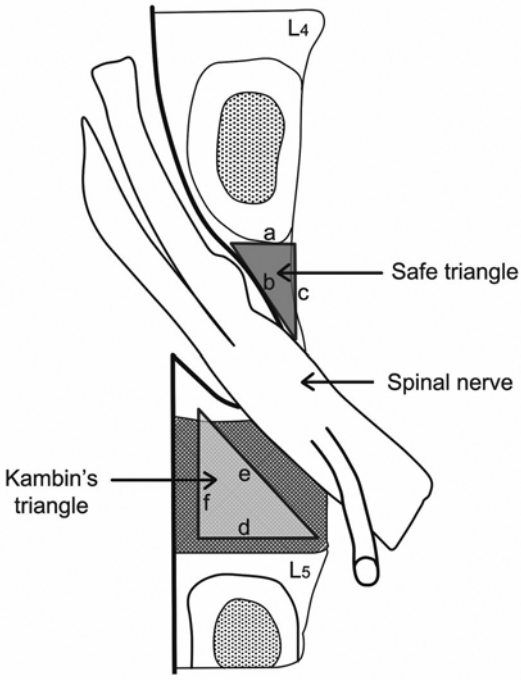

Fig. 1. *Retrodiscal and subpedicular approaches for the transforaminal epidural block in the lumbar spine. The safe triangle for the subpedicular approach is defined by the lower border of the pedicle (a: base), exiting nerve root (b: hypotenuse), and the lateral border of the spine body (c: height). The Kambin's triangle for the retrodiscal approach is defined as a right triangle over the dorsolateral disc and superior border of the caudal vertebra (d: base), the exiting nerve root (e: hypotenuse), and the dura/traversing nerve root (f: height).*

On the other hand, Jasper JF (13) suggested a more ventral and caudad approach to the retrodiscal epidural space. Glaser and Shah (8) subsequently defined this space as the "Kambin's triangle," the anatomical boundary was first described by Kambin in 1972 (14), which is defined as a 3-dimensional anatomical right triangle over the dorsolateral disc (Fig. 1). This space was proven to be safer than the traditional subpedicular triangle regarding severe adverse effects causing paralysis (7,9). The RD approach allows the target to be reached directly through a short path in comparison with the SP approach in certain discal pathologies and is expected to show a better clinical effect in selected patients and is proven to cause fewer serious complications such as intravascular injection.

The RD approach showed a better effect in pain control than the SP approach in one study (15), while other studies showed no difference between the 2 approaches (16,17). However, the previous studies did not clearly prove the advantages and superiority in pain control between the 2 approaches since the disease entities and severities in the patient groups were heterogeneous, and the criteria for evaluating the effectiveness of treatment were disorganized.

We designed a prospective study to evaluate the efficacy and complications of the SP and RD approaches. In addition, the contrast media spread patterns into

the pathologic target were analyzed through a newly established specific criterion. We also investigated whether the severity of patients' spinal disease influenced this pattern.

Methods

Patients

We conducted a prospective, randomized, controlled, observational study approved by the Institutional Review Board of our institute (No. B-1608-358-005). This study was carried out between January 2017 and May 2020 in our hospital. We followed CONSORT guidelines and proceeded with the study. All participants received written and verbal information about the trial before providing written consent. The inclusion criteria were as follows: 1) age 18 to 80 years; 2) patients who were diagnosed with lumbar spinal stenosis or HIVD at the L4/5 level in magnetic resonance imaging (MRI) performed within 6 months; 3) patients with lower back pain with/without leg radiating pain; and 4) pain ≥ 3 months with visual analog scale (VAS) score > 5. Exclusion criteria were as follows: 1) no MRI before the procedure; 2) oral, peripheral, or epidural steroid use within the last 3 months; 3) patients with uncontrolled diabetes mellitus; 4) patients with coagulopathy; and 5) patients with post-lumbar internal fixation at the L4/5/S1 level. Participants were randomly assigned to receive TF injection with the SP approach (SP group) or the RD approach (RD group). Before the procedure, patients were randomized into 2 groups using a computer-generated random list. Participants and outcome assessors (2 experienced pain physicians) were blinded to the study groups.

Procedures

All injections were performed by 2 pain doctors (EJ Choi, PB Lee). Each patient was positioned prone on the procedure table, underwent sterile draping, and subsequently received local anesthesia at the puncture site. A 22G, 12-cm Quincke-type spinal needle (Taechang Industrial Co., Kongju, Korea) was used for each procedure.

For SP TFEI, the safe triangle was viewed under a fluoroscope. The needle was gently advanced under fluoroscopic guidance with an oblique view, and proper needle placement was confirmed under both anteroposterior (AP) and lateral fluoroscopic projections.

For RD TFEI, the C-arm was tilted and rotated obliquely such that the endplates of the targeted disc were aligned, and under the C-arm, the lateral surface of the superior articular process (SAP) was placed at the center of the intervertebral space. The needle was advanced slowly and cautiously toward the lateral surface of the SAP under tunnel view. After confirming that the needle had touched the SAP, the C-arm was rotated in the lateral projection to check the depth. In the lateral view, the needle was further advanced past the SAP toward the posterior border of the disc with caution. The hard feel and resistance to needle advancement were used as a sign to stop advancing the needle, and the tip of the final needle position at the interpedicular line was confirmed in the AP view.

In both approaches, after confirming each expected final needle position, the contrast media was injected starting from 0.5 mL and increasing in increments of 0.5 mL up to 3.0 mL. The contrast image was stored at each point. After confirmation of the final contrast image and no intravascular or intradiscal uptake, the physician injected a drug mixture of 5 mg of dexamethasone and 3 mL of 0.18% ropivacaine. If intravascular or intradiscal uptake was suspected, the needle was redirected, and injection was performed after no further intravascular or intradiscal uptake was confirmed.

Outcome Measurements

The primary outcome measures were pain relief at 2 and 4 weeks after the procedure. Pain relief was assessed using the VAS (range 0-10). All complications and adverse reactions were also recorded.

The secondary outcome measure of this study was the flow pattern of the contrast media. On the AP and lateral views, we analyzed the maximal distribution of flow by injecting contrast medium (0.5, 1, 1.5, 2, 2.5, and 3 mL; total, 6 times; 10-s interval) after the procedure for both groups. The spread pattern in each patient was analyzed by 2 experienced pain physicians, neither of whom was involved in the procedures.

The spread patterns of contrast medium were graded into 4 categories (Fig. 2). This new grading system was proposed by 3 pain physicians (HS Jin, EJ Choi, and PB Lee) and confirmed by a single experienced radiologist (JW Lee). In both groups, grade 1 was defined as spread at the exiting nerve root (L4 or L5 spinal nerve) or/and epidural sleeve at the needle-insertion level, and grade 2 was defined as spread at the epidural space (interpedicular line) with uptake at the target nerve root (L4 or L5 spinal nerve) at the needle-insertion level. Grades 3 and 4 were defined differently

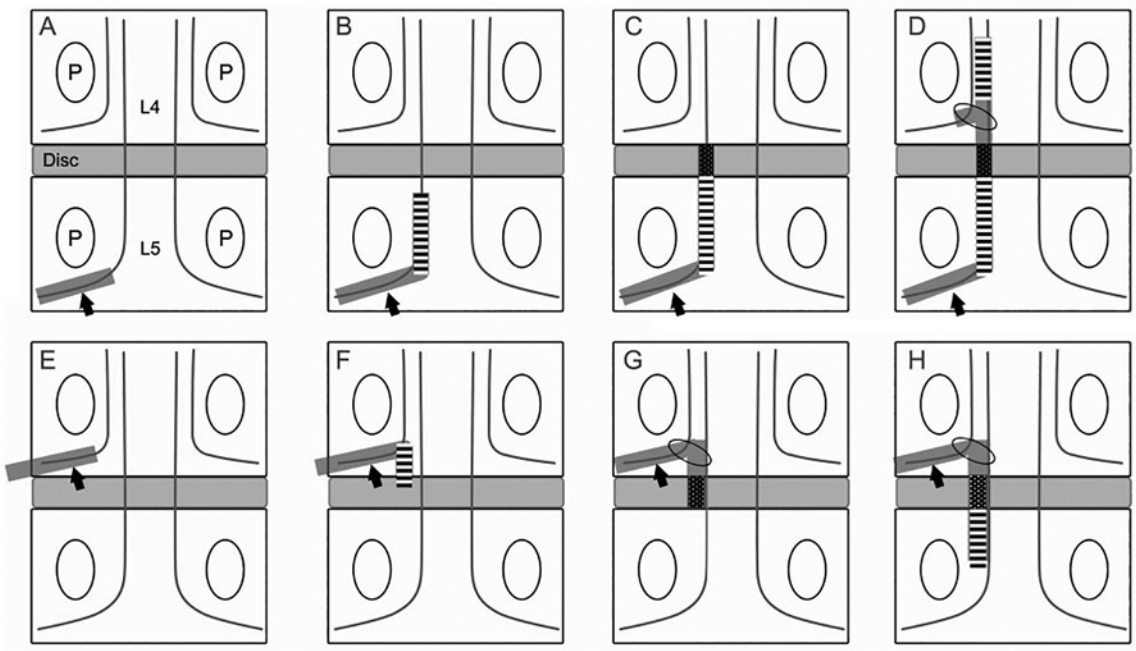

Fig. 2. *A. Grade 1 of the SP group: spread at the exiting nerve root (L5 spinal nerve, arrow) or/and epidural sleeve at the needle-insertion level, B. Grade 2 of the SP group: spread at the epidural space (interpedicular line, stripe pattern) with uptake at the target nerve root (L5 spinal nerve, arrow) at the needle-insertion level, C. Grade 3 of the SP group: spread at the epidural space (interpedicular line, stripe pattern) with uptake to the exiting nerve root (L5 spinal nerve, arrow) and coverage of the disc proximal to the targeted intervertebral disc (L4-5, dot pattern), D: Grade 4 of the SP group: coverage of the traversing nerve root (circle) and the medial to the interpedicular line (stripe pattern) at the proximal level (L4) including grade 3, E. Grade 1 of the RD group: spread at the exiting nerve root (L4 spinal nerve, arrow) or/and epidural sleeve at the needle-insertion level, F. Grade 2 of the RD group: spread at the epidural space (interpedicular line, stripe pattern) with uptake at the target nerve root (L4 spinal nerve, arrow) at the needle-insertion level, G. Grade 3 of the RD group: spread at the epidural space with uptake to the exiting (L4 spinal nerve, arrow) and traversing nerve roots (circle) and coverage of the disc at the targeted intervertebral disc (L4-5, dot pattern) medial to the interpedicular line, H. Grade 4 of the RD group: coverage of the medial to the interpedicular line (stripe pattern) at the distal level (L5) while including grade 3. P: pedicle, L4: body of L4, L5: body of L5.*

in each group. In the SP group, grade 3 was defined as spread at the epidural space with uptake to the exiting nerve root (L5 spinal nerve) and coverage of the disc proximal to the targeted intervertebral disc (L4-5), while in the RD group, it was defined as spread at the epidural space with uptake to the exiting (L4 spinal nerve) and traversing nerve roots (L5) and coverage of the disc at the targeted intervertebral disc (L4-5) medial to the interpedicular line. In the SP group, grade 4 was defined as coverage of the traversing nerve root and the medial to the interpedicular line at the proximal level (L4), including grade 3. Grade 4 of the RD group was defined as coverage of the medial to the interpedicular line at the distal level (L5), including grade 3. Grade 4 was considered the most appropriate contrast media pattern. For example, in the L5 SP approach, if contrast media spread at the epidural space (interpedicular line) with uptake at the target nerve root (L5 spinal nerve), it was classified as grade 2 spread (Fig. 3). In addition to the spread pattern, vascular uptake and intradiscal injection were also recorded.

We also collected data for age, gender, weight, height, diagnosis, MRI findings (grading of central or foraminal spinal stenosis, type of HIVD), and history of previous spine surgery (discectomy, laminectomy at L4/5 level). In our study, we adopted the stenosis severity criteria suggested by the Lee classification (18).

Statistical Analysis

In the previous study comparing the effects of the SP and RD approaches (12), the change in the VAS at 2 months after each procedure was 3.5 ± 1.5 in the SP

group and 3.0 ± 1.6 in the RD group. The effect size was calculated as 0.33, and a total sample size of 304 achieved 80% power with a type 1 error of 0.05. To allow for a 5% dropout rate, the final sample size was 160 patients per group. Age, gender, height, weight, diagnosis, grade of contrast flow, and complications were compared using the t-test, χ^2 test, or Fisher's exact test. Repeated-measures analysis of variance of the VAS scores for back pain and leg radiating pain was used to compare continuous numerical data over time. In addition, these values were compared at each follow-up point. SPSS version 25.0 (IBM, Armonk, NY) was used for statistical analyses. Results were expressed as means (SD). A *P* value < 0.05 was considered to indicate statistical significance.

Results

A total of 320 patients were enrolled in the study, and 10 patients were excluded prior to randomization. Of these 10 patients, 5 had recovered from the symptoms before the intervention; two were diagnosed as showing malignancy, and 3 refused interventions. Finally, 310 patients were randomly assigned to the 2 groups (155 patients to each group). However, 30 patients (RD group = 21, SP group = 9) were lost to follow-up, and 134 patients in the RD group and 146 in the SP group were eventually analyzed (Fig. 4).

Patient characteristics are shown in Table 1. The 2 groups showed no significant difference in patient characteristics. Severe central spinal stenosis was observed in 29.9% (40/134) of the patients in the RD group and 25.3% (37/146) of those in the SP group, while severe foraminal spinal stenosis was observed in 20.1% (27/134) of the patients in the RD group and 13.8% (20/146) of the patients in the SP group. Moreover, previous surgery was performed in 9% (12/134) of patients in the RD group and 5.5% (8/146) of those in the SP group. Both groups demonstrated a significant decrease in pain relief (*P* value < 0.01) at 2 and 4 weeks after the procedures, but no significant difference was found between the 2 groups (Fig. 5).

In the intergroup analysis between the RD and SP groups, the grade of contrast media showed no difference at all volume points, except with the injection of 1.5 mL of contrast media (*P* value < 0.01) (Table 2). When 1.5 mL of contrast media was injected at the target site, more patients in the RD group (17.2%) showed grade 3 findings than the SP group (8.2%), whereas grade 2 or 4 findings were observed more often in the SP group. On the other hand, in subgroup analysis according to the type and severity of disease pathology, the RD group showed superior results. Among patients with severe central spinal stenosis, the RD group showed a better

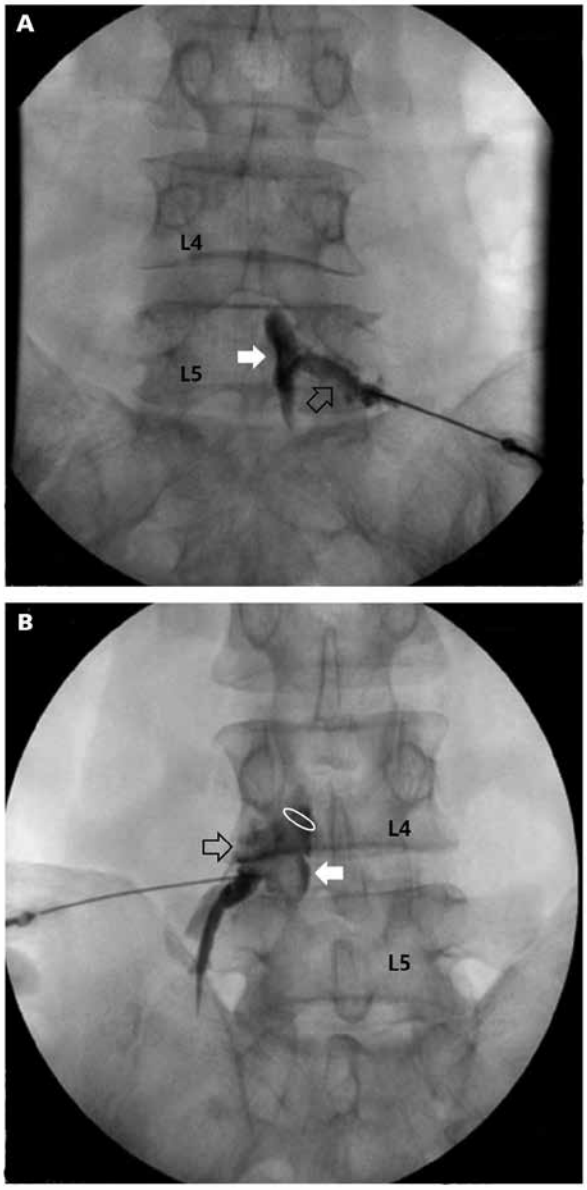

Fig. 3. *A. Grade 2 of the SP group. The contrast media spread at the epidural space (interpedicular line, white arrow) with uptake at the target nerve root (L5 spinal nerve, empty arrow), B. Grade 3 of the RD group. The spread at the epidural space with uptake to the exiting (L4 spinal nerve, empty arrow) and traversing nerve roots (circle) and coverage of the disc at the targeted intervertebral disc (L4-5, white arrow) medial to the interpedicular line.*

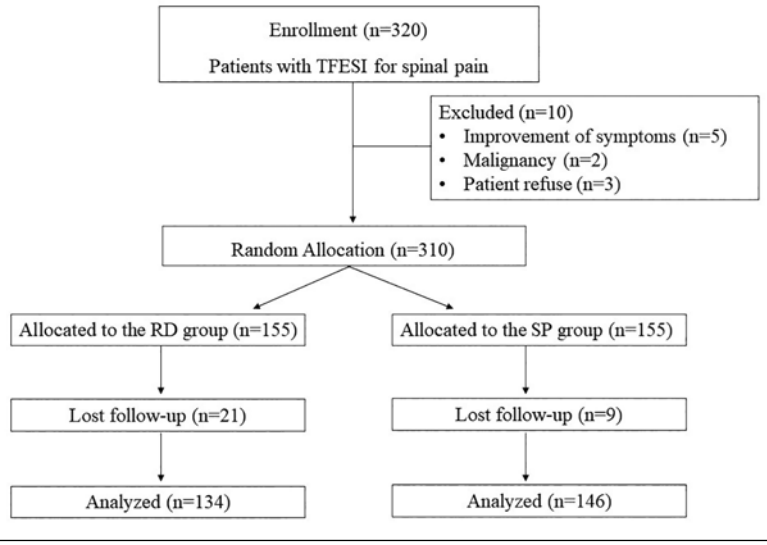

Fig. 4. *Flow diagram of patients included in this study. TFESI, transforaminal epidural steroid injection; RD, retrodiscal approach; SP, subpedicular approach.*

Table 1. *Comparison of demographic and clinical characteristics between the retrodiscal (RD) and subpedicular (SP) groups.*

Characteristic	RD group (n = 134)	SP group (n = 146)	*P* values
Gender (M/F)	58/76	66/80	0.81
Age (years)	63.4 ± 15.1	63.3 ± 9.4	0.98
Height (cm)	162.1 ± 8.6	161.4 ± 11.9	0.51
Weight (kg)	64.3 ± 12.9	63.7 ± 11.8	0.64
Pain duration (months)	43.6 ± 63.2	45.7 ± 43.2	0.74
Severity of central stenosis			0.44
Mild, n (%)	57 (42.5)	57 (39.1)	
Moderate, n (%)	37 (27.6)	52 (35.6)	
Severe, n (%)	40 (29.9)	37 (25.3)	
Severity of foraminal stenosis			0.32
Mild, n (%)	61 (45.6)	70 (48.3)	
Moderate, n (%)	46 (34.3)	55 (37.9)	
Severe, n (%)	27 (20.1)	20 (13.8)	
Type of HIVD			0.18
Bulging, n (%)	40 (29.9)	32 (21.9)	
Protrusion, n (%)	45 (33.6)	47 (32.2)	
Extrusion, n (%)	29 (21.6)	29 (19.9)	
Sequestration, n (%)	1 (0.7)	1 (0.7)	
Previous spine surgery			
Yes/No, n (%)	12 (9)/122 (91)	8 (5.5)/138 (94.5)	0.35

Data are reported as the mean ± standard deviation or number (%) of patients.
HIVD, Herniated intervertebral disc.

spread pattern (more grade 3 and 4) with 1.5-, 2-, and 2.5-mL contrast media injections (*P* value = 0.02, 0.03, 0.04). Moreover, in patients with severe foraminal stenosis, the RD group showed a better spread pattern (more grade 3 and 4) with 1.5- and 2-mL contrast media injections (*P* value = 0.01, 0.02) than SP group (Table 3). Interestingly, the type of HIVD or a history of previous spine surgery had no effect on the spread pattern of the contrast medium, regardless of the amount of contrast media.

Although only 3% (4/134) of patients in the RD group demonstrated vascular uptake during the procedure, 8.2% (12/146) of patients in the SP group demonstrated vascular uptake under real-time fluoroscopic imaging. In the RD group, 10.4% of the patients (14/134) showed intradiscal injection. In comparison, 3.4% of the patients (5/146) in the SP group showed intradiscal injection (*P* = 0.015, Table 4).

Discussion

The results of this study demonstrate that the RD approach yielded a better spread pattern of the contrast media in more severe central or foraminal spinal stenosis. However, the pain relief after the procedure was not significantly different between the 2 groups.

Previous studies comparing the clinical effects of the RD and SP approaches also showed conflicting results. Jeong et al compared the short-term (1 month) or mid-term (6 months) pain relief after TF injection with the RD or SP approaches (15). They reported that the RD approach yielded a better treatment effect than the SP approach only in the short-term follow-up. On the other hand, other studies could not prove that the RD approach had a superior clinical effect over the SP approach, as in our study (18,19). Jeong et al evaluated

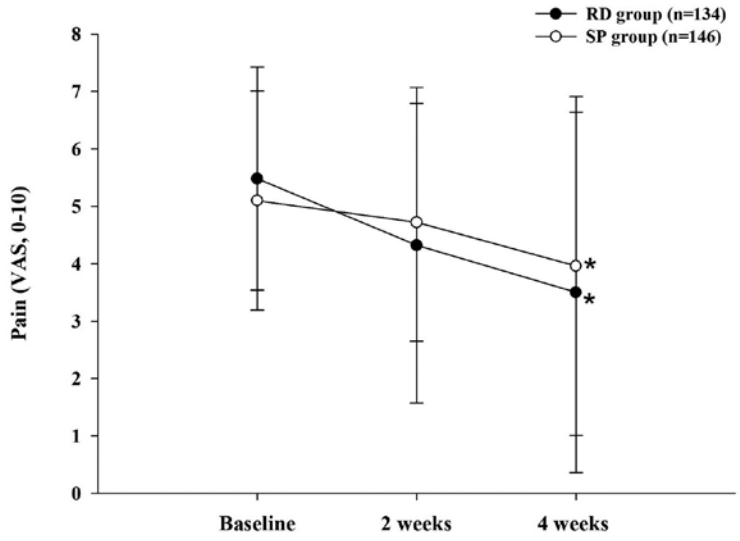

Fig. 5. *Changes in visual analog scale (VAS) scores (0 = no pain, 10 = the worst pain imaginable) for lower back pain with/without leg radiating pain between the RD (retrodiscal approach) and SP (subpedicular) groups. Both groups showed a reduction in pain scores from baseline at 4 weeks. No significant difference was observed between the 2 groups. The error bar indicates standard deviation. *Significant at P < 0.01, compared to the baseline VAS score.*

239 patients (SP group = 127, RD group = 112) with spinal pain. Their study was different from other previous studies in that more than 80% of the patients were diagnosed with HIVD in both groups. In contrast, our study included 280 patients (SP group = 134, RD group = 146) with central or foraminal spinal stenosis with or without HIVD. Since spinal pain is mediated by several factors, determination of the effectiveness of a single procedure in treating complex spinal pain conditions can be difficult, necessitating subgroup analysis and adjustment of the balance of the severity of pathology between groups. Moreover, these factors highlight the importance of defining proper criteria to assess whether the drug has reached the lesion accurately in both approaches.

The spread patterns of contrast media in different approaches have been analyzed previously. Ruchi et al compared pain relief and contrast media spread between midline, parasagittal, and transforaminal epidural steroid injections in 60 patients with HIVD (4) and reported that the anterior epidural spread of the contrast media was associated with pain improvement and was observed more often in TFEI, with significant differences between methods. Appropriate TFEI, which is characterized by an anterior epidural spread, reflects the direct dispersion of drugs into the pain-inducing lesion, such as a compressed spinal nerve root, dorsal root ganglia, or adhesion. Therefore, the spread pattern of the contrast media, as well as the clinical efficacy, have been compared between the SP and RD

Table 2. *Comparison of grade for contrast pattern between retrodiscal (RD) and subpedicular (SP) groups.*

			Groups		*P* value
			RD	SP	
Contrast 0.5 mL	Grade 1	n (%)	20 (14.9)	11 (7.5)	0.053
	Grade 2	n (%)	100 (74.6)	117 (80.1)	
	Grade 3	n (%)	11 (8.2)	8 (5.5)	
	Grade 4	n (%)	3 (2.2)	10 (6.8)	
Contrast 1 mL	Grade 1	n (%)	7 (5.2)	3 (2.1)	0.07
	Grade 2	n (%)	90 (67.2)	110 (75.3)	
	Grade 3	n (%)	23 (17.2)	13 (8.9)	
	Grade 4	n (%)	14 (10.4)	20 (13.7)	
Contrast 1.5 mL	Grade 1	n (%)	7 (5.2)	1 (0.7)	< 0.01*
	Grade 2	n (%)	84 (62.7)	103 (70.5)	
	Grade 3	n (%)	23 (17.2)	12 (8.2)	
	Grade 4	n (%)	20 (14.9)	30 (20.5)	
Contrast 2.0 mL	Grade 1	n (%)	6 (4.5)	1 (0.7)	0.07
	Grade 2	n (%)	81 (60.4)	96 (65.8)	
	Grade 3	n (%)	22 (16.4)	15 (10.3)	
	Grade 4	n (%)	25 (18.7)	34 (23.3)	
Contrast 2.5 mL	Grade 1	n (%)	5 (3.8)	1 (0.7)	0.12
	Grade 2	n (%)	76 (57.6)	94 (64.4)	
	Grade 3	n (%)	24 (18.2)	17 (11.6)	
	Grade 4	n (%)	27 (20.5)	34 (23.3)	
Contrast 3.0 mL	Grade 1	n (%)	8 (6.0)	1 (0.7)	0.08
	Grade 2	n (%)	81 (60.4)	91 (62.3)	
	Grade 3	n (%)	16 (11.9)	22 (15.1)	
	Grade 4	n (%)	29 (21.6)	32 (21.9)	

**P* value < 0.05
Data are reported as number (%) of patients.

Table 3. *Comparison of grade for contrast pattern by severity of spinal stenosis between the retrodiscal (RD) and subpedicular (SP) groups.*

			Groups		*P* value
Central spinal stenosis			RD	SP	
Contrast 1.5 mL					
Mild	Grade 1	n (%)	4 (7.1)	1 (1.7)	0.31
	Grade 2	n (%)	37 (64.9)	38 (66.7)	
	Grade 3	n (%)	8 (14)	6 (10.5)	
	Grade 4	n (%)	8 (14)	12 (21.1)	
Moderate	Grade 1	n (%)	-	-	0.21
	Grade 2	n (%)	23 (62.2)	33 (63.5)	
	Grade 3	n (%)	8 (21.6)	5 (9.6)	
	Grade 4	n (%)	6 (16.2)	14 (26.9)	
Severe	Grade 1	n (%)	3 (7.5)	-	0.02*
	Grade 2	n (%)	24 (60)	32 (86.5)	
	Grade 3	n (%)	7 (17.5)	1 (2.7)	
	Grade 4	n (%)	6 (15)	4 (10.8)	
Contrast 2.0 mL					
Mild	Grade 1	n (%)	4 (7)	1 (1.7)	0.48
	Grade 2	n (%)	34 (59.6)	35 (61.5)	
	Grade 3	n (%)	7 (12.3)	6 (10.5)	
	Grade 4	n (%)	12 (21.1)	15 (26.3)	
Moderate	Grade 1	n (%)	-	-	0.69
	Grade 2	n (%)	23 (62.2)	30 (57.7)	
	Grade 3	n (%)	7 (18.9)	8 (15.4)	
	Grade 4	n (%)	7 (18.9)	14 (26.9)	
Severe	Grade 1	n (%)	2 (5.0)	-	0.03*
	Grade 2	n (%)	24 (60.0)	31 (83.8)	
	Grade 3	n (%)	8 (20.0)	1 (2.7)	
	Grade 4	n (%)	6 (15.0)	5 (13.5)	
Contrast 2.5 mL					
Mild	Grade 1	n (%)	3 (5.3)	1 (1.7)	0.71
	Grade 2	n (%)	32 (56.1)	36 (63.2)	
	Grade 3	n (%)	7 (12.3)	6 (10.5)	
	Grade 4	n (%)	15 (26.3)	14 (24.6)	
Moderate	Grade 1	n (%)	-	-	0.57
	Grade 2	n (%)	19 (52.8)	28 (53.8)	
	Grade 3	n (%)	10 (27.8)	10 (19.2)	
	Grade 4	n (%)	7 (19.4)	14 (26.9)	
Severe	Grade 1	n (%)	2 (5.0)	-	0.04*
	Grade 2	n (%)	24 (60.0)	31 (83.8)	
	Grade 3	n (%)	7 (17.5)	1 (2.7)	
	Grade 4	n (%)	7 (17.5)	5 (13.5)	
			Groups		*P* value
Foraminal spinal stenosis			RD	SP	
Contrast 1.5 mL					
Mild	Grade 1	n (%)	4 (6.6)	-	0.14
	Grade 2	n (%)	44 (72.2)	45 (64.3)	
	Grade 3	n (%)	7 (11.4)	10 (14.3)	
	Grade 4	n (%)	6 (9.8)	15 (21.4)	
Moderate	Grade 1	n (%)	2 (4.3)	1 (1.8)	0.15
	Grade 2	n (%)	27 (58.7)	41 (74.5)	
	Grade 3	n (%)	7 (15.2)	2 (3.6)	
	Grade 4	n (%)	10 (21.7)	11 (20)	
Severe	Grade 1	n (%)	1 (5.3)	-	0.01*
	Grade 2	n (%)	13 (48.1)	16 (80.0)	
	Grade 3	n (%)	9 (33.3)	-	
	Grade 4	n (%)	4 (14.8)	4 (20.0)	
Contrast 2.0 mL					
Mild	Grade 1	n (%)	3 (4.9)	-	0.26
	Grade 2	n (%)	42 (68.9)	40 (57.1)	
	Grade 3	n (%)	8 (13.1)	12 (17.2)	
	Grade 4	n (%)	8 (13.1)	18 (25.7)	
Moderate	Grade 1	n (%)	2 (4.3)	1 (1.8)	0.33
	Grade 2	n (%)	26 (56.5)	40 (72.7)	
	Grade 3	n (%)	6 (13.0)	3 (5.5)	
	Grade 4	n (%)	11 (26.1)	11 (20.0)	
Severe	Grade 1	n (%)	1 (3.7)	-	0.02*
	Grade 2	n (%)	13 (48.1)	15 (75.0)	
	Grade 3	n (%)	8 (29.6)	-	
	Grade 4	n (%)	5 (18.5)	5 (25.0)	

Table 4. *Incidence of complications between the retrodiscal (RD) and subpedicular (SP) groups.*

Complication	RD group (n = 134)	SP group (n = 146)	*P* values
			0.015
No, n (%)	116 (86.6)	129 (88.4)	
Intradiscal injection, n (%)	14 (10.4)	5 (3.4)	
Vascular uptake, n (%)	4 (3.0)	12 (8.2)	

approaches in TFEI. To our knowledge, 3 randomized controlled trials have compared the clinical effect, and spread pattern of contrast media between the SP and RD approaches in TFEI. Park et al studied the patterns following 1 mL of contrast medium injection between the 2 approaches (16) and found that 95.4% and 100% of patients in the SP and RD groups, respectively, showed anterior epidural spread. However, Babita

et al reported that 73.7% and 56.7% of patients in the SP and RD groups, respectively, showed anterior epidural spread following injections with incremental doses of 0.5 mL up to 2 mL (19). Kim et al compared the SP and RD approaches by investigating contrast spread patterns with high volumes of contrast media (0.5, 2.5, and 6 mL) (17) and found no significant intergroup difference, although injection of 3 mL of contrast media showed more extensive distribution in the RD group. These conflicting results may be due to differences in patient characteristics and measurement criteria of each study. Moreover, previous studies did not take into account the severity of central or foraminal stenosis, type of disc, and history of previous spine surgery.

In our study, we tried to analyze the spread patterns of contrast media more accurately than in previous studies by establishing a new radiologic imaging criterion. Previous reports used various image criteria (18,19) or the number of vertebral levels covered with high-volume injectate (17). In our new imaging criterion, the target area was divided in relation to significant anatomic structures such as the subarticular space, intervertebral disc, or nerve root. This grading system (Fig. 2) showed greater specificity by defining whether the injection covered the right pathologic lesion. Grades 3 and 4 indicated appropriate coverage of the targeted site. In our study, the grade of contrast spread showed no significant intergroup difference at all volume points except with the injection of 1.5 mL of contrast media (Table 2), which could be attributed to the differences in severity for each patient and the uneven distribution in the evaluation. We performed further subgroup analysis of both groups by the severity of spinal stenosis, type of HIVD, and history of previous spine surgery. The RD group showed a better spread pattern (more grade 3 and 4) in patients with severe central and foraminal spinal stenosis (Table 3). Thus, in severe spinal stenosis, the RD approach could show better injectate spread and be a better option than the SP approach, and 1.5-2.5 mL of injectate might be enough for drug delivery to the target site. Although subgroup analysis was not performed in previous studies (16,17,19), 56.4% to 100% anterior epidural spread was reported when 1-3 mL of contrast media was injected in the RD approach. Thus, the RD approach with 1.5-2 mL of contrast media can deliver drugs to target lesions more effectively than the SP approach in severe spinal stenosis.

The main advantage of the RD approach over the SP approach is that drugs can be delivered directly to the lesion in the former (20). The main differences between the 2 approaches are the direction and barriers along the pathway of the injectate spread. In the SP approach, the retrospective flow of the injectate through the neural foramen, passing through the subarticular space to reach the upper intervertebral disc level, is important, whereas in the RD approach, the injectate spread into the retrodiscal space and downward movement through the subarticular space covering the traversing nerve root is crucial, and the ideal point of exit is through the foramen. Therefore, in patients with severe foraminal or subarticular spinal stenosis, the drugs may not reach the upper intervertebral disc level with the SP approach, and the RD approach may be advantageous, which is supported by our findings.

Another advantage of the RD approach may be the reduction in the risk of nerve trauma and vascular injection. The target of the RD approach, the Kambin's triangle, is the best-preferred entry site of endoscopic excision for the HIVD (20). Theoretically, this triangle has no exiting nerve root and no traversing vessel passage and is free from dural sheath extension, potentially protecting the nervous and vascular system (13). According to one previous study, intravascular spreading patterns were observed in 11 of 111 TFEIs performed with a lumbar SP approach (9.9%) (22). Another study reported that in 761 TFEIs with a lumbosacral SP approach, the overall rate of intravascular injections was 11.2% (23). Our findings showed similar incidence rates of intravascular injections, which occurred in 12 cases (8.2%) in the SP group but only 4 cases (3.0%) in the RD group. The TF approach enters a previously considered "safe triangle," but this triangle is no longer considered completely safe. Since the spinal nerve root and segmental artery travel within this safe triangle, and the Adamkiewicz artery passes through the intervertebral foramen from T9 to L1 and through the intervertebral foramen from L2 to L4 in rare cases (24), careful attention is required. The RD approach can address these concerns. Despite these important advantages, the RD approach is associated with a greater risk of intradiscal injection, and our results also showed intradiscal injections in 14 cases (10.4%) in the RD group and only 5 cases (3.4%) in the SP group. With more medial needle advancement, the incidence of intradiscal injection may be higher (25). Thus, during the RD approach, it is necessary to pay attention to the depth of the needle and to reduce these concerns by touching the SAP.

Limitations

This study had several limitations. First, we did not evaluate long-term effects and could not definitively correlate the spreading pattern of contrast medium with the therapeutic effect. Second, because we used the contrast media to grade the spread, the drug injectate may have shown a different or better spread pattern with differences in viscosity. However, contrast imaging is currently the only method to grade the injectate spread, and it can be assumed to follow the contrast spreading pattern. In addition, the inclusion of some patients who had previous operation history in our study may have introduced confounding effects in interpreting the results, but since we excluded fusion or instrumentation operation history, these cases were considered not so different from other degenerative spinal pain cases.

Conclusion

In conclusion, the RD approach for TFEI showed a better contrast spreading pattern than the SP approach, especially in patients with severe central and foraminal spinal stenosis. The RD approach for TFEI might be more beneficial for patients with severe central and foraminal spinal stenosis in short-term follow-up assessments.

References

1. Manchikanti L, Knezevic NN, Navani A, et al. Epidural interventions in the management of chronic spinal pain: American Society of Interventional Pain Physicians (ASIPP) comprehensive evidence-based guidelines. *Pain Physician* 2021; 24:S27-S208.
2. Helm II S, Harmon PC, Noe C, et al. Transforaminal epidural steroid injections: A systematic review and meta-analysis of efficacy and safety. *Pain Physician* 2021; 24:S209-S232.
3. Desai MJ, Shah B, Sayal PK. Epidural contrast flow patterns of transforaminal epidural steroid injections stratified by commonly used final needle-tip position. *Pain Med* 2011; 12:864-870.
4. Gupta R, Singh S, Kaur S, Singh K, Aujla K. Correlation between epidurographic contrast flow patterns and clinical effectiveness in chronic lumbar discogenic radicular pain treated with epidural steroid injections via different approaches. *Korean J Pain* 2014; 27:353-359.
5. Lee JH, Shin KH, Park SJ, et al. Comparison of clinical efficacy between transforaminal and interlaminar epidural injections in lumbosacral disc herniation: A systematic review and meta-analysis. *Pain Physician* 2018; 21:433-448.
6. Bogduk N. Epidural steroids. *Spine (Phila Pa 1976)* 1995; 20:845-848.
7. Glaser SE, Falco F. Paraplegia following a thoracolumbar transforaminal epidural steroid injection. *Pain Physician* 2005; 8:309-314.
8. Glaser SE, Shah RV. Root cause analysis of paraplegia following transforaminal epidural steroid injections: The 'unsafe' triangle. *Pain Physician* 2010; 13:237-244.
9. Atluri S, Glaser SE, Shah RV, Sudarshan G. Needle position analysis in cases of paralysis from transforaminal epidurals: Consider alternative approaches to traditional techniques. *Pain Physician* 2013; 16:321-334.
10. Nahm FS, Lee CJ, Kim TH, et al. Risk of intravascular injection in transforaminal epidural injections. *Anaesthesia* 2010; 65: 917-921.
11. Smuck M, Fuller BJ, Yoder B, Huerta J. Incidence of simultaneous epidural and vascular injection during lumbosacral transforaminal epidural injections. *Spine J* 2007; 7:79-82.
12. Park CH, Lee SH, Park HS. Lumbar retrodiscal versus post-ganglionic transforaminal epidural steroid injection for the treatment of lumbar intervertebral disc herniations. *Pain Physician* 2011; 14:353-360.
13. Jasper JF. Lumbar retrodiscal transforaminal injection. *Pain Physician* 2007; 10:501-510.
14. Kambin P. Arthroscopic microdiskectomy. *Mt Sinai J Med* 1991; 58:159-164.
15. Jeong HS, Lee JW, Kim SH, Myung JS, Kim JH, Kang HS. Effectiveness of transforaminal epidural steroid injection by using a preganglionic approach: A prospective randomized controlled study. *Radiology* 2007; 245:584-590.
16. Park JW, Nam HS, Cho SK, Jung HJ, Lee BJ, Park YB. Kambin's triangle approach of lumbar transforaminal epidural injection with spinal stenosis. *Ann Rehabil Med* 2011; 35:833-843.
17. Kim WJ, Shin HY, Yoo SH, Park HS. Comparison of epidural spreading patterns and clinical outcomes of transforaminal epidural steroid injection with high-volume injectate via the subpedicular versus the retrodiscal approach. *Pain Physician* 2018; 21:269-278.
18. Lee GY, Lee JW, Choi HS, Oh KJ, Kang HS. A new grading system of lumbar central canal stenosis on MRI: An easy and reliable method. *Skeletal Radiol* 2011; 40:1033-1039.
19. Ghai B, Gupta AK, Makkar JK, Dhatt SS. Contrast medium volume needed to reach anterior epidural space via the Kambin triangle or subpedicular approach for transforaminal epidural injection. *Pain Physician* 2020; 23:383-392.
20. Furman MB, Lee TS, Mehta A, Simon JI, Cano WG. Contrast flow selectivity during transforaminal lumbosacral epidural steroid injections. Pain Physician 2008; 11:855-861.
21. Kambin P, Savitz MH. Arthroscopic microdiscectomy: An alternative to open disc surgery. *Mt Sinai J Med* 2000; 67:283-287.
22. Kim DW, Han KR, Kim C, Chae YJ. Intravascular flow patterns in transforaminal epidural injections: A comparative study of the cervical and lumbar vertebral segments. *Anesth Analg* 2009; 109:233-239.
23. Furman MB, Giovanniello MT, O'Brien EM. Incidence of intravascular penetration in transforaminal cervical epidural steroid injections. *Spine (Phila Pa 1976)* 2003; 28:21-25.
24. Alleyne CH Jr, Cawley CM, Shengelaia GG, Barrow DL. Microsurgical anatomy of the artery of Adamkiewicz and its segmental artery. *J Neurosurg* 1998; 89:791-795.
25. Lee J, Jo D, Song S, Park D, Kim D, Oh J. Effect of needle tip position on contrast media dispersion pattern in transforaminal epidural injection using Kambin's triangle approach. *J Pain Res* 2020; 13:2869-2878.