Ph.D Dissertation of Medicine

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

경추간공 경막외강 주사의 척추경하 접근법과 디스크후방 접근법 사용시 조영제 확산의 비교: 전향적 무작위 연구

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Graduate School of Medicine
Seoul National University
Anesthesiology and Pain Medicine

Hyun Seung Jin

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지도교수 이 평 복

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Pyung Bok Lee, Thesis director

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Graduate School of Medicine
Seoul National University
Anesthesiology and Pain medicine
Hyun Seung Jin

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Abstract

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

Hyun Seung Jin

Anesthesiology and Pain Medicine

The Graduate School

Seoul National University

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 analogue 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 four 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.

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

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Chapter 1. Introduction

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 (7,8,9). 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).

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) and is defined as a three-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.

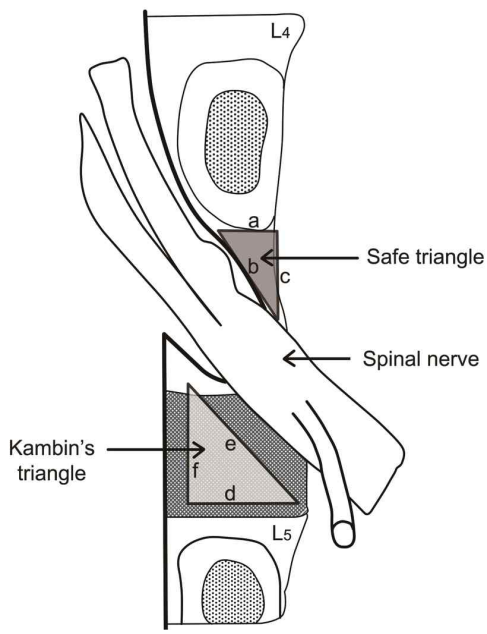

Fig. 1. Retrodiscal and subpedicular approaches for the transforaminal epidural block in the lumbar spine.

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).

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 heterogenous, 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.

Chapter 2. 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 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 TFEIs 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 experienced pain physicians both with expertise in the procedure. Arbitrarily exchanging the randomly allocated group before the procedure, and patient drop out due to unsatisfactory procedure were strictly prohibited. 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 below the L5 pedicle 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(L4/5) were aligned, and under the C-arm, the lateral surface of the superior articular process (SAP) of L5 was placed at the center of the intervertebral space. The needle was advanced slowly and cautiously through the L4/5 foramen 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 was 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 possibility of arbitrary switching of groups while contrast analysis was eliminated since the level of needle insertion was different, L5/S1 in SP group and L4/5 in RD group, and thus two groups were clearly distinguishable.

The spread patterns of contrast medium were graded into 4 categories (Fig. 2). This new grading system was proposed by three 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/below 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/below the target nerve root (L4 or L5 spinal nerve) at the needle-insertion level. Grade 3 and 4 were defined differently 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

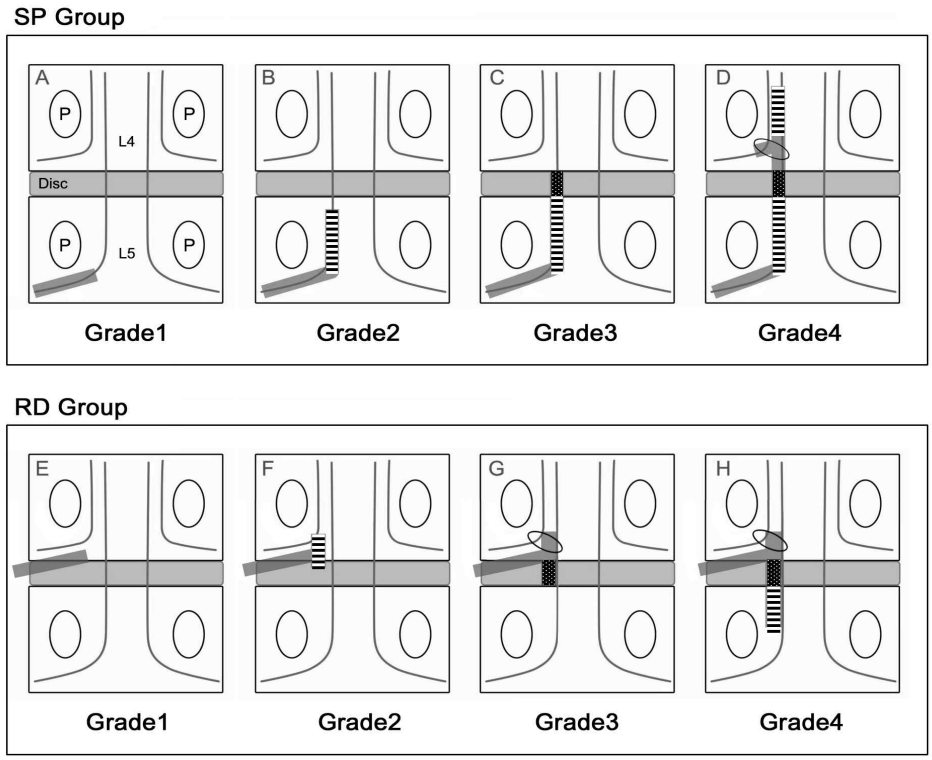

Fig. 2. Grading system of contrast spreading pattern

A. Grade 1 of the SP group: spread at the exiting nerve root (L5 spinal nerve) 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) 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) 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 below the exiting nerve root (L4 spinal nerve) 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 below the target nerve root (L4 spinal nerve) at the needle-insertion level, G. Grade 3 of the RD group: spread at the epidural space with uptake below the exiting (L4 spinal nerve) and along the 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.

as spread at the epidural space with uptake below the exiting (L4 spinal nerve) and along the 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, sex, weight, height, diagnosis, MRI findings (grading of central or foraminal spinal stenosis, type of HIVD), and history of previous spine surgery.

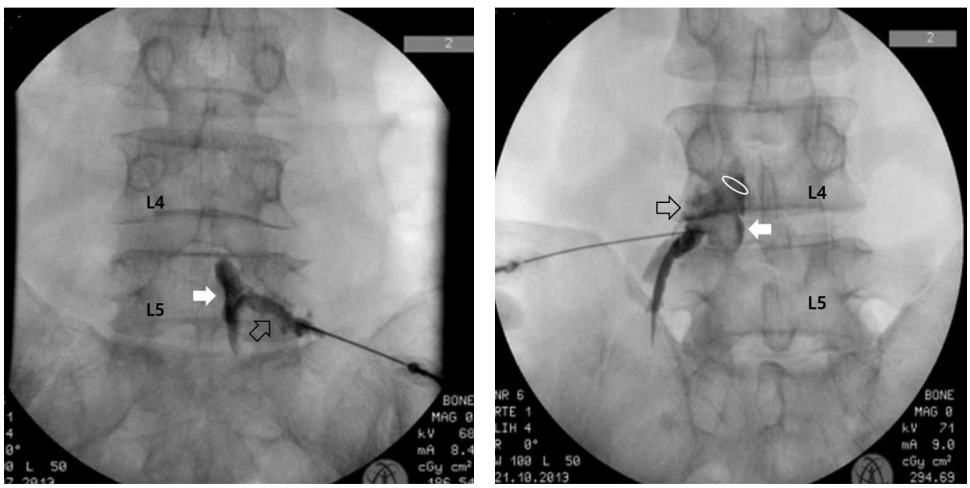

Fig. 3. C-arm images of SA and RD approaches

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.

In our study, we adopted the stenosis severity criteria suggested by Lee classification (18,19). The severity of central stenoses were classified as grade 0 to grade 3, depending on the degree of CSF space obliteration and clumping of the cauda equina, and foraminal stenoses were graded in terms of perineural fat obliteration and morphological changes in the nerve root. Grade 3 for central canal stenosis indicated severe obliteration of anterior CSF space, marked compression of the dural sac, and none of the cauda equina visually seperated, and grade 3 for foraminal stenosis were defined when there was both obliteration of perineural fat and morphological change of the nerve root.

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. 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, sex, 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, USA) was used for statistical analyses. Results are expressed as means (SD). A P-value < 0.05 was considered to indicate statistical significance.

Chapter 3. 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, 2 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).

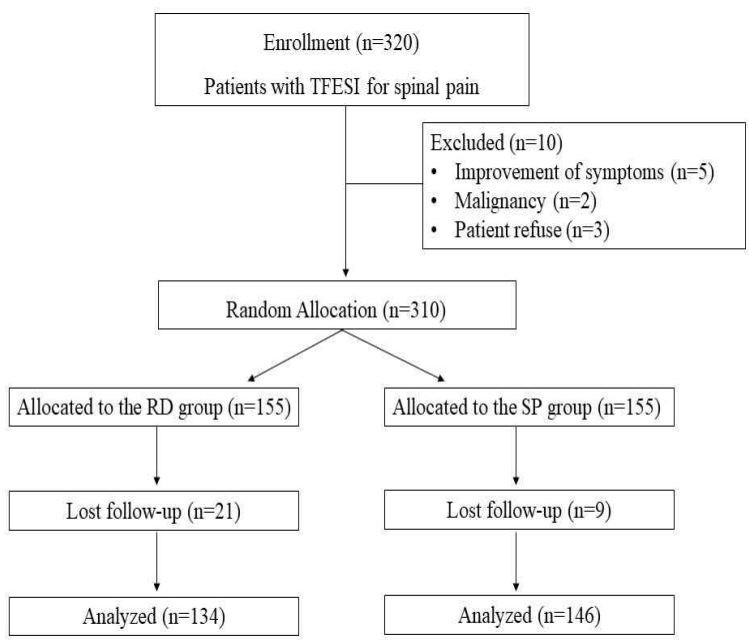

Fig. 4. Flow diagram of patients included in this study.

TFESI, transforaminal epidural steroid injection; RD, retrodiscal approach; SP, subpedicular approach.

Patient characteristics are shown in Table 1. The 2 groups showed no significant difference in patient characteristics.

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
Sex (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.

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 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

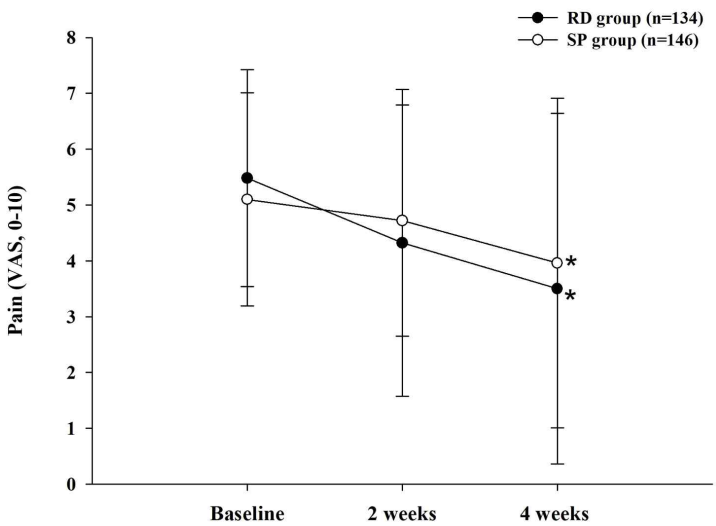

Fig. 5. Changes in visual analog scale (VAS) scores (0 = no pain, 10 = the worst pain imaginable) for lower back pain with/without leg radiating pain between the RD (retrodiscal approach) and SP (subpedicular) groups.

Both groups showed a reduction in pain scores from baseline at 4 weeks. No significant difference was observed between the two groups. The error bar indicates standard deviation. *Significant at $P < 0.01$, compared to the baseline VAS score.

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 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 patients with foraminal stenosis (Table 3). Interestingly, the type of HIVD or a history of previous spine surgery had no effect on the spread pattern of 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)

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

Central spinal stenosis			Groups RD	Groups SP	P-value
Contrast 1.5ml					
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 2.0ml					
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 2.5ml					
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 1.5ml					
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 2.0ml					
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)	

Chapter 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 two 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 using two approaches (15). Preganglionic and ganglionic approaches were compared in this study, where the former and the latter corresponded to RD and SP group of our study, respectively. The preganglionic approach was not an exact equivalent of RD approach since it did not target the disc, but the concept of bypassing the root compression by subarticular or retrodiscal lesion was similar, and the study reported that the preganglionic approach yielded a better treatment effect than the ganglionic(equivalent of 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 (18,20). Jeong et al evaluated 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 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 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 (20). 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 previous studies by establishing a new radiologic imaging criterion. Previous reports used various image criteria (18,20), 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 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 (16,17,20), 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 the anatomy that allows drugs to be delivered directly to the lesion. 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 (21). 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). Intradiscal injection is a critical complication which may cause discal infection or degeneration. Therefore efforts to reduce the incidence during RD approach are crucial, and touching the SAP before advancing the needle in lateral view could help control the depth of the needle. Further studies regarding the techniques to reduce the incidence of intradiscal injection in RD approach may be needed.

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. Clinical experience proves that the more accurately the procedure is done and the injectate spread precisely over the

targeted area, the longer the duration of pain relief. This implies that if the study evaluated a longer period for pain relief, there might have been a positive correlation between the contrast spread and its clinical 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. Third, 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. Another important limitation is rather a technical problem, where the possibility of RD approach resulting in a SP approach-like contrast spread, or vise versa. Since the anatomy of the patients undergoing the procedure are usually distorted, these unintended changeovers between the approach technique, or in other words technical failures, may happen. To reduce this confounding factor, in future studies relating the the RD technique, the final target point of the needle should be more specified, preferably below the lower 1/3 of the disc in true lateral C-arm view.

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. However, this superiority in contrast spread pattern did not correlate with superiority in pain reduction, and SP approach still may be considered a noble technique assuming that intravascular complication could be controlled.

Conflicts of interest

The authors have no competing interests to declare.

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초록

연구 배경: 요추부 경추간공 경막외강 스테로이드 주사는 요추부 추간판 탈출증 및 척추관협착증으로 인한 요부 축성 통증 및 방사통을 효과적으로 감소시킨다. 이때 약물이 목표지점으로 정확하게 도달하는 것이 통증을 감소시키고 부작용을 줄이는데 있어 매우 중요하다. 본 연구는 기존의 척추경하 접근법과, 디스크후방 접근법을 비교하여 새로운 분류 기준을 사용해 조영제의 확산 양상을 분석하고 합병증을 평가하였다. 또한 질환의 심각성이 조영제 확산 양상에 영향을 주는지 함께 조사하였다.

연구 방법: 본 연구는 요추 4/5번 레벨의 디스크탈출 및 척추관협착증 질환을 진단받고 경추간공 경막외강 스테로이드 주사를 시행받는 환자를 무작위로 두 군으로 배정하여 각각 척추경하 접근법 및 디스크후방 접근법으로 받게 하였다. 시각통증점수를 이용한 통증 감소 및 혈관 및 디스크내 주입의 부작용을 분석하였다. 조영제의 확산 양상은 0.5mL 부터 0.5mL씩 증가시켜 3mL를 주입할때까지 매번 촬영하여 본 연구에서 새로 정의한 분류에 따라 4개의 단계로 구분하였다.

연구 결과: 두군 모두에서 시술 2주와 4주후 유의한 통증 감소가 있었으나 (P값<0.01), 두 군간의 유의한 차이는 없었다. 척추경하 접근법과 디스크후방 접근법의 비교 분석에서는, 1.5mL의 조영제 주입시 디스크후방 접근법 군(17.2%)에서 척추경하 접근법 군(8.2%)보다 유의하게 많은 환자에서 3등급 조영제 확산을 보였다. 하위그룹 분석에서는, 디스크후방 접근법군에서 더 우세한 조영제 확산 양상(3등급 또는 4등급)이 심한 중심부 척추관협착증에서 1.5−, 2−, 그리고 2.5mL 주입시에 (P값=0.02, 0.03, 0.04), 또한 심한 추간공

척추관협착증에서 1.5-와 2mL 주입시에 (P값=0.01, 0.02) 관찰되었다.

결론: 경추간공 경막외강 스테로이드 주입술의 디스크후방 접근법에서 기존의 척추경하 접근법에 비해 특히 심한 중심관 또는 추간공 척추관협착증 환자에서 더 우수한 조영제 확산 양상을 관찰할 수 있었다. 디스크후방 접근법은 심한 중심관 또는 추간공 척추협착증 환자의 경우 단기 추적 관찰 측면에서 더 유리할 수 있으나, 장기적인 통증 감소 효과 및 더 적은 약용량에서의 효과는 입증되지 않았다.

주요어: 조영제, 경막외강, 경막외강주사, 방사통, 추간판탈출증, 척추관협착증

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