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Diagnostic Role of Selective Spinal Nerve Block in Treatment of Lumbar Spine Diseases by Percutaneous Endoscopic Technique

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ABSTRACT

AIM: To assess the role of our modified selective spinal nerve block (SSNB) procedure to predict the results of the subsequent Percutaneous endoscopic transforaminal lumbar surgeries (PETLS).

MATERIAL and METHODS: We retrospectively analyzed data of patients who underwent our modified SSNBs before PETLS from February 2013 to March 2018 Clinical outcome data were collected 3 days after PETLS and at follow-up visits.

RESULTS: A total of 120 modified SSNB procedures (transforaminal-78 paravertebral-24, and interlaminar-18) in 92 patients presented positive response. The median follow-up period was 30.6 months. Based on Macnab criteria, the overall success rate (excellent and good results) was 83.7%. Fair and poor outcomes were observed in 10 and 5 patients, respectively. Patients with atypical extraforaminal herniations, and patients with two-level or multiple-level lumbar disc herniations or stenosis achieved desirable results after PETLS. There was significant improvement in the average VAS score for the leg three days after surgery (7.38±0.97 vs. 1.96 ±1.17, $p<0.05$) and on follow-up visits (1.21 ± 0.83, $p<0.05$). ODI was also significantly improved three days after surgery (37.20 ± 2.36 vs. 10.95 ± 2.25, $p<0.05$ and at follow-up visits (8.90 ± 1.72, $p<0.05$)

CONCLUSION: The needle tip should be located closely near the intended compressed nerve via suitable approach combined with slowly injecting 1 ml lidocaine (1%) when performing our modified SSNB technique. It presents an alternative diagnostic procedure to identify the origin of pain of complicated lumbar diseases and to predict PETLS outcomes.

KEYWORDS: Selective spinal nerve block (SSNB), Selective spinal root block (SSRB), Percutaneous endoscopic transforaminal lumbar surgery (PETLS), Accurate diagnosis, Target spinal nerve

ABBREVIATIONS: SSNB: Selective spinal nerve block, **SSRB:** Selective spinal root block, **VAS:** Visual analog scale, **ODI:** Oswestry Disability Index, **MRI:** Magnetic resonance imaging, **CT:** Computed tomography

INTRODUCTION

In clinical practice, determining the source of pain, in most cases, is based on clinical symptoms, signs and image findings. However, patients with extraforaminal herniation, lumbar degenerative herniation or spinal stenosis, and patients with failed back surgery syndrome (FBSS) may not present with the typical dermatomal patterns of pain distribution. In these patients, it is difficult to confirm the affected level of radicular pain. In approximately 62% of these patients, dermatomal overlap between adjacent spinal nerves, especially between L5 and S1, may be exhibited (1), which may further complicate the diagnostic process.

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The importance of preoperative identification of target spinal nerves in atypical cases of extraforaminal herniation, multi-level herniation, spinal stenosis and FBSS has been emphasized (15). Accurate diagnosis is necessary due to preference of minimally invasive surgical strategy and to help clinicians in formulating a reasonable individualized surgical strategy.

In recent years, many researchers have proposed the use of preoperative selective spinal nerve block (SSNB) to identify potential compressed nerves (18). Previous studies mainly focused on the exiting nerves located outside of neural foramen (7,8,17). The exiting nerves are identified by stimulating them to reproduce pain, which is then followed by neural blockade using local anesthetic agents. Transforaminal injections may result in contrast flow into the epidural space where may be considered pathologic site. The contrast or medication may cover more than one level, resulting in false positive. Due to the non-selective nature of SSNB, we suggest that this approach might not identify the source of radicular pain where the target nerves are compressed. In this study, we aimed to assess the predictive value of our modified SSNB procedure on subsequent endoscopic surgery outcomes.

MATERIAL and METHODS

We retrospectively analyzed data on patients who underwent modified SSNB before Percutaneous Endoscopic Transforaminal Lumbar Surgeries (PETLS) from February 2013 to March 2018 in our hospital. All patients were imaged before the procedure: plain X-rays (antero-posterior, lateral view and lateral X-ray dynamic positioning in flexion and extension), magnetic resonance imaging (MRI) and computed tomography (CT) of the lumbar spine. The following patients were included in the study: (1) Patients with minor extraforaminal disc herniation on CT or MRI, with notably serious symptoms; (2) Patients with radicular symptoms and has previously had lumbar fusion surgery, and the symptoms, signs and dermatomal pain distribution suggests insufficient decompression. (3) Patients with $\geq$ two level degenerative lumbar disc herniations secondary to spinal canal stenosis on imaging; (4) Patients who received nonsteroidal anti-inflammatory medications or steroids in combination with bed rest, and showed no significant symptom improvement after 3 months of preoperative treatment. (5) Patients who had a positive response to the modified SSNB procedure and were offered subsequent PETLS. Patients excluded from the study included patients with lumbar instability on lateral view and lateral X-ray dynamic positioning in flexion and extension, patients with prior surgery with definite spinal instability due to screw loosening, patients with pregnancy or history of neurological disorders, and patients who underwent PETLS and were classified into fair or poor based on the Macnab criteria and the post-operative CT and MRI results demonstrated inadequate decompression or residual herniation.

Operative Technique and Strategy

All SSNB procedures were performed under fluoroscopic guidance by a team consisting of the authors of this paper. The study protocol and the informed consent forms were approved by the Institutional Review Board. No analgesic medications were given to patients 4 h prior to the procedures. Preoperative imaging studies were performed to determine the location of the suspected site of nerve compression (within the spinal canal or extraforaminal). We modified the SSNB procedure described by several authors (7,8,17). We adopted the different block approach based on the different pathological sites. If the suspected site was located within the spinal canal, transforaminal or interlaminar approach was adopted, while if the suspected site was located outside the intervertebral foramen (extraforaminal), a paravertebral approach was adopted (Figure 1).

Transforaminal Approach.

Under local anesthesia, the patient assumed an upward lateral decubitus position on the affected side on a radiolucent table, and the procedure was performed under the guidance of C-arm fluoroscopy. The skin's entry point was approximately 10–12 cm from the midline. Approximately 3 mL of local anesthetic (0.5% lidocaine) was administered around the entry point. An 18 cm long, 22-gauge spinal needle with a metal inner core was introduced under fluoroscopic imaging. Once the needle tip reached the lateral part of the superior articular process (SAP), its direction was adjusted toward the lower part of the intervertebral space under lateral X-ray fluoroscopy. The needle tip was then skipped closely under SAP through Kambin's triangle (9) and pushed forward to the posterior edge of vertebral body. Correct placement of needle tip inside the foramen was confirmed with anteroposterior and lateral fluoroscopy (Figure 1). The pain from the compressed nerve root might be reproduced. After carefully confirming absence of CSF or blood during aspiration, 1 ml of lidocaine (1%) was slowly injected to relieve pain without affecting limb muscle strength. If there was apparent resistance during injection, rotation of the spinal needle, redirection of needle tip obliquely, or slight retraction of the needle was attempted. If the injection could still not be completed successfully, we considered that the procedure failed, and the patient was excluded from the study. After successful instillation of lidocaine, the needle was removed and a sterile dressing applied.

Interlaminar Approach

The patient assumed the prone position with the knee and hip joints flexed to widen the interlaminar window, the skin's entry point was approximately 5 mm from the midline. A 10 cm long, 22-gauge spinal needle with a metal inner core was introduced under fluoroscopic imaging. Once the needle tip reached the inner edge of the superior articular process of S1, its direction was adjusted toward the inner side under lateral X-ray fluoroscopy. Disappearance of the resistance from the ligamentum flavum suggested the needle was in the epidural space. Once the pain from the S1 nerve root was elicited, and absence of CSF and blood was confirmed by aspiration, 1 ml lidocaine (1%) was slowly injected to block S1 nerve. The needle was then removed, and a sterile dressing was applied.

After the injection, the patient was asked about the immediate effects of the anesthetic which usually induces pain. If the pain

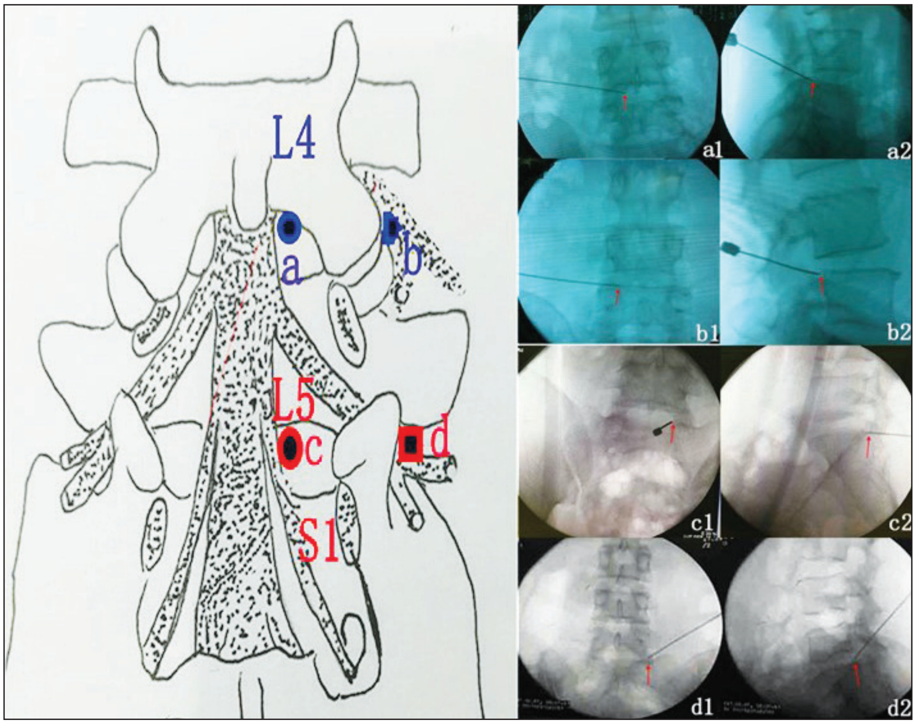

Figure 1: Diagram and X-rays to show the location of tips of spinal needles. a, a1, a2 show the site of block L5 transverse nerve root (transforaminal approach). b, b1, b2 the site of block L4 spinal exiting nerve. (paravertebral approach). c, c1, c2 the site of block S1 transverse nerve root (interlaminar approach). d, d1, d2 the site of block L5 spinal exiting nerve (paravertebral approach).

decreased to 75%, the result was considered as a positive response; otherwise, the result was considered negative. Only a single segment was injected with the anesthetic at any time point during SSNB. In case of confusion as to which segment caused pain, blockage of different spinal nerves on separate occasions was considered. In addition, if nerves at two levels were suspected to cause the pain, the lower spinal nerve was blocked first, and the adjacent upper spinal nerve was blocked on a separate occasion. PETLS was performed on the patients with positive response to the modified SSNB, adopting the techniques by Thomas Hoogland (9).

Paravertebral Approach

Under local anesthesia, the patient took an upward lateral decubitus position on the affected side on a radiolucent table and the procedure was performed under the guidance of C-arm fluoroscopy. The entry point on the skin was approximately 4–6 cm from the midline. Approximately 3 mL of local anesthetic (0.5% lidocaine) was administered around the entry point, then a 22-gauge spinal needle with a metal inner core was introduced under fluoroscopic imaging. Once the needle tip reached the dorsal part of superior articular process, its direction was adjusted toward the lower part of the intervertebral space under lateral X-ray fluoroscopy. The needle tip was skipped closely along the lateral superior articular process and pushed forward to the posterior edge of vertebral body. Correct placement of the needle tip in extraforaminal area was confirmed with anteroposterior and lateral fluoroscopy (Figure 1). The follow-up injection procedure was the same as previously described.

Clinical outcome data, including visual analog scale (VAS) scores, preoperative Oswestry disability index (ODI) scores, patient's condition 3 days after the surgery and at follow-up visits were collected. The outcomes were evaluated according to Macnab criteria at follow-ups. All the procedures of PETLS were performed by a team consisting of authors of this paper at the same unit.

Statistical Analysis

All analyses were performed with SPSS software. "Mean ± standard deviations" was obtained for continuous variables, and frequency (percent) for categorical variables. Intragroup pre- and postoperative VAS and ODI scores were compared with paired t-test. A p value of < 0.05 indicated statistical significance.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the local ethics committee. (Tianjin Medical University. Date of meeting 14 May 2019).

RESULTS

PETLS was offered to 98 patients with positive responses. Six patients whose symptoms were not relieved because of inadequate endoscopic decompression or residual herniation determined by postoperative CT and MRI results after PETLS were excluded. Of the 92 patients enrolled, 54 were male and 38 were female; the median age was 53 (32 to 77) years. Four pathological subgroup identified included: 10 patients with minor extraforaminal disc herniation on CT or MRI; 16 patients with past history of lumbar fusion surgery who presented radicular symptoms, 20 patients with two level lumbar disc herniations; and 46 patients with multi-level lumbar spinal stenosis secondary to degenerative herniation on imaging.

A total of 120 SSNB procedures involving 92 patients had positive responses. Three segments were identified at L2–L3, 18 at L3–L4, 69 at L4–L5 and 30 at L5–S1. Two-level blockage on separate occasions was offered to 28 cases, among whom 16 presented two-level blockage at L4–L5 and L5–S1 levels, 10 cases at L4–L5 and L3–L4 levels, and 2 cases at L3–L4 and L2–L3 levels. Overall, 78 procedures were performed via the transforaminal approach, 24 procedures via the paravertebral approach, and 18 via the interlaminar approach.

The median follow-up period was 30.6 months (12–50 months). Based on Macnab criteria, excellent and good outcomes were achieved in 30 and 47 patients, respectively, indicating an overall success rate of 83.7%. Fair and poor outcomes were observed in 10 and 5 patients, respectively (Table I). In the four subgroups, 9 in 10 (90%) patients with minor extraforaminal disc herniation on CT or MRI who underwent PETLS achieved significant improvements (case in Figure 2A-F). The remaining one case exhibited fair results. Of the 16 patients with radicular symptoms after previous lumbar fusion surgery, 7 (43.5%) obtained desirable results (case in Figure 3A-F). Fair outcomes were observed in 6 patients and p oor outcomes in the remaining 3 patients. Desirable results were achieved in 20 (100%) patients with possible two-level involved lumbar disc herniations by image findings (case in Figure 4A-K). Good outcomes were seen in 40 out of 46 (87.0%) aged patients with multilevel lumbar spinal stenosis secondary to degenerative herniation (case in Figure 5A-E). Fair outcomes were seen in 4 patients and poor outcomes in 2 patients.

Table I: The MacNab Results of 92 Patients After PETLS

Outcome	No. of Patients (%)
MacNab criteria	
Excellent	30 (32.6)
Good	47 (51.1)
Fair	10 (10.8)
Poor	5 (5.4)

There was significant improvement in the average VAS score for the leg three days after surgery (7.38 ± 0.97 vs. 1.96 ± 1.17, $p<0.05$) and on follow-up visits (1.21 ± 0.83, $p<0.05$). ODI was also significantly improved three days after surgery (37.20 ± 2.36 vs. 10.95 ± 2.25, $p<0.05$ and at follow-up visits (8.90 ± 1.72, $p<0.05$) (Table II).

DISCUSSION

In most patients with lumbar radicular pain, clinical examination and imaging studies can accurately localize the origin of

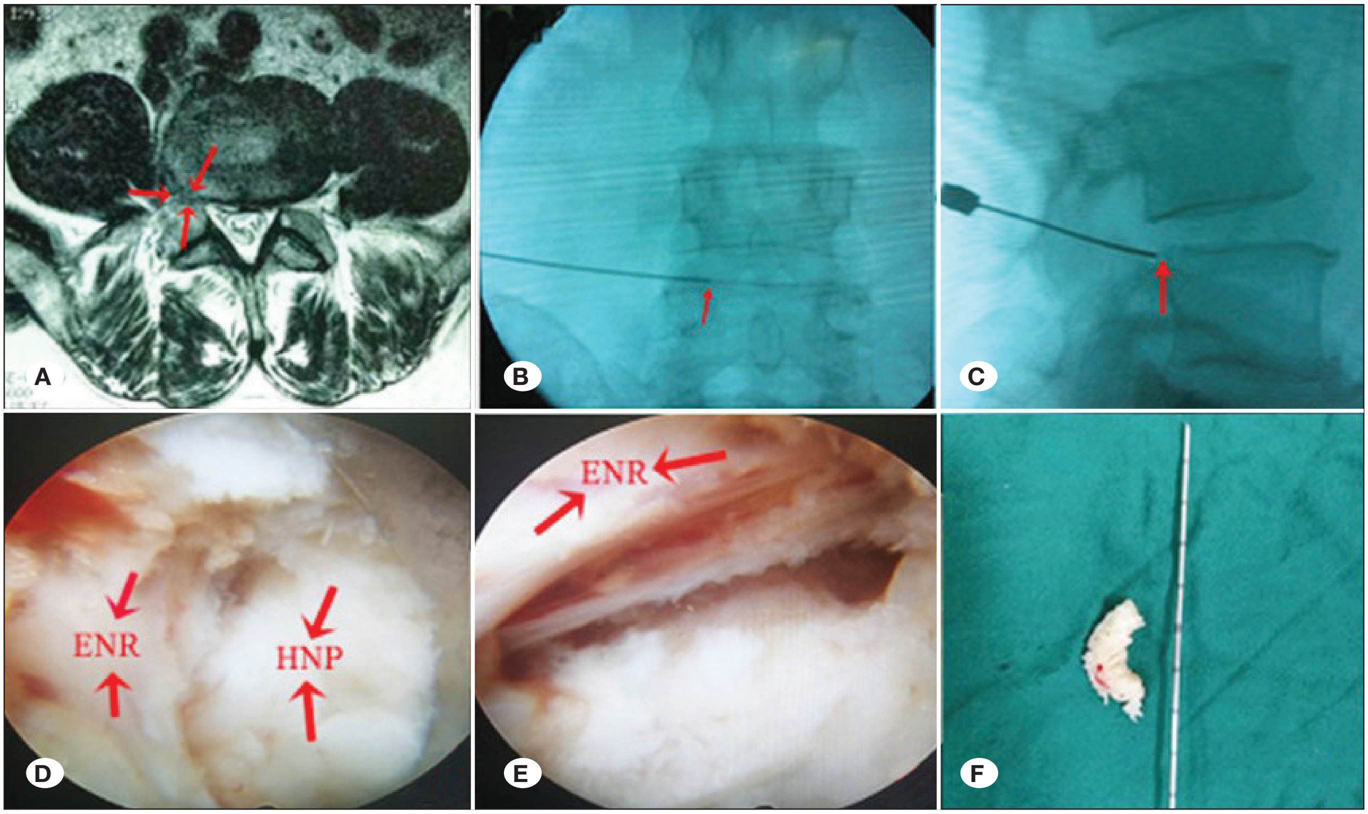

Figure 2: Imaging results showing a small-size herniated nucleus pulposus (HNP) of a male patient (63 years old) experiencing extremely serious pain with. **A)** Small-size HNP (red arrow). **B)** Location of the needle tip in antero-posterior X-rays. **C)** Location of the needle tip in lateral X-rays. **D)** Exiting nerve root (ENR) and HNP at the ventral side of ENR. **E)** ENR after sufficient decompression. **H)** Protrusions obtained during PETLS.

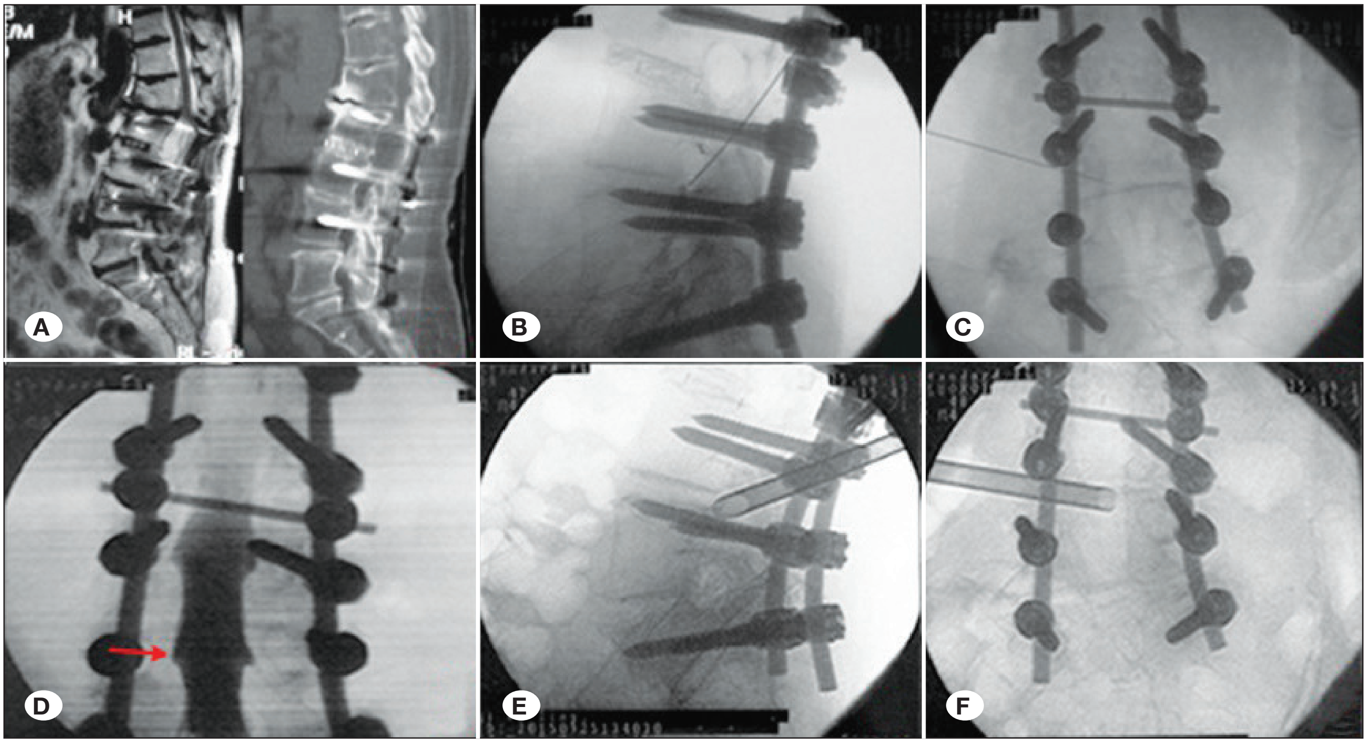

Figure 3: Imaging results for female patient (67 years old) whose radicular pain of the right limb with intermittent claudication occurred immediately after multilevel lumbar fusion. the symptoms were relived partially after the dissection of partial SAP during the PELS. **A)** MRI of lumbar fusion surgery of the patient. **B, C)** Location of needle tip during modified SSNB under lateral and antero-posterior X-rays. **D)** Myelography revealed compression of the right L5 nerve root (red arrow). **E, F)** Location of working cannula during PTELS under lateral and antero-posterior X-rays.

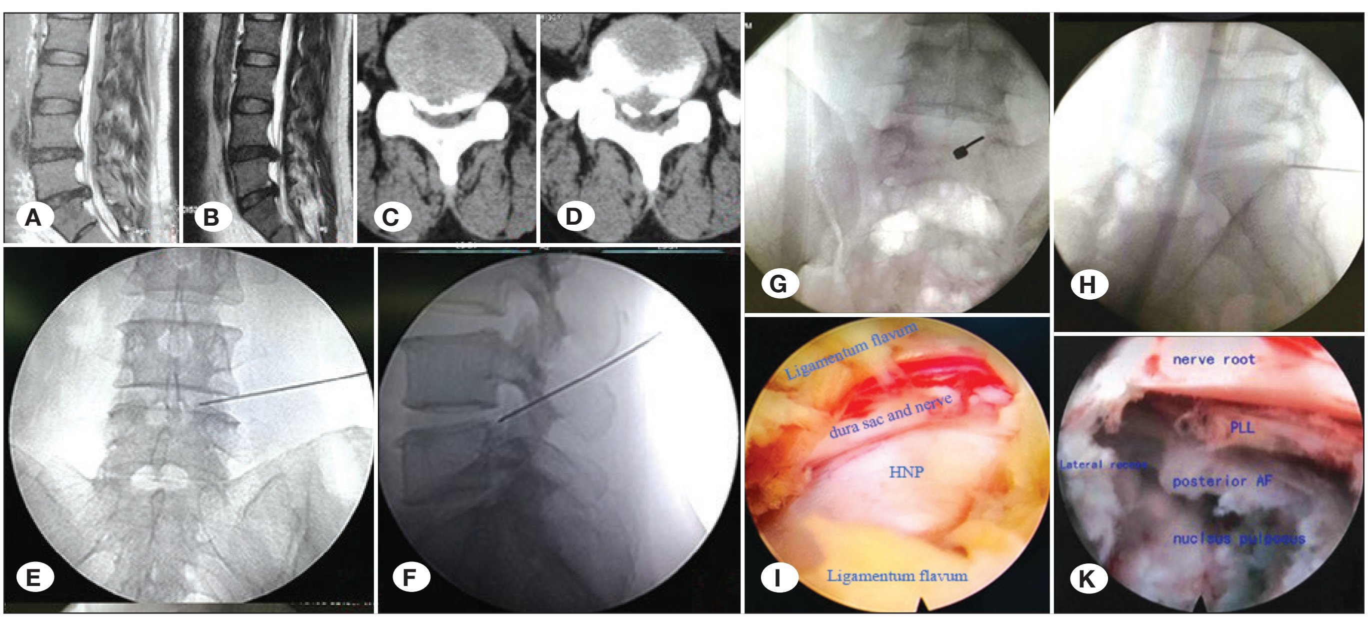

Figure 4: Imaging results for a male patient (30 years old) experiencing extremely serious left radicular limb pain with two-level herniation. Modified SSNB test revealed positive result for the L4–L5 segment; PETLS was performed on the L4–L5 segment. **A)** and **B)** L4–L5 and L5–S1 segments with evident herniation, respectively. **C)** and **D)** CT vertebral posterior margin amputation with calcified herniation in the L5-S1 segment. **E–H)** Location of needle tip in modified SSNB for L4–L5 and L5–S1. The results showed positive response for L5 nerve root and negative response for S1 nerve root. **I)** L5 nerve root compressed by protrusions under spine endoscopy before decompression. **K)** L5 nerve root after sufficient decompression.

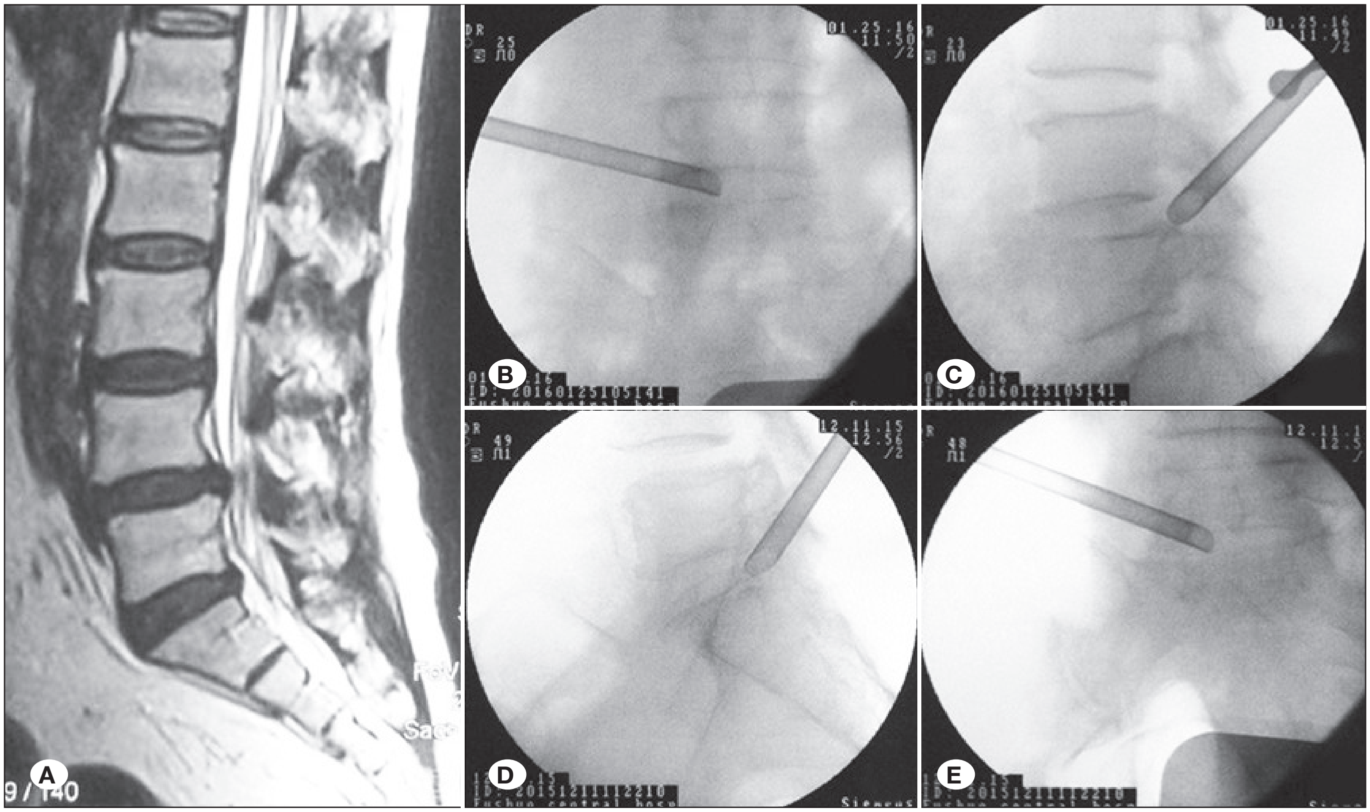

Figure 5: Imaging results for a male patient (65 years old) diagnosed with degenerative herniation with secondary spinal stenosis with intermittent claudication (200 m). Modified SSNB test revealed positive results for both segments. The patient was treated with PETLS for both L4–L5 and L5–S1 segments. **A)** Preoperative MRI displaying L4–L5 and L5–S1 herniation. **B)** and **C)** Location of working cannula of L4–L5 segment under X-ray during PETLS. **D)** and **E)** Location of working cannula of L5–S1 segment under X-ray during PETLS.

Table II: VAS and ODI Before and Three Days After Surgery and Follow-Up Time Point After PETLS of 92 Patients

	Preoperative	Three days after the surgery	Time point of follow up after surgery
VAS	7.38 ± 0.97	1.96 ± 1.17*	1.21 ± 0.83*
ODI (%)	37.20 ± 2.36	10.95 ± 2.25#	8.90 ± 1.72#

***,#** *indicate significant difference compared with preoperatively.*
***VAS:** Visual analog scale;* ***ODI:** Oswestry Disability Index.*

pain (10,12). However, in some cases, the clinical symptoms and examination findings are inconsistent with the imaging findings; especially in patients with prior history of surgery or multilevel segment pathology. Clinical symptoms and signs associated with lumbosacral nerve root compression is similar to those of simple non-specific low back pain with referred leg pain (6). Deyo RA et al. assumed that weak association between symptoms, pathological changes, and image findings were related to musculo-ligamentous injuries or degenerative changes (3) .

In this study, we opted not to name the procedure "selective spinal root block (SSRB)" which was adopted by previous studies (7,8,11,17,19), due to lack of accuracy in its description (4,5,14). In reviewing the anatomy, ventral and dorsal roots join together to form the segmental spinal nerve, which traverses the neural foramen. The spinal nerve bifurcates into dorsal and ventral rami outside the foramen. The distribution of ventral rami causes radicular pains (2). Therefore, we named the procedure, in which the needle tip was located outside the foramen, as SSNB, a term advocated by Furman and O'Brien (5). However, if the needle tip is located inside of spinal canal, which is closely near the transverse nerve root, we named this procedure SSRB, which we think is an accurate description. Therefore, the naming depends on the different location of needle tip. In this study, we call both techniques "modified SSNB".

In this study, we proposed our modified technique, in which the needle tip is located near the site of nerve compression. Before SSNB or SSRB technique, imaging studies were conducted to determine whether the suspected compression site was located within the spinal canal or at the extraforaminal area, thus guiding the selection of transforaminal, interlaminar or paravertebral approach to block the transverse nerve roots or exiting spinal nerves. The modified SSNB technique represents a useful diagnostic test that may provide relatively accurate and reliable identification of a symptomatic nerve.

We agreed to use a technique reported by several studies on the diagnosis of radicular pain of uncertain segments to reproduce typical pain distribution in the patient's leg with a puncture needle, aiming to stimulate the exit spinal nerve following the injection of local anesthetics (7,8,13,15,17,18). However, sometimes we think the procedure might not help the clinician to determine the real pathological site. For example, in a patient with symptoms of the fifth lumbar nerve, stimulating the L5 nerve at the L5–S1 segmental level might not determine the real pathological site inside the spinal canal at the L4-L5 segmental level.

In our study, we chosed 1% lidocaine (1 ml) as it would not decrease the extensor strength of lower limbs, and does not have negative impact on the walking ability of patients. Although the volume of local anesthetic was decreased to 1 ml, diffusion of medication to adjacent segments may still occur leading to false positive results. The maximum dose of anesthetic agent is limited by its intended nerve under fluoroscopic guidance, confirmed by the diffusion of injection of contrast medium as mentioned in previous studies (4,14). We assume that the volume, concentration, injection speed of local anesthetics and limited diffusion of the local anesthetics in intraspinal tissues may result in false positive or false negative results in SSNB or SSRB, resulting in questionable diagnosis. Although the transverse and exiting nerves in the same level or segment were anesthetized, we could easily pinpoint the responsible nerve by deduction in combination with results from imaging studies. Based on the results of blocking, the target nerve of endoscopic surgery was identified preoperatively.

In cases where the responsible nerves involved two levels, we first blocked the lower spinal nerve and then blocked the adjacent upper spinal nerve to prevent the blocked transverse nerve root of the upper segment from interfering with the identification of the compressed exiting nerve root of the lower segment. The focus of our study was on pathological site of nerve compression, which could be blocked by local anesthetic agents. This differs from previous studies where the focus was on exiting nerves (8).

Occasionally, the size of protrusion of extraforaminal herniation on CT or MRI is small, but the symptoms are notably serious. This condition often leads to difficulties in diagnosis. Therefore, SSNB is a useful diagnostic tool for atypical extraforaminal disc herniations. In imaging studies, 9 in 10 patients with minor extraforaminal disc herniation demonstrated significant postoperative improvements. The overall success rate was 90% in the subgroup. As common endoscopic findings, increased tension of exiting nerve originates from the protrusion under its ventral side (Figure 2). In patients with prior history of lumbar fusion surgery, the origin of radicular pain could not be identified adequately by imaging studies and myelogram. SSNB combined with myelography (Figure 3) usually provides an appropriate diagnosis and helps to offer treatment plan regardless of the prior fusion surgery. In this study, we achieved relatively fair and poor endoscopic results in these patients, which were similar to previous studies (8). The primary treatment goal for these patients was dissection of partial superior articular process to achieve sufficient dorsal bony decompression of dura sac and transverse nerve root. At the same time, release and removal of adhesion tissues on the ventral side of dural sac and traversing nerve root was performed. The pathologies of these patients were more complicated. Extensive epidural scaring, fibrous adhesion or insufficient decompression might be crucial factors accounting for poor outcomes.

SSNB or SSRB could be used evaluate the results of endoscopic surgery in patients presenting with two-level lumbar disc herniations revealed on imaging; however, PETLS was performed only at the symptomatic level identified preoperatively by SSNB or SSRB. All these patients achieved good outcomes in this study. In patients with long-existing multilevel lumbar spinal canal stenosis secondary to lumbar degenerative herniation, the results by SSNB or SSRB in identifying symptomatic level were relatively reliable. We therefore designed reasonable endoscopic decompression of the responsible segmental level. A single unilateral nerve could be responsible for symptoms in the majority of patients. This finding is especially beneficial in identification of origin of leg pain in elderly patients. In our study, 40 out of 46 patients with spinal canal stenosis secondary to multi-level involved lumbar disc herniation obtained good outcomes. In this type of pathology, fair and poor outcomes were shown in 4 and 2 patients, respectively. Unfavorable outcomes might be related to complicated spinal biomechanics.

Despite the largely favorable outcomes, this study's findings cannot be generalized due to the small sample size that precluded group analysis.

CONCLUSION

In summary, when performing a SSNB or SSRB injection based on different pathological type, the needle tip should be located near the compressed intended nerve, and the procedure should be monitored with precise X-ray imaging. SSNB or SSRB is a useful diagnostic procedure in identifying the origin of pain in patients with atypical extraforaminal herniations, patients with prior lumbar fusion surgery, and patients with multiple-level involved lumbar disc herniation or lumbar spinal stenosis secondary to degenerative herniation. Although false positive or false negative results may result from local anesthetic agent diffusion, which is limited in intraspinal tissues, these results did not interfere with the performance of SSNB or SSRB. Therefore, SSNB or SSRB is a supplementary diagnostic tool in clinical diagnosis of the origin of pain, and can also be used to evaluate or predict the results of PETLS in the above-mentioned conditions.

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REFERENCES

1. Bartynski WS, Kang MD, Rothfus WE: Adjacent double-nerve root contributions in unilateral lumbar radiculopathy. AJNR Am J Neuroradiol 31:327-333, 2010
2. Bogduk N, Twomey LT: Clinical anatomy of the lumbar spine and sacrum. 3rd ed. New York: Churchill Livingstone, 1997:128-132
3. Deyo RA, Rainville J, Kent D L: What can the history and physical examination tell us about low back pain? JAMA 268: 760-765, 1992
4. Furman MB, Lee TS, Mehta A, Simon JI, Cano WG: Contrast flow selectivity during transforaminal lumbosacral epidural steroid injections. Pain Physician 11:855-861, 2008
5. Furman MB, O'Brien EM: Is it really possible to do a selective nerve root block? Pain 85:526, 2000
6. Germon T, Singleton W, Hobart J: Is NICE guidance for identifying lumbar nerve root compression misguided? Eur Spine J 23:S20-S24, 2014
7. Haueisen DC, Smith BS, Myers SR, Pryce ML: The diagnostic accuracy of spinal nerve injection studies. Their role in the evaluation of recurrent sciatica. Clin Orthop Relat Res 198:179-183, 1985
8. Herron LD: Selective nerve root block in patient selection for lumbar surgery: Surgical results. J Spinal Disord 2:75-79, 1989
9. Kambin P, Sampson S: Posterolateral percutaneous suction-excision of herniated lumbar intervertebral discs. Report of interim results. Clin Orthop Relat Res 207:37-43,1986
10. Kido T, Okuyama K, Chiba M, Sasaki H. Seki N, Kamo K, Miyakoshi N, Shimada Y: Clinical diagnosis of upper lumbar disc herniation: Pain and/or numbness distribution are more useful for appropriate level diagnosis. J Orthop Sci 21:419-424, 2016
11. Ko S, Chae S, Choi W, Kwon J: Prolonged pain reducing effect of Sodium Hyaluronate-Carboxymethyl Cellulose solution in the Selective Nerve Root Block (SNRB) of lumbar radiculopathy: A prospective, double-blind, randomized controlled clinical trial. Spine J 19(4):578-586, 2019
12. Kreiner DS, Hwang SW, Easa JE, Resnick DK, Baisden JL, Bess S, Cho CH, DePalma MJ, Dougherty P, Fernand R, Ghiselli G, Hanna AS, Lamer T, Lisi AJ, Mazanec DJ, Meagher RJ, Nucci RC, Patel RD, Semrano JN, Sharma AK, Summers JT, Taleghani CK, Tontz Jr WL, Toton JF, North American Spine Society: An evidence-based clinical guideline for the diagnosis and treatment of lumbar disc herniation with radiculopathy. Spine J 14:180-191, 2014
13. Li X, Bai X, Wu Y, Ruan D: A valid model for predicting responsible nerve roots in lumbar degenerative disease with diagnostic doubt. BMC Musculoskelet Disord 17:128, 2016
14. Makkar JK, Singh NP, Rastogi R: Volume of contrast and selectivity for lumbar transforaminal epidural steroid injection. Pain Physician 18:101-105, 2015
15. Sasso RC, Macadaeg K, Nordmann D, Smith M: Selective nerve root injections can predict surgical outcome for lumbar and cervical radiculopathy: Comparison to magnetic resonance imaging. J Spinal Disord Tech 18:471-478, 2005
16. Schubert M, Hoogland T: Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disk herniation. Oper Orthop Traumatol 17:641-661, 2005
17. White AH: Injection techniques for the diagnosis and treatment of low back pain. Orthop Clin North Am 14:553-567, 1983
18. Williams AP, Germon T: The value of lumbar dorsal root ganglion blocks in predicting the response to decompressive surgery in patients with diagnostic doubt. Spine J 15:S44-S49, 2015
19. Yeom JS, Lee JW, Park KW, Chang BS, Lee CK, Buchowski JM, Riew KD: Value of diagnostic lumbar selective nerve root block: A prospective controlled study. Am J Neuroradiol 29:1017-1023, 2008