



PRE-INCISIONAL CAUDAL EPIDURAL ANALGESIA VERSUS LOCAL SURGICAL-SITE INFILTRATION FOR EARLY PAIN CONTROL AFTER LUMBAR MICRODISCECTOMY: A RETROSPECTIVE COMPARATIVE COHORT STUDY

✉ Mehmet Alpay Çal¹, ✉ Ahmed Yasin Yavuz²

¹Liv Hospital Ulus, Clinic of Neurosurgery, İstanbul, Türkiye

²Medicana Zincirlikuyu Hospital, Clinic of Neurosurgery, İstanbul, Türkiye

ABSTRACT

Objective: Preemptive analgesia may reduce early postoperative pain after lumbar microdiscectomy, but the optimal anatomical target for local anesthetic delivery remains unclear. This study compared pre-incisional caudal epidural analgesia (pre-CEA) with pre-incisional local surgical-site infiltration (pre-LSSI) for single-level lumbar microdiscectomy.

Materials and Methods: This retrospective comparative cohort study analyzed prospectively recorded perioperative pain data from adults undergoing single-level lumbar microdiscectomy in 2022. Analgesic protocols were not randomized; patients selected pre-LSSI, pre-CEA, or no preemptive analgesia after preoperative discussion. The primary analysis compared pre-LSSI with pre-CEA; the control cohort was exploratory. The primary outcome was the 24-hour visual analog scale (VAS)-back area under the curve (AUC). Secondary outcomes included VAS-leg AUC, rescue analgesia, opioid rescue, ambulation time, length of stay, and adverse events.

Results: The study included 138 patients: 47 pre-LSSI, 42 pre-CEA, and 49 controls. VAS-back AUC was lower with pre-CEA than pre-LSSI (42.2 ± 8.0 vs. 64.0 ± 6.0 ; $p < 0.001$), as was VAS-leg AUC [0.0 ($0.0-0.0$) vs. 8.0 ($8.0-8.0$); $p < 0.001$]. Rescue analgesia was required in all pre-LSSI patients but in none of the pre-CEA patients ($p < 0.001$). Neither active-treatment group required opioid rescue.

Conclusion: Pre-CEA was associated with lower early postoperative pain burden and no rescue analgesic requirement during the first 24 hours compared with pre-LSSI. Given the preference-based, non-randomized design and non-equivalent bupivacaine protocols, prospective, randomized, dose-standardized studies are needed to confirm these findings.

Keywords: Lumbar microdiscectomy, preemptive analgesia, caudal epidural analgesia, local infiltration, postoperative pain

INTRODUCTION

Lumbar microdiscectomy is commonly performed for symptomatic lumbar disc herniation and is generally associated with rapid relief of radicular symptoms. Nevertheless, early postoperative pain remains clinically relevant because it can affect patient comfort, analgesic requirement, mobilization, and discharge readiness. Contemporary procedure-specific pain management recommendations for lumbar posterior decompressive procedures emphasize multimodal analgesia and generally reserve opioids for rescue treatment, reflecting the need for effective opioid-sparing strategies in the early postoperative period⁽¹⁾. In lumbar spine surgery, preemptive analgesia has been evaluated as one such strategy, with meta-analytic evidence suggesting potential reductions in early

postoperative pain and analgesic consumption, although the magnitude of benefit varies according to the analgesic technique and surgical context⁽²⁾.

The rationale for preemptive analgesia is based on the concept that noxious input before and during surgery may contribute to postoperative pain amplification through peripheral and central sensitization. Experimental work by Woolf⁽³⁾ demonstrated that tissue injury can produce a central component of post-injury pain hypersensitivity, providing an important biological basis for strategies aimed at limiting nociceptive input before it becomes established. Kissin⁽⁴⁾ later emphasized that preemptive analgesia should be understood not merely as an intervention given before incision, but as an attempt to reduce postoperative pain by preventing or attenuating sensitization caused by perioperative noxious stimuli. More recent network

Address for Correspondence: Mehmet Alpay Çal, Liv Hospital Ulus, Clinic of Neurosurgery, İstanbul, Türkiye

E-mail: dr.alpaycal@gmail.com

ORCID ID: orcid.org/0000-0003-3620-2993

Received: 08.06.2026 **Accepted:** 24.08.2026 **Publication Date:** 14.10.2026

Cite this article as: Çal MA, Yavuz AY. Pre-incisional caudal epidural analgesia versus local surgical-site infiltration for early pain control after lumbar microdiscectomy: a retrospective comparative cohort study. J Turk Spinal Surg. 2026;37(4):155-164



meta-analytic evidence also supports the general concept that preemptive analgesic interventions can improve postoperative pain outcomes, while highlighting heterogeneity across drug classes, routes, and procedures⁽⁵⁾.

Within contemporary enhanced recovery after surgery (ERAS) pathways for spine surgery, multimodal opioid-sparing analgesia and early mobilization are central components of perioperative care⁽⁶⁾. Regional analgesic techniques are increasingly incorporated into these pathways to improve early pain control while limiting systemic opioid exposure. Among newer fascial-plane approaches, erector spinae plane block (ESPB) and thoracolumbar interfascial plane (TLIP) block have accumulated substantial randomized and meta-analytic evidence in lumbar spine surgery⁽⁷⁻⁹⁾. Both techniques have been associated with lower postoperative pain scores and opioid consumption, although comparative evidence remains heterogeneous and no single regional technique has been established as universally optimal⁽⁷⁻⁹⁾. Caudal epidural analgesia represents a different, neuraxial approach that may provide cephalad epidural distribution through a sacral access point and can be performed after prone positioning without altering the operative setup. In adult lumbar spine surgery, however, its contemporary evidence base is smaller than that of ESPB and TLIP, particularly for direct comparisons with simpler surgical-site infiltration protocols.

Within this broader multimodal framework, pre-incisional local surgical-site infiltration (pre-LSSI) and pre-incisional caudal epidural analgesia (pre-CEA) represent two practical but anatomically distinct approaches to pain control in lumbar microdiscectomy. Local surgical-site infiltration targets the skin, subcutaneous tissue, and paraspinal muscle layers and is technically simple, familiar, and widely applicable. However, systematic reviews of local anesthetic wound or paraspinal infiltration in lumbar spine surgery have reported variable and often modest early analgesic effects^(10,11). By contrast, caudal epidural analgesia delivers local anesthetic into the epidural compartment and may provide a broader proximal neural target for early postoperative analgesia. Randomized studies have suggested that preemptive caudal epidural local anesthetic administration can reduce early postoperative pain and analgesic requirement after lumbar disc or lumbosacral spine surgery^(12,13). Despite the availability of studies evaluating these techniques separately, direct comparative evidence between pre-LSSI and pre-CEA in single-level lumbar microdiscectomy remains limited. Clarifying this comparison is clinically relevant because these methods differ not only in technical invasiveness but also in anatomical target, drug distribution, and expected analgesic field. Therefore, this study aimed to compare pre-LSSI with pre-CEA for early postoperative pain control after single-level lumbar microdiscectomy. The primary endpoint was cumulative visual analog scale (VAS)-back pain burden during the first 24 postoperative hours, expressed as area under the curve (AUC). Secondary outcomes included VAS-leg AUC, postoperative VAS trajectories, rescue analgesic requirement, ambulation time,

length of hospital stay, and adverse events. A no preemptive analgesia control cohort was retained as an exploratory contextual comparator.

MATERIALS AND METHODS

Study Design and Ethics

This study was conducted as a retrospective comparative cohort analysis of prospectively recorded standardized perioperative pain data. The study was approved by the University of Health Sciences Türkiye, Prof. Dr. Cemil Taşcıoğlu City Hospital Ethics Committee before data analysis (approval no: 22, date: 23.01.2023) and was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent for surgery and perioperative analgesic procedures was obtained according to institutional practice.

Consecutive adult patients who underwent single-level lumbar microdiscectomy for lumbar disc herniation during 2022 were screened for eligibility. Patients were classified according to the analgesic approach actually performed before skin incision: pre-LSSI, pre-CEA, or no preemptive analgesia.

The primary analysis focused on the active-treatment comparison between pre-LSSI and pre-CEA. The no preemptive analgesia control cohort was retained only as an exploratory contextual comparator to describe the clinical magnitude of preemptive analgesia relative to no preemptive intervention.

Preemptive analgesic interventions were not assigned by randomization. In routine clinical practice, patients were informed preoperatively about available postoperative pain control options, and the selected pre-incisional analgesic technique was performed when the patient consented to and preferred that approach. Because the analgesic technique was selected according to patient preference after preoperative discussion rather than random allocation, the active-treatment groups may have differed in unmeasured factors such as pain expectations, anxiety, treatment preference, or perceived need for neuraxial analgesia. These potential sources of selection bias were considered when interpreting the results.

Participants

Patients were included if they were 18 years of age or older, had American Society of Anesthesiologists (ASA) physical status I or II, had magnetic resonance imaging-confirmed single-level lumbar disc herniation with radiculopathy, and underwent standard single-level lumbar microdiscectomy.

Patients were excluded if they underwent multilevel surgery, revision surgery, additional decompressive procedures, fusion surgery, or a surgical approach other than standard single-level lumbar microdiscectomy. Patients with ASA physical status III or IV, morbid obesity, known allergy to any study medication, drug or alcohol abuse, chronic narcotic use, or incomplete perioperative pain records were also excluded.

Anesthesia and Surgical Procedure

All procedures were performed under general anesthesia in the prone position using the same institutional anesthetic protocol. General anesthesia was induced with propofol and fentanyl 2 µg/kg, and tracheal intubation was facilitated with atracurium. The induction dose of fentanyl represented the total intraoperative fentanyl exposure; no additional fentanyl or other intraoperative opioid bolus was administered, and remifentanyl infusion was not used. Anesthesia maintenance followed the institutional volatile anesthetic protocol. However, individual volatile anesthetic concentrations and end-tidal minimum alveolar concentration (MAC) values were not systematically available in the retrospective records and therefore could not be reliably analyzed.

A standard posterior lumbar microdiscectomy was performed in all patients. After a midline lumbar skin incision, the thoracolumbar fascia was opened, and the paraspinal muscles were dissected subperiosteally from the lamina on the symptomatic side. Under the operating microscope, limited laminotomy and flavectomy were performed as required. The affected nerve root was mobilized, the disc fragment was removed, and neural decompression was confirmed. The wound was then closed in layers after hemostasis.

Pre-incisional Analgesic Techniques

Pre-LSSI

In the pre-LSSI group, 10 mL of 0.25% bupivacaine was administered without saline dilution before skin incision. After sterile preparation and draping in the prone position, the local anesthetic was first infiltrated into the skin and subcutaneous tissue along the planned incision line. Without completely withdrawing the needle, the needle was then advanced toward the ipsilateral paraspinal muscle layer attached to the spinous process and laminae at the operative level. Multifocal infiltration was performed into the multifidus and adjacent paraspinal muscle tissues on the side of surgery. No additional local anesthetic infiltration was performed after skin incision.

Pre-CEA

In the pre-CEA group, the caudal epidural procedure was performed by the operating surgeon before skin incision, after prone positioning and sterile preparation. A loss-of-resistance technique was not used. Under fluoroscopic guidance, a 20-22-gauge spinal needle was advanced through the sacral hiatus into the caudal epidural space. After needle placement, negative aspiration for blood and cerebrospinal fluid was confirmed. Epidural location was subsequently verified by injection of 1-2 mL of contrast medium, with cephalad epidural spread confirmed on the lateral fluoroscopic view and no fluoroscopic evidence of intravascular or intrathecal distribution. After confirmation of epidural placement, 3 mL of 0.25% bupivacaine (7.5 mg) was diluted with sterile normal saline to a total volume of 10 mL and administered as a single-

shot caudal epidural injection. No failed caudal epidural procedure or repeat needle insertion was recorded. Procedure duration was not systematically documented and therefore could not be reliably retrieved for retrospective analysis.

Control Cohort

Patients in the control cohort underwent standard single-level lumbar microdiscectomy without pre-LSSI or pre-CEA.

These interventions represented two technique-based perioperative analgesia protocols used in clinical practice and were not designed as equal-dose bupivacaine regimens. The pre-LSSI protocol delivered 25 mg of bupivacaine to the surgical site, whereas the pre-CEA protocol delivered 7.5 mg of bupivacaine into the caudal epidural space.

Postoperative Analgesia and Mobilization Protocol

All patients received the same routine postoperative analgesic protocol. Intravenous paracetamol 1 g was administered every 6 hours, with the first dose given during the awakening phase. Additional rescue analgesia was administered according to a pre-defined VAS-based institutional algorithm. Diclofenac 75 mg intravenously was administered for moderate pain (VAS 4-6) and could be repeated if clinically required, with a maximum total dose of 150 mg within 24 hours. For severe pain (VAS ≥7), tramadol 50 mg intravenously was added. No patient-controlled analgesia was used.

Postoperative VAS scores were assessed at rest while patients remained in bed during the early postoperative period. Assessments at the pre-defined time points were performed jointly by the ward nurse and the neurosurgery resident responsible for postoperative care. Rescue analgesia was administered by the same clinical team according to the pre-defined VAS thresholds, which were applied uniformly to all study groups. Because these interventions represented routine clinical care rather than a blinded prospective trial, neither the VAS assessors nor the staff administering rescue analgesia were blinded to the pre-incisional analgesic protocol.

Ambulation time was recorded as the time from surgery to first mobilization. According to the routine postoperative care protocol of the institution, patients were not mobilized before the sixth postoperative hour; therefore, 6 hours represented the earliest permitted ambulation time in this cohort.

Outcomes

VAS-back and VAS-leg scores were recorded preoperatively and at pre-defined postoperative time points: 0, 1, 2, 4, 6, 12, 18, and 24 hours after surgery.

The primary endpoint was cumulative postoperative back pain burden during the first 24 hours, calculated as the AUC of VAS-back scores from 0 to 24 hours using the trapezoidal rule.

Secondary outcomes included VAS-leg AUC from 0 to 24 hours, repeated postoperative VAS-back and VAS-leg trajectories, any rescue analgesic requirement within 24 hours, opioid rescue requirement, time to first rescue analgesia, ambulation time, length of hospital stay, and adverse events. Adverse events

were defined as postoperative nausea/vomiting requiring treatment, urinary retention, clinically apparent new motor block, wound-related complications, neurological deterioration, allergic reaction, or procedure-related complications within the first 24 hours.

Because rescue analgesia could influence subsequent VAS scores, rescue analgesic requirement and time to first rescue analgesia were evaluated as key secondary outcomes and interpreted alongside the VAS AUC and pain trajectory analyses.

Statistical Analysis

Statistical analyses were performed using Jamovi software, version 2.6.26.0 (Sydney, Australia). Continuous variables were summarized as mean $\pm$ standard deviation (SD) or median with interquartile range (IQR) according to distributional characteristics. Categorical variables were summarized as counts and percentages.

The primary analysis compared the two active preemptive analgesia groups: pre-LSSI and pre-CEA. The control cohort was shown descriptively as an exploratory contextual comparator and was not included in the primary hypothesis testing.

The primary endpoint, VAS-back AUC 0-24 h, was calculated using the trapezoidal rule. Between-group comparison of VAS-back AUC was performed using an independent-samples test according to distributional characteristics. VAS AUC values were presented as mean $\pm$ SD for descriptive consistency. AUC values are expressed as VAS score $\times$ hour. Welch's t-test was used for VAS-back AUC. Because VAS-leg AUC showed a skewed distribution with floor effects, the between-group p-value for VAS-leg AUC was calculated using the Mann-Whitney U test. Postoperative VAS trajectories were presented descriptively to illustrate the temporal pattern of pain scores; no repeated-measures one-way analysis of variance or mixed-effects model was performed because the primary longitudinal pain comparison was prespecified as VAS AUC over 24 hours. Categorical outcomes, including rescue analgesic requirement, opioid rescue requirement, and adverse events, were compared using Fisher's exact test or the chi-square test, as appropriate.

Time to first rescue analgesia was summarized among patients who required rescue analgesia. If no rescue analgesic event occurred in one of the active-treatment groups, this outcome was reported descriptively without formal between-group hypothesis testing.

Secondary outcomes were analyzed as exploratory endpoints, and no adjustment for multiple comparisons was applied. For exploratory three-group description, values from the control cohort were presented in tables and figures to provide clinical context. However, p-values in the main tables were restricted to the pre-defined active-treatment comparison between pre-LSSI and pre-CEA. Because 6 hours represented the earliest permitted ambulation time according to institutional routine practice, the proportion of patients ambulating exactly at 6 postoperative hours was also analyzed as an exploratory binary recovery outcome using Fisher's exact test.

A two-sided p-value <0.05 was considered statistically significant for the primary analysis.

No a priori sample size calculation was performed because this was a retrospective analysis of eligible patients treated during the study period.

RESULTS

Study Cohort

During 2022, 458 lumbar microdiscectomy procedures were screened for eligibility. The main reasons for exclusion were multilevel surgery, revision surgery, additional decompressive procedures, fusion procedures, ASA III-IV status, chronic narcotic use, or incomplete perioperative pain records. After application of the inclusion and exclusion criteria, 138 patients were included in the final study cohort. Of these, 47 patients received pre-LSSI, 42 patients received pre-CEA, and 49 patients underwent lumbar microdiscectomy without preemptive analgesia and constituted the exploratory control cohort. The primary active-treatment analysis included 89 patients in the pre-LSSI and pre-CEA groups.

Baseline Characteristics

Baseline demographic and clinical characteristics are summarized in Table 1. The two active-treatment groups were comparable in terms of age, sex, ASA physical status, operated disc level, symptom side, preoperative VAS-back score, and preoperative VAS-leg score. The mean age was 49.6 ± 9.3 years in the pre-LSSI group and 50.1 ± 11.5 years in the pre-CEA group. Preoperative VAS-back scores were low in both active-treatment groups, with a median value of 0 (0-0) in both groups. Preoperative VAS-leg scores were also similar between the pre-LSSI and pre-CEA groups, with median values of 6 (6-8) and 6 (6-7), respectively.

Postoperative Pain Outcomes

Postoperative pain and recovery outcomes are shown in Table 2. The primary endpoint, VAS-back AUC 0-24 h, was significantly lower in the pre-CEA group than in the pre-LSSI group. The mean VAS-back AUC was 64.0 ± 6.0 in the pre-LSSI group and 42.2 ± 8.0 in the pre-CEA group ($p < 0.001$). In the exploratory control cohort, the mean VAS-back AUC was 90.6 ± 11.3 .

VAS-leg AUC 0-24 h was also lower in the pre-CEA group compared with the pre-LSSI group. Because VAS-leg AUC showed a skewed distribution with floor effects, it was summarized as median (IQR). VAS-leg AUC 0-24 h was lower in the pre-CEA group than in the pre-LSSI group [0.0 (0.0-0.0) vs. 8.0 (8.0-8.0); $p < 0.001$]. In the exploratory control cohort, the median VAS-leg AUC was 8.0 (8.0-8.0).

The postoperative VAS trajectories are illustrated descriptively in Figure 1; no repeated-measures statistical model was applied to these trajectory plots. Mean VAS-back scores remained consistently lower in the pre-CEA group than in the pre-LSSI and control cohorts throughout the first 24 postoperative

Table 1. Baseline demographic and clinical characteristics of the study cohort

Variable	Pre-LSSI (n=47)	Pre-CEA (n=42)	Control (n=49)	p-value*
Age, years, mean $\pm$ SD	49.6 $\pm$ 9.3	50.1 $\pm$ 11.5	49.4 $\pm$ 9.9	0.840
Sex, n (%)				1.000
Female	22 (46.8)	20 (47.6)	20 (40.8)	
Male	25 (53.2)	22 (52.4)	29 (59.2)	
ASA status, n (%)				0.674
ASA I	21 (44.7)	21 (50.0)	25 (51.0)	
ASA II	26 (55.3)	21 (50.0)	24 (49.0)	
Operated level, n (%)				0.988
L2-3	3 (6.4)	3 (7.1)	1 (2.0)	
L3-4	7 (14.9)	7 (16.7)	5 (10.2)	
L4-5	16 (34.0)	13 (31.0)	25 (51.0)	
L5-S1	21 (44.7)	19 (45.2)	18 (36.7)	
Symptom side, n (%)				0.832
Left	24 (51.1)	23 (54.8)	25 (51.0)	
Right	23 (48.9)	19 (45.2)	24 (49.0)	
Preoperative VAS-back, median (IQR)	0 (0-0)	0 (0-0)	0 (0-0)	0.881
Preoperative VAS-leg, median (IQR)	6 (6-8)	6 (6-7)	7 (7-7)	0.470

Values are presented as mean $\pm$ SD, median (IQR), or n (%), as appropriate. *: p-values compare the two active-treatment groups (pre-LSSI vs. pre-CEA) only; the control cohort is shown descriptively as an exploratory contextual comparator, ASA: American Society of Anesthesiologists, IQR: Interquartile range, pre-CEA: Pre-incisional caudal epidural analgesia, pre-LSSI: Pre-incisional local surgical-site infiltration, SD: Standard deviation, VAS: Visual analog scale

Table 2. Postoperative pain, analgesic requirement, and recovery outcomes

Outcome	Pre-LSSI (n=47)	Pre-CEA (n=42)	Control (exploratory) (n=49)	p-value*
Pain outcomes				
VAS-back AUC 0-24 h, mean $\pm$ SD	64.0 $\pm$ 6.0	42.2 $\pm$ 8.0	90.6 $\pm$ 11.3	<0.001
VAS-leg AUC 0-24 h, median (Q1-Q3)	8.0 (8.0-8.0)	0.0 (0.0-0.0)	8.0 (8.0-8.0)	<0.001
Rescue analgesia outcomes				
Any rescue analgesic requirement, n (%)	47 (100.0)	0 (0.0)	49 (100.0)	<0.001
Opioid rescue requirement, n (%)	0 (0.0)	0 (0.0)	11 (22.4)	-
Time to first rescue analgesia, h [†]	4 (4-6)	No rescue required	0 (0-0)	-
Recovery and safety outcomes				
Ambulation time, h, median (IQR) [‡]	6 (6-12)	6 (6-6)	18 (12-24)	<0.001
Ambulation at earliest permitted time point (6 h), n (%)	33 (70.2)	42 (100.0)	3 (6.1)	<0.001
Length of hospital stay, days, median (IQR)	1 (1-1)	1 (1-1)	1 (1-1)	-
Adverse events, n (%)	0 (0.0)	0 (0.0)	3 (6.1)	-

Values are presented as mean $\pm$ SD, median (IQR), median (Q1-Q3), or n (%), as appropriate. *: p-values compare the two active-treatment groups (pre-LSSI vs. pre-CEA) only; the control cohort is shown descriptively as an exploratory contextual comparator. Welch's t-test was used for VAS-back AUC. VAS-back AUC values are expressed as VAS score $\times$ hour. Because VAS-leg AUC showed a skewed distribution with floor effects, it is presented as median (Q1-Q3), and the p-value was calculated using the Mann-Whitney U test. The Mann-Whitney U test was used for ambulation time; Fisher's exact test was used for any rescue analgesic requirement and ambulation at the earliest permitted time point. Dashes indicate that no inferential test was performed because both active-treatment groups had zero events, no variance, or no rescue event in the pre-CEA group. [†]: Time to first rescue analgesia was summarized among patients who required rescue analgesia. [‡]: Ambulation time should be interpreted in the context of institutional routine practice, in which patients were not mobilized before 6 postoperative hours. All adverse events in the control cohort were postoperative nausea and vomiting after tramadol administration. AUC: Area under the curve, IQR: Interquartile range, pre-CEA: Pre-incisional caudal epidural analgesia, pre-LSSI: Pre-incisional local surgical-site infiltration, SD: Standard deviation, VAS: Visual analog scale

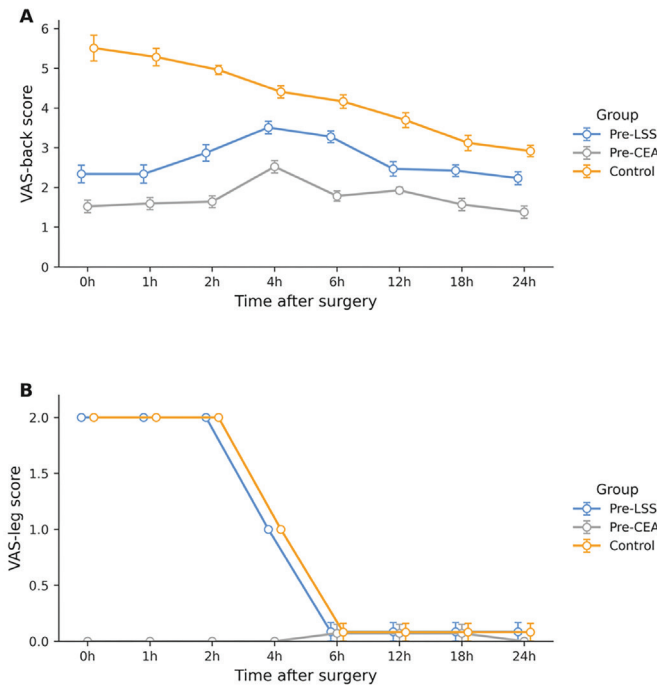


Figure 1. Postoperative VAS-back and VAS-leg trajectories during the first 24 hours after surgery.

Mean postoperative VAS-back (A) and VAS-leg (B) scores are shown for the pre-LSSI, pre-CEA, and exploratory control cohorts across pre-defined postoperative time points. Error bars indicate 95% confidence intervals. Group markers were slightly offset horizontally within each time point to improve visual clarity. Preoperative VAS scores are not displayed and were not included in AUC calculations. The trajectory plots are descriptive and were not analyzed using repeated-measures ANOVA or mixed-effects models, because the primary longitudinal pain comparison was prespecified as VAS AUC over 24 hours. VAS was measured on a 0-10 scale, with higher scores indicating greater pain intensity; the y-axis in panel B was scaled to the observed postoperative range for visual clarity. pre-CEA: Pre-incisional caudal epidural analgesia, pre-LSSI: Pre-incisional local surgical-site infiltration, VAS: Visual analog scale, AUC: Area under the curve, ANOVA: One-way analysis of variance

hours. Mean VAS-leg scores decreased rapidly after surgery in all groups; however, the pre-CEA group showed the lowest early postoperative VAS-leg trajectory.

Rescue Analgesia

Rescue analgesic requirement differed significantly between the two active-treatment groups. All patients in the pre-LSSI group required additional rescue analgesia within the first 24 hours, whereas no patient in the pre-CEA group required rescue analgesia (47/47 vs. 0/42; $p < 0.001$). In the control cohort, all patients required rescue analgesia.

No patient in either active-treatment group required opioid rescue analgesia. In contrast, opioid rescue analgesia was required in 11 patients in the control cohort (22.4%). Among patients who required rescue analgesia, the median time to first rescue analgesia was 4 (4-6) hours in the pre-LSSI group and 0 (0-0) hours in the control cohort. Because no rescue analgesic event occurred in the pre-CEA group, time to first

rescue analgesia was not formally compared between the two active-treatment groups. Although all pre-LSSI patients eventually required rescue analgesia, the median time to first rescue analgesia was longer in the pre-LSSI group than in the exploratory control cohort, suggesting an early analgesic effect relative to no preemptive intervention.

Recovery and Safety Outcomes

Ambulation time distribution differed between the two active-treatment groups. The median ambulation time was 6 (6-12) hours in the pre-LSSI group and 6 (6-6) hours in the pre-CEA group ($p < 0.001$). In the control cohort, the median ambulation time was 18 (12-24) hours. Because the institutional postoperative care protocol did not allow routine mobilization before the sixth postoperative hour, 6 hours represented the earliest permitted ambulation time. When ambulation was analyzed as achievement of the earliest permitted mobilization time, 42 of 42 patients (100.0%) in the pre-CEA group ambulated exactly at 6 hours compared with 33 of 47 patients (70.2%) in the pre-LSSI group ($p < 0.001$). In the exploratory control cohort, 3 of 49 patients (6.1%) ambulated at 6 hours.

Length of hospital stay was similar between the two active-treatment groups, with a median of 1 (1-1) day in both groups. No adverse events were recorded in the pre-LSSI or pre-CEA groups. The three adverse events recorded in the control cohort consisted of postoperative nausea and vomiting occurring after tramadol administration and were therefore considered likely opioid-related events.

DISCUSSION

In this retrospective comparative cohort analysis of prospectively recorded perioperative pain data, pre-CEA was associated with lower early postoperative pain burden than pre-LSSI after single-level lumbar microdiscectomy. Pre-CEA was associated with lower VAS-back and VAS-leg AUCs during the first 24 postoperative hours and no rescue analgesic requirement. The exploratory control cohort showed the highest cumulative VAS-back burden and universal rescue analgesic requirement, providing contextual support for the clinical relevance of preemptive analgesia. Because the study was non-randomized and the primary comparison was pre-defined between the two active pre-incisional techniques, these findings should be interpreted as associations rather than definitive evidence of superiority. In particular, patients who preferred caudal epidural analgesia may have differed from those who preferred local surgical-site infiltration in unmeasured factors such as pain expectations, anxiety, or attitudes toward postoperative analgesia, and these factors may have influenced the observed differences.

Caudal or epidural analgesia and local wound or surgical-site infiltration have been investigated as perioperative analgesic strategies in lumbar disc and decompressive spine surgery. Previous studies have suggested that caudal or epidural

administration of local anesthetics, with or without adjuncts, may reduce early postoperative pain and analgesic consumption after lumbar disc surgery or decompression^(12,14). Similarly, local anesthetic infiltration into the wound, paraspinal muscles, or surgical field has been associated with reduced early pain scores, delayed first analgesic requirement, or lower opioid consumption^(11,15). Broader comparative evidence from regional analgesia studies also supports local and neuraxial techniques as components of multimodal postoperative pain control after lumbar spine surgery⁽⁷⁾. However, these approaches have generally been evaluated against placebo, systemic analgesia, or standard care rather than directly against each other^(7,11,12,14,15). The present study addresses this gap by comparing two practical, technique-based pre-incisional analgesic protocols in the same single-level microdiscectomy setting.

Our findings are consistent with randomized studies suggesting that caudal epidural administration of local anesthetics can improve early postoperative analgesia after lumbar disc and lumbosacral spine surgery. In a randomized prospective study of 120 patients with single-level lumbar disc herniation, Cine and Uysal⁽¹²⁾ evaluated preemptive caudal bupivacaine, with or without methylprednisolone, against caudal saline and reported lower postoperative VAS scores and reduced additional analgesic requirement in the active caudal groups. Kumar et al.⁽¹⁶⁾ also reported in a prospective randomized controlled trial that a single preoperative caudal injection of 0.2% ropivacaine provided effective analgesia in degenerative lumbar spine surgery, further supporting the role of preemptive caudal local anesthetic administration in posterior lumbar procedures. Similarly, Samagh et al.⁽¹³⁾ found lower postoperative VAS scores, reduced intraoperative fentanyl requirement, longer time to rescue analgesia, and no hemodynamic or neurological adverse effects after preemptive caudal ropivacaine. In single-level lumbar discectomy, Hady et al.⁽¹⁷⁾ also reported that adding caudal epidural bupivacaine to general anesthesia reduced intraoperative narcotic consumption, postoperative VAS scores, intravenous analgesic requirement, and postoperative nausea and vomiting. Rajwade et al.⁽¹⁸⁾ showed that caudal ropivacaine with fentanyl prolonged postoperative analgesia compared with ropivacaine alone. Taken together, these studies support the clinical plausibility of our finding that pre-CEA was associated with lower 24-hour VAS-back and VAS-leg pain burden and no rescue analgesic requirement. However, unlike most previous caudal studies, the present study compared pre-CEA directly with a commonly used pre-LSSI protocol.

Local wound or surgical-site infiltration has also been widely studied in lumbar spine surgery, although the magnitude and consistency of its analgesic benefit remain variable. In a systematic review of double-blind randomized trials, Kjærgaard et al.⁽¹⁰⁾ found that local anesthetic wound infiltration reduced pain scores in only a minority of comparisons and produced, at most, small-to-modest reductions in early postoperative pain intensity and opioid consumption. The same review noted that the evidence was difficult to interpret because of heterogeneity

in surgical procedures, infiltration timing, tissue planes, local anesthetic agents, and outcome reporting. More recent reviews focusing on intramuscular or field infiltration have similarly suggested that local infiltration may delay the first analgesic request and modestly reduce early opioid consumption, but its effect on pain scores is often short-lived and most apparent during the immediate postoperative period^(11,15). Importantly, timing may also influence the efficacy of local infiltration. Gurbet et al.⁽¹⁹⁾ reported that pre-emptive levobupivacaine infiltration at the surgical site provided better postoperative analgesia than infiltration administered at closure in lumbar disc surgery. In this context, our pre-LSSI protocol should be interpreted as a practical pre-incisional surgical-site technique targeting the skin, subcutaneous tissue, and ipsilateral multifidus/paraspinal muscle layer rather than as a neuraxial analgesic strategy. The lower VAS-back AUC in the pre-LSSI group compared with the control cohort is consistent with an early somatic analgesic effect of local infiltration; however, the higher cumulative pain burden and universal rescue analgesic requirement compared with pre-CEA suggest less complete early analgesia than caudal epidural delivery.

The current regional analgesia landscape in lumbar spine surgery has expanded substantially with the increasing use of ultrasound-guided fascial-plane blocks. A network meta-analysis of 34 randomized trials involving 2,365 patients compared TLIP, ESPB, wound infiltration, and control strategies and found that TLIP was associated with the greatest reduction in 24-hour opioid consumption, while ESPB and wound infiltration also represented effective regional alternatives⁽⁷⁾. More recent systematic reviews have similarly demonstrated reductions in postoperative pain and opioid consumption with ESPB⁽⁸⁾ and TLIP⁽⁹⁾, although heterogeneity in surgical procedures, block levels, local anesthetic regimens, and comparators remains substantial. These newer techniques avoid intentional neuraxial access and may be particularly attractive within multimodal ERAS pathways. However, the present study did not directly compare pre-CEA with ESPB or TLIP, and our results should not be interpreted as evidence that caudal epidural analgesia is preferable to contemporary fascial-plane blocks. Rather, they suggest that the caudal epidural route remains a potentially relevant technique-based option that warrants direct comparison with contemporary regional strategies in future randomized studies.

The observed difference between pre-LSSI and pre-CEA may be partly explained by the anatomical compartment targeted by each technique. Pre-LSSI primarily addresses somatic nociceptive input from the incision and muscle dissection, consistent with systematic evidence showing that wound infiltration is simple and attractive but heterogeneous, often modest, and mostly limited to the early postoperative period^(10,11). By contrast, caudal epidural injection delivers local anesthetic into the epidural space, where neural blockade may occur at spinal nerve roots and proximal afferent transmission. Samagh et al.⁽¹³⁾ described preemptive caudal epidural analgesia as

blocking sensory input at the spinal cord level, while Rajwade et al.⁽¹⁸⁾ noted that epidural local anesthetic produces neural blockade after fixation to spinal nerve roots. This broader neural target may help explain why pre-CEA was associated with lower VAS-back and VAS-leg AUCs and no rescue analgesic requirement. Importantly, pre-CEA protocol used a lower total bupivacaine dose than pre-LSSI. Therefore, these findings suggest that anatomical targeting may be clinically relevant in early postoperative analgesia after microdiscectomy. However, because dose, dilution, volume, route, and tissue compartment differed simultaneously, this study cannot determine whether the observed association was attributable to anatomical targeting, drug distribution, total dose, or other protocol-related factors. Accordingly, the present study should be regarded as a comparison of two complete, clinically used, non-dose-equivalent analgesic protocols rather than as a controlled comparison of bupivacaine administered through two different anatomical routes. The independent contribution of route cannot be separated from differences in total bupivacaine dose, dilution, distribution, and tissue compartment in the present design. The results should therefore not be interpreted as proof that target compartment is more important than absolute local anesthetic dose.

The clinical relevance of these findings lies primarily in the reduction of early rescue analgesic requirement. Procedure-specific recommendations for lumbar laminectomy emphasize multimodal analgesia and reserve opioids mainly for rescue treatment, reflecting efforts to reduce opioid exposure after spine surgery⁽¹⁾. Similarly, meta-analytic evidence suggests that preemptive analgesia can reduce early postoperative pain and analgesic consumption after lumbar spine surgery, although effects vary according to the technique used⁽²⁾. In the present cohort, no patient in the pre-CEA group required rescue analgesia during the first 24 postoperative hours, whereas all patients in the pre-LSSI and control cohorts required additional analgesia. This finding suggests that the pre-CEA protocol was associated not only with lower pain intensity but also with less need for supplemental postoperative medication. However, because opioid rescue was not required in either active-treatment group, our results should not be interpreted as demonstrating an opioid-sparing advantage of pre-CEA over pre-LSSI. Rather, the main clinical distinction between the two active techniques was the absence of rescue analgesic requirement in the pre-CEA group. Ambulation findings should also be interpreted cautiously: although the pre-CEA patients reached the earliest permitted mobilization time more consistently, institutional protocol did not allow routine ambulation before the sixth postoperative hour. Therefore, this result should be considered a marker of smoother early recovery rather than proof of accelerated mobilization. Length of hospital stay was similar between active-treatment groups, suggesting that the benefit of pre-CEA was most evident in early pain control rather than discharge timing.

The complete absence of rescue analgesic requirement in the pre-CEA group deserves particular caution because the magnitude of this association appears stronger than that generally reported in previous randomized studies of caudal epidural analgesia. Earlier studies have predominantly demonstrated lower postoperative pain scores, reduced analgesic consumption, or a longer time to first rescue medication rather than universal avoidance of rescue analgesia during the first 24 hours^(12,13,16-18). In our protocol, all patients received scheduled intravenous paracetamol, and rescue treatment was triggered by a standardized resting VAS threshold of ≥ 4 . Thus, the absence of rescue medication in the pre-CEA cohort was consistent with the pre-defined institutional algorithm. Nevertheless, this striking finding should not be interpreted as proof of an unusually strong causal effect of caudal epidural analgesia. Patient-preference-based treatment selection, unmeasured differences in pain expectations or anxiety, the absence of assessor blinding, the relatively modest sample size, and differences in bupivacaine dose and drug distribution between the protocols may all have contributed to the observed effect size. Confirmation in a randomized, blinded, dose-standardized comparison is therefore particularly important.

From a practical standpoint, pre-CEA appears feasible because it can be performed after prone positioning without changing the operative setup. However, caudal epidural analgesia remains a neuraxial intervention and carries potential procedure-related risks. Reported complications of epidural and neuraxial techniques include inadvertent intravascular, intrathecal, or subdural injection, epidural hematoma, infection or epidural abscess, direct neural injury, local anesthetic systemic toxicity, motor blockade, urinary retention, and hemodynamic effects such as hypotension^(20,21). Although serious neurological complications are uncommon, their potential severity requires careful patient selection, strict aseptic technique, accurate needle positioning, and appropriate monitoring^(20,21). Previous randomized studies of caudal analgesia in lumbar surgery have also reported acceptable short-term safety profiles, with no major hemodynamic, neurological, or block-related complications in the studies by Samagh et al.⁽¹³⁾, Hady et al.⁽¹⁷⁾, and Rajwade et al.⁽¹⁸⁾. In our protocol, negative aspiration for blood or cerebrospinal fluid was followed by fluoroscopic contrast confirmation of epidural spread before local anesthetic administration; no failed procedure, repeat needle insertion, clinically apparent motor block, urinary retention, or other procedure-related adverse event was documented in the pre-CEA cohort. No adverse events were observed in either active-treatment group, whereas the three adverse events recorded in the control cohort consisted of postoperative nausea and vomiting after tramadol administration. These events should therefore be interpreted as likely opioid-related events rather than as evidence of a direct comparative safety advantage of either pre-incisional technique. Nevertheless, the absence of procedure-related complications among

42 pre-CEA patients cannot establish procedural safety or reliably estimate the incidence of uncommon adverse events. Contemporary fascial-plane techniques such as ESPB and TLIP avoid intentional epidural access and may therefore offer a different procedural risk profile when selecting among regional analgesic strategies.

Study Limitations

This study has several limitations. First, although perioperative pain data were recorded prospectively using pre-defined time points, the present analysis was retrospective and non-randomized. In particular, treatment selection may have been influenced by patient preference, surgeon-patient discussion, pain expectations, anxiety, or perceived need for neuraxial analgesia; therefore, residual confounding and selection bias cannot be excluded. Second, neither patients nor outcome assessors were blinded, which may have affected subjective VAS reporting and rescue analgesic administration. Although rescue analgesia was administered according to a pre-defined VAS-based algorithm, the absence of blinding may have influenced subjective VAS reporting or clinical administration of rescue medication. Third, the pre-LSSI and pre-CEA protocols were not dose-equivalent bupivacaine regimens; thus, the study should be interpreted as a comparison of clinical technique-based protocols rather than a pharmacologic dose-response comparison. Although the intraoperative opioid protocol was standardized and no additional opioid or remifentanyl was used after the fentanyl induction dose, individual volatile anesthetic concentrations and MAC values were not reliably retrievable from the retrospective records. Consequently, residual confounding related to anesthetic depth or volatile anesthetic exposure cannot be completely excluded. Fourth, rescue analgesia may have influenced subsequent VAS scores, although this was addressed by evaluating VAS AUC and rescue analgesic requirement together. Fifth, this single-center study included only single-level lumbar microdiscectomy patients with 24-hour follow-up, limiting generalizability to multilevel surgery, fusion, revision procedures, and longer-term outcomes. Finally, the control cohort was retained only as an exploratory contextual comparator and was not part of the primary active-treatment hypothesis. In addition, because no a priori sample size calculation was performed, the study may have been underpowered for secondary outcomes with low event rates, including opioid rescue requirement and adverse events. Future prospective randomized studies with blinded outcome assessment, standardized local anesthetic dosing, pre-defined opioid-equivalent consumption metrics, patient satisfaction measures, discharge-readiness criteria, and longer follow-up are needed to determine whether pre-CEA is associated with reproducible clinical benefits over local surgical-site infiltration after lumbar microdiscectomy.

CONCLUSION

In patients undergoing single-level lumbar microdiscectomy, pre-CEA was associated with lower early postoperative VAS-back and VAS-leg pain burden than pre-LSSI. Pre-CEA was also associated with no rescue analgesic requirement during the first 24 postoperative hours, whereas rescue analgesia was required in all patients receiving pre-LSSI. The exploratory control cohort further supported the clinical relevance of preemptive analgesia by showing the highest postoperative back pain burden and universal rescue analgesic use. These findings suggest that the anatomical target of pre-incisional analgesia may be important for early postoperative pain control after lumbar microdiscectomy. However, because this was a non-randomized, non-dose-standardized analysis, prospective randomized dose-standardized studies are required to determine whether pre-CEA is associated with reproducible clinical benefits over local surgical-site infiltration.

Ethics

Ethics Committee Approval: The study was approved by the University of Health Sciences Türkiye, Prof. Dr. Cemil Taşcıoğlu City Hospital Ethics Committee before data analysis (approval no: 22, date: 23.01.2023) and was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Written informed consent for surgery and perioperative analgesic procedures was obtained according to institutional practice.

Footnotes

AI-based language editing assistance was used in this manuscript preparation. The authors reviewed, verified, and take full responsibility for the scientific content, data accuracy, interpretation, and final version of the manuscript.

Authorship Contributions

Surgical and Medical Practices: M.A.Ç., A.Y.Y., Concept: M.A.Ç., A.Y.Y., Design: M.A.Ç., A.Y.Y., Data Collection or Processing: M.A.Ç., A.Y.Y., Analysis or Interpretation: M.A.Ç., Literature Search: M.A.Ç., A.Y.Y., Writing: M.A.Ç.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. Peene L, Le Cacheux P, Sauter AR, Joshi GP, Beloeil H. Pain management after laminectomy: a systematic review and procedure-specific post-operative pain management (PROSPECT) recommendations. *Eur Spine J*. 2021;30:2925-35.
2. Zhang LK, Li Q, Quan RF, Liu JS. Is preemptive analgesia a good choice for postoperative pain relief in lumbar spine surgeries?: a meta-analysis of randomized controlled trials. *Medicine (Baltimore)*. 2021;100:e25319.

3. Woolf CJ. Evidence for a central component of post-injury pain hypersensitivity. *Nature*. 1983;306:686-8.
4. Kissin I. Preemptive analgesia. *Anesthesiology*. 2000;93:1138-43.
5. Xuan C, Yan W, Wang D, Li C, Ma H, Mueller A, et al. Efficacy of preemptive analgesia treatments for the management of postoperative pain: a network meta-analysis. *Br J Anaesth*. 2022;129:946-58.
6. Büchel C, Treanor C, Davies B, Anderson DB, Fehlings M, Zipser CM. Enhanced recovery after surgery (ERAS) in spine surgery: a systematic review and meta-analysis of spinal surgery sub - specialties, interventions and efficacy. *Global Spine J*. 2026;16:1660-72.
7. Hong B, Baek S, Kang H, Oh C, Jo Y, Lee S, et al. Regional analgesia techniques for lumbar spine surgery: a frequentist network meta-analysis. *Int J Surg*. 2023;109:1728-41.
8. Muthu S, Viswanathan VK, Annamalai S, Thabrez M. Bilateral erector spinae plane block for postoperative pain relief in lumbar spine surgery: a PRISMA-compliant updated systematic review & meta-analysis. *World Neurosurg*. 2024;23:100360.
9. Long G, Liu C, Liang T, Zhan X. The efficacy of thoracolumbar interfascial plane block for lumbar spinal surgeries: a systematic review and meta-analysis. *J Orthop Surg Res*. 2023;18:318.
10. Kjærgaard M, Møiniche S, Olsen KS. Wound infiltration with local anesthetics for post-operative pain relief in lumbar spine surgery: a systematic review. *Acta Anaesthesiol Scand*. 2012;56:282-90.
11. Tsaousi G, Tsitsopoulos PP, Pourzitaki C, Palaska E, Badenes R, Bilotta F. Analgesic efficacy and safety of local infiltration following lumbar decompression surgery: a systematic review of randomized controlled trials. *J Clin Med*. 2021;10:5936.
12. Cine HS, Uysal E. Preemptive caudal anesthesia on back pain after lumbar discectomy: a randomized and controlled study. *Cir Cir*. 2023;91:641-7.
13. Samagh N, Pai RK, Mathews TK, Jangra K, Varma RG. Pre-emptive caudal epidural analgesia with ropivacaine for lumbosacral spine surgery: a randomized case control study. *J Anaesthesiol Clin Pharmacol*. 2018;34:237-41.
14. Hermans SMM, Lantinga-Zee AAG, Rijkers K, van Santbrink H, van Hemert WLW, Reinders MK, et al. Intraoperative epidural analgesia for pain relief after lumbar decompressive spine surgery: a systematic review and meta-analysis. *Brain Spine*. 2021;1:100306.
15. Perera AP, Chari A, Kostusiak M, Khan AA, Luoma AM, Casey ATH. Intramuscular local anesthetic infiltration at closure for postoperative analgesia in lumbar spine surgery: a systematic review and meta-analysis. *Spine (Phila Pa 1976)*. 2017;42:1088-95.
16. Kumar S, Palaniappan JM, Kishan A. Preemptive caudal ropivacaine: an effective analgesic during degenerative lumbar spine surgery. *Asian Spine J*. 2017;11:113-9.
17. Hady SMFMA, Ahmed AYI, Neamat-Allah HSAH, Basta MRZ, El Fawal SMM. Combined caudal epidural with general anesthesia for lumbar discectomy. *Ain Shams Medical Journal*. 2022;73:695-704.
18. Rajwade S, Dubey R, Khetarpal M, Ramchandani S, Panda CK, Kumar M, et al. Comparative analysis of the postoperative analgesic effects of caudal epidural injection of ropivacaine combined with fentanyl versus ropivacaine alone in lumbosacral spine surgeries: a randomized double-blinded study. *Cureus*. 2024;16:e70963.
19. Gurbet A, Bekar A, Bilgin H, Korfali G, Yilmazlar S, Tercan M. Pre-emptive infiltration of levobupivacaine is superior to at-closure administration in lumbar laminectomy patients. *Eur Spine J*. 2008;17:1237-41.
20. Maddali P, Moisi M, Page J, Chamiraju P, Fisahn C, Oskouian R, et al. Anatomical complications of epidural anesthesia: a comprehensive review. *Clin Anat*. 2017;30:342-6.
21. Pozza DH, Tavares I, Cruz CD, Fonseca S. Spinal cord injury and complications related to neuraxial anaesthesia procedures: a systematic review. *Int J Mol Sci*. 2023;24:4665.