“Beyond the Incision”: A Case-Control Study on IV and Epidural Preemptive Analgesia in Lumbar Spine Surgery

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Abstract

Introduction

Effective pain management in lumbar spine surgery is critical to enhancing postoperative recovery and minimizing complications. Preemptive analgesia, administered either intravenously or epidurally, has shown promise in controlling pain; however, limited data exist comparing the two routes directly to determine the optimal approach for lumbar procedures.

Purpose

To evaluate and compare pain control efficacy, recovery outcomes, and postoperative complications between IV and epidural preemptive analgesia routes in lumbar spine surgeries.

Methods

A retrospective case-control study comparing the efficacy of intravenous (IV) and epidural preemptive analgesia in patients undergoing lumbar spine surgery. Patients undergoing lumbar spine surgery were divided into three groups based on the analgesia route: Epidural, IV and Control respectively. Pain scores, analgesic consumption, and recovery profiles were assessed postoperatively. Statistical analyses, including ANOVA and Chi-square tests, were used to evaluate differences in pain control and recovery outcomes between groups.

Results

Epidural preemptive analgesia demonstrated significantly lower postoperative pain scores and reduced analgesic consumption compared to IV administration in the early post-operative period. Highlighting only a marginal route-specific benefit in lumbar spine surgery.

Conclusion

This study fills a critical gap by directly comparing IV and epidural preemptive analgesia in lumbar spine surgery, providing insights for clinical decision-making. Findings suggest IV analgesia offers comparable pain control to epidural, presenting a safer alternative with fewer procedural risks. Results hold valuable implications for optimizing perioperative care.

LEVEL OF EVIDENCE

Level IV

INTRODUCTION

Preemptive analgesia has emerged as a significant focus in the management of postoperative pain, particularly in the context of spine surgery, where patients often experience substantial discomfort. The primary aim of preemptive analgesia is to mitigate the physiological and psychological responses to surgical trauma, thereby enhancing recovery and improving overall patient satisfaction. [1] Effective pain management in spine surgery is crucial not only for the immediate postoperative period but also for long-term outcomes, including functional recovery and quality of life. [2]

In recent years, various analgesic techniques have been evaluated, with intravenous (IV) and epidural routes gaining prominence due to their distinct pharmacological profiles and delivery mechanisms. Intravenous analgesia offers systemic pain relief through rapid distribution, while epidural analgesia targets specific spinal nerves, providing localized pain control with potentially fewer systemic side effects. [3] Despite the growing body of literature on pain management strategies, there remains a paucity of studies directly comparing the efficacy of these two approaches in the context of preemptive analgesia for spine surgery. [4]

For surgeons, effective pain control is of paramount importance in optimizing patient outcomes. Adequate pain management facilitates smoother postoperative recovery, reduces the risk of complications, and improves patient mobility, which is critical in spine surgery. [5] Moreover, from a practical standpoint, well-controlled pain can lead to shorter hospital stays and early rehabilitation, which is beneficial for both patients and healthcare systems. [6] By incorporating effective analgesic strategies into their practice, surgeons can not only enhance the overall surgical experience for their patients but also achieve better functional outcomes, ensuring that the benefits of surgery are maximized. [7]

This case-control study aims to investigate the efficacy of preemptive analgesia administered via intravenous and epidural routes in patients undergoing lumbar spine surgery. By comparing these two methods, we hope to elucidate their respective roles in enhancing pain control and improving postoperative outcomes, ultimately contributing to the ongoing discourse in the field of perioperative medicine. Through rigorous analysis and evaluation, this study seeks to inform clinical practice and optimize analgesic protocols in spine surgery, ensuring better patient-centered care and outcomes.

Materials and Method

This is a prospective case-control study conducted at Manipal Comprehensive Spine Care Center, Bangalore, between July 2024 and October 2024. The objective was to evaluate postoperative pain in patients undergoing robotic circumferential decompression and fusion of the lumbar spine. The patients satisfying the following inclusion criteria were included in the study: Patients undergoing robotic circumferential decompression and fusion of the lumbar spine, surgical levels extending across three segments from L3 to S1, patients aged between 18 and 70 years, and patients who provided informed consent to participate. Patients with a BMI greater than 30, those who underwent open surgery, cervical

and thoracic spine fusions, patients not medically fit for NSAIDs, and long-segment fusions involving L2 and above were excluded from the study.

A total of 90 patients fitting the inclusion criteria were selected and block-randomized into three groups of 30 participants each. Group 1: Received 0.2% Ropivacaine epidural injection after prone positioning. After necessary skin preparation, the epidural space was identified one level above the affected level with the help of prescribed landmark using a loss of resistance technique aided by an 18G Tuohy needle. Subsequently, a premixed solution of 0.2% Ropivacaine was injected at least 20 minutes prior to the surgical incision. (Fig. 1) The dosage was 4 mL for a single-level fusion, with an additional 2 mL per extra level fused, up to a maximum of 8 mL. Group 2: Received preoperative intravenous paracetamol (1 g), Ketorolac (30 mg), and Pregabalin (75 mg) four hours before surgery. Group 3 (Control Group) - Received only standard intra-operative and postoperative analgesia without any preemptive intervention.

All patients, across the three groups, received a standardized protocol of intra-operative analgesia, comprising of intravenous Dexmedetomidine and Fentanyl infusion following a bolus dose per kilogram bodyweight. Postoperatively, patients were administered their first "rescue analgesic" of Pentazocine (10 mg) upon requesting analgesia, and the time from extubation to the first rescue analgesic was recorded. During the first 4-hour postoperative period in the ICU, patients were given additional 10mg doses of Pentazocine based on their pain levels and requests for analgesia. Pain was assessed using the Visual Analogue Scale (VAS) at 4, 8, 12, and 24 hours post-surgery. These assessments were performed in a blinded manner by a duty doctor and ward nurse. Postoperative analgesia in the ward was provided based on patient requests and alternated between Paracetamol, Ketorolac, and Tramadol. Outcome was measured in terms of VAS Pain Scores: recorded at 4, 8, 12, and 24 hours postoperatively, intra-operative fentanyl consumption, time to first rescue analgesic, and total 24-hour analgesic consumption.

Data were analyzed using SPSS for Windows, version 21. Quantitative data were expressed as mean ± standard deviation, and qualitative data were presented as percentages. The chi-squared test was used to compare frequencies between groups. The study was conducted in a double-blinded manner. The study was approved by the hospital's ethics committee and the departmental scientific committee prior to its commencement. Informed consent was obtained from all participants.

RESULTS

The study compared three groups across various parameters, revealing significant differences in several key areas. (Table 1) Demographic and the number of levels operated between the 3 groups showed no significant difference distribution among the groups. In the study, the administration of drugs resulted in notable reductions in hemodynamic parameters such as heart rate (HR), systolic blood pressure (SBP) and mean arterial pressure (MAP) but, on inter-group comparison, it showed no difference between control and intervention groups. Pain-scores were measured by the Visual Analog Scale (VAS), which showed highly significant differences at all time points (4-, 8-, 12-, and 24-hours post-operation; all $p < 0.0001$). Group 3 consistently reported higher pain scores, particularly at 4 hours compared to Group 2

and Group 1. Analgesic-related parameters also differed significantly among groups wherein control group showed shortest time to first analgesic, highest total fentanyl consumption and total paracetamol (PCT), tramadol, and ketorolac consumption. Amongst the intervention groups, although group 2 showed higher pain scores in the early postoperative period at 4 hours, both group 1 and 2 were comparable in pain scores after 8 hours and total 24-hour analgesic consumption.

Table 1
Results of the comparative of all 3 groups across all parameters.

	G1	G2	G3	P-value
MALE (%)	53.33333333	41.37931034	51.02041	
FEMALE (%)	46.66666667	58.62068966	48.97959	
LEVELS	2.07 ± 0.94	2.28 ± 0.88	1.76 ± 0.80	0.0339
HR (BL)	84.40 ± 9.94	82.45 ± 11.41	81.33 ± 11.07	0.4773
SBP (BL)	129.00 ± 11.52	131.17 ± 11.53	130.65 ± 11.91	0.7507
DBP (BL)	82.73 ± 9.68	82.55 ± 10.03	82.12 ± 9.96	0.9612
MAP (BL)	98.16 ± 7.04	98.76 ± 8.52	98.30 ± 7.77	0.9518
HR (I)	78.20 ± 9.37	77.41 ± 8.95	75.16 ± 7.90	0.2692
SBP (I)	110.40 ± 12.29	110.55 ± 12.02	111.39 ± 11.32	0.9217
DBP (I)	71.10 ± 11.48 7	3.00 ± 12.87	68.41 ± 11.63	0.2457
MAP (I)	84.20 ± 10.00	85.52 ± 9.41	82.73 ± 8.84	0.4371
PAIN SCORE (4)	5.13 ± 0.86	6.79 ± 1.29	8.92 ± 0.84	< 0.0001
PAIN SCORE (8)	4.97 ± 0.93	5.07 ± 0.92	6.96 ± 0.84	< 0.0001
PAIN SCORE (12)	3.23 ± 0.94	3.79 ± 1.18	5.82 ± 0.81	< 0.0001
PAIN SCORE (24)	3.17 ± 0.91	3.21 ± 0.94	5.55 ± 0.50	< 0.0001
Time to first analgesic	26.00 ± 9.77	25.00 ± 9.82	10.41 ± 3.51	< 0.0001
Total Fentanyl	32.20 ± 4.99	30.90 ± 8.78	62.55 ± 12.34	< 0.0001
Total PCT	1.00 ± 0.00	1.03 ± 0.19	2.00 ± 0.00	< 0.0001
Total Keto	50.00 ± 0.00 5	1.72 ± 9.28	100.00 ± 0.00	< 0.0001
Total Tramadol	45.00 ± 15.26	49.66 ± 16.58	73.47 ± 15.08	< 0.0001

DISCUSSION

Preemptive analgesia has emerged as a crucial concept in modern pain management, particularly in the context of spine surgery. This approach involves administering analgesics before surgical incision to prevent central sensitization caused by incisional and inflammatory injuries. [8] The importance of effective pain management in spine surgery cannot be overstated, as it significantly impacts patient recovery, satisfaction, and overall surgical outcomes. Anesthesiologists are tasked with selecting appropriate intra-operative analgesic techniques that not only provide effective pain relief but also minimize opioid consumption and associated side effects such as postoperative respiratory depression, nausea and vomiting. This approach aligns with the broader goal of enhanced recovery after surgery (ERAS) protocols, which aim to improve patient outcomes and reduce hospital stay. [9,10] Surgeons, too, recognize the critical importance of pain management in spine surgery. Optimal pain control in the immediate postoperative period allows for earlier mobilization of patients which plays a vital role in recovery, right from the improvement in pulmonary toilet and risk of pneumonia, to potentially reducing the risk of complications such as deep vein thrombosis and bed sores associated with long-term immobilization. [11] Early mobilization of patients also has a drastic impact on the psyche of the patient, and relatives, on the continuity of treatment in its entirety. From a larger perspective this also reduces the risk of disuse atrophy in muscles, quicker achievement of physiotherapy goals, earlier discharge from hospital, lower cost and risk of hospital acquired infections. Surgeons who prioritize pain management foster trust, improve patient satisfaction, and enhance their professional reputation. By taking an active role in both acute and chronic pain management, surgeons not only ensure better patient care but also strengthen their clinical practice. The development of perioperative pain management in surgeries has evolved significantly over the past few decades. Traditional approaches relied heavily on opioid-based analgesia, which, while effective, often led to numerous side effects and potential for long-term dependence. [12] The shift towards multimodal analgesia, incorporating preemptive techniques, has revolutionized pain management in spine surgery.

Two primary methods of preemptive analgesia have gained prominence in spine surgery: epidural analgesia and intravenous (IV) cocktail-based analgesia. Epidural route provides excellent pain control by directly blocking nociceptive pathways at the spinal level. Local anesthetic agents introduced into the epidural space get fixed to the nerve roots in about 20 minutes and effectively prevent the perception of nociceptive stimulus. This can prevent central nervous system plasticity and allow satisfactory pain relief in the first 24 hours after surgery. [13] On the other hand, IV cocktail-based preemptive analgesia typically includes NSAIDs, ketamine, lidocaine, and sometimes gabapentinoids. Each component targets different aspects of the pain pathway: NSAIDs block secretion of prostaglandins, thus reducing the inflammatory process and the hypersensitivity state. Pregabalin blocks α2δ subunit of voltage-dependent calcium channels which gets upregulated after surgical trauma, thus aiding in preventing central sensitization. In addition, administration of NSAIDs and GABA analogues is believed to have a synergistic action. Paracetamol is a selective cyclooxygenase-2 (COX-2) inhibitor that exerts analgesic effect through activation of descending serotonergic pathways. Moreover, the inhibition of COX-3 in brain and the spinal cord has been described recently and is believed to be responsible, especially for its effects on pain relief. [14,15] Both epidural and IV cocktail-based preemptive analgesia have their

advantages and disadvantages. Epidural analgesia offers superior pain control, especially for major spine surgeries, and can be continued postoperatively for extended analgesia. However, it requires expertise and carries risks such as dural puncture, epidural hematoma, and hypotension. IV cocktail-based analgesia, while generally safer and easier to administer, may not provide as profound analgesia for extensive procedures. [16,17] It also requires careful consideration of drug interactions and individual patient factors.

Our study not only provides valuable insights into the efficacy of preemptive analgesia but also compares the difference in various forms of preemptive analgesia in the same sub-set of patients. The data showed minimal changes in hemodynamic responses post induction in all 3 groups. This was assessed with particular interest in the epidural group, to assess safety of such intervention immediately prior to surgery, but we found a similar magnitude of change in hemodynamics in all three groups, which goes to show that the preemptive drugs, have a minimal to no effect on hemodynamics and can be safely administered.

In this study, the results showed that G3 consistently reported the highest VAS scores across all time points. Even after 24 hours, G3's pain scores remained elevated, whereas G1 and G2 experienced a greater reduction in pain levels. These elevated pain levels in G3 were also reflected in their significantly higher analgesic consumption and a shorter time to first analgesic administration, re-iterating the efficacy of preemptive analgesia and its role in optimizing pain relief. On the other hand, G2 consistently reported slightly higher pain levels compared to G1, specifically at the 4-hour window. While this indicates that G2 experienced more pain initially, by 24 hours, G1 and G2 had similar pain scores, narrowing the difference. Analgesic consumption between the two groups also showed some variation, with G2 requiring slightly more opioid consumption, which although was statistically significant, did not amount to much clinical significance. The total amount of pain relief required in both groups was relatively similar, and the differences in pain scores diminished over time, suggesting that both G1 and G2 responded well to the analgesic regimens they received. From a clinical perspective, while G2 may have experienced slightly more intense pain and required marginally more analgesics, these variations are not substantial enough to warrant significant changes in pain management protocols between the two groups. Both groups had adequate pain control, and the slight differences in early pain perception do not appear to translate into a major clinical impact. Overall, the differences between G1 and G2 are statistically notable but likely not clinically meaningful.

Overall, the study not only establishes the efficacy of preemptive analgesia, but rather fills an important gap in the literature by providing comparative data on different preemptive analgesic techniques in lumbar spine surgery. While previous studies have examined the efficacy of individual methods, our research offers a direct comparison between epidural and IV cocktail-based approaches, as well as a control group. The potential for clinical practice based on our findings is significant. Different surgeons prefer different modalities of preemptive analgesia, be it their expertise in administering epidural injections safely, the risks involved, and the additional time taken in the process, or be it the doubt in efficacy of an intravenous route of preemptive analgesia. Our study has demonstrated that, regardless of

the administration route, the effectiveness of intravenous preemptive analgesia is nearly equivalent to that of the epidural route, while avoiding the more significant potential risks associated with epidural administration.

A few limitations of our study are the small patient population in each group and that our patient population, all underwent robotic lumbar spine surgery which is a minimally invasive procedure involving smaller incisions and lesser soft tissue dissection by virtue of a robotic guide to visualize the unseen. We recommend further studies in conventional open surgeries and robotic surgeries with a larger patient population.

CONCLUSION

In conclusion, preemptive analgesia represents a crucial advancement in pain management for spine surgery. By addressing pain before it begins, this approach offers the potential to significantly improve patient outcomes and satisfaction. Our study contributes to the growing body of evidence supporting the use of preemptive analgesia in spine surgery and provides a basis for further optimization of these techniques in clinical practice.

Declarations

The authors have no conflict of interest

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Author Contribution

A.X.J, A.K, B.T, A.S, A.V wrote the main manuscript text A.X.J, A.K, B.T, A.S, M.P, A.V and V.S collected dataA.X.J analysed the dataAll authors reviewed the manuscript.

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Figures

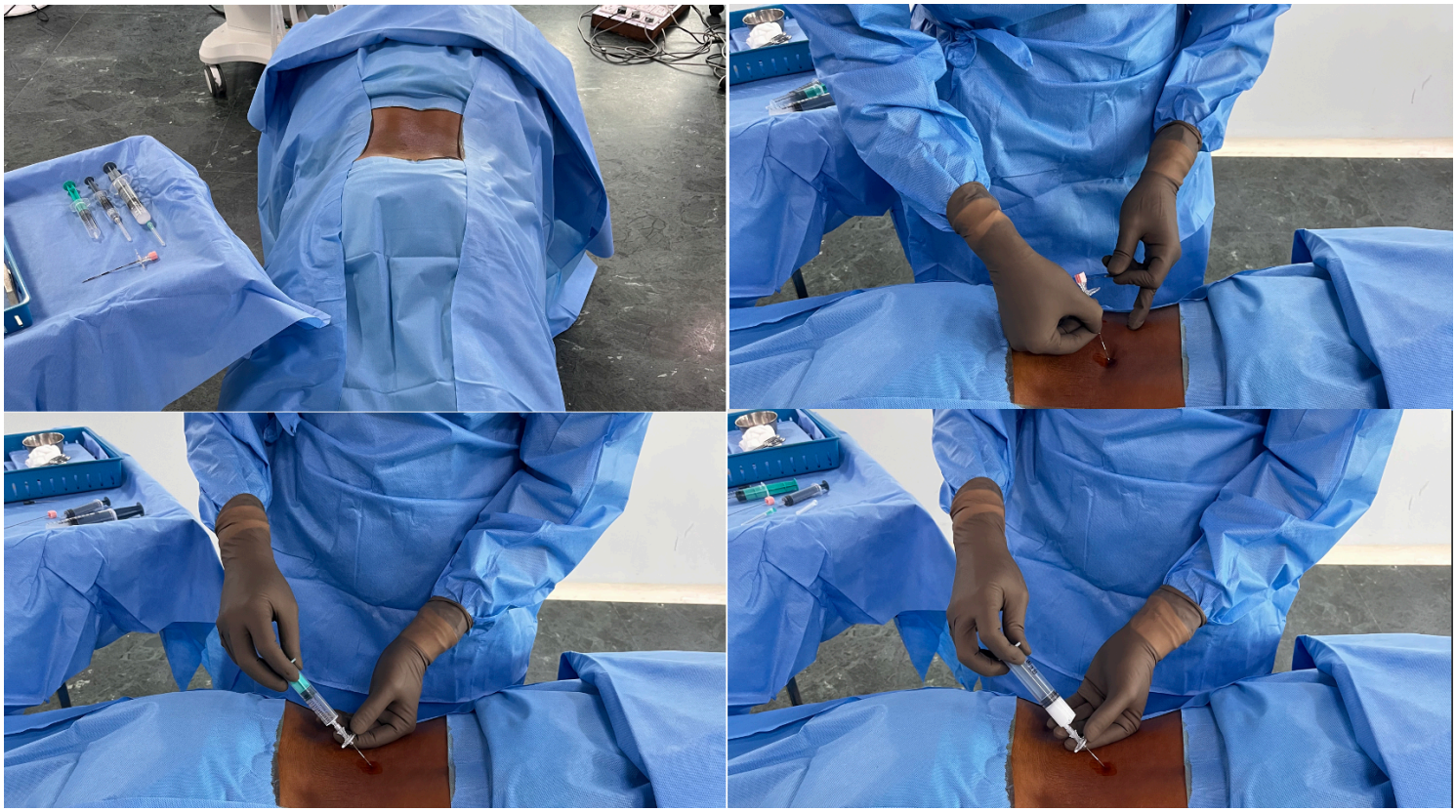

Figure 1

Patient positioned prone and epidural injection being given using low of resistance technique.