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Research Article

Comparison of Caudal Epidural Ropivacaine Alone Versus Ropivacaine with Dexmedetomidine for Postoperative Analgesia in Lumbosacral Spine Surgery: A Randomized Double-Blind Study

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ABSTRACT

Background: Postoperative pain following lumbosacral spine surgery is often intense and may hinder early recovery and ambulation. Caudal epidural analgesia using local anesthetics, particularly when combined with adjuvants, has shown potential in enhancing pain control. Dexmedetomidine which has a high affinity for α2-adrenergic receptors, may augment the analgesic effects of ropivacaine and extend its duration. To evaluate the effectiveness and safety of caudal epidural administration of ropivacaine alone versus ropivacaine combined with dexmedetomidine in patients undergoing lumbosacral spine surgery under general anesthesia.

Methods: A total of 60 adult patients (ASA I–II) scheduled for elective lumbosacral spine procedures were enrolled in this prospective, randomised, double-blind trial. Participants were assigned to two groups. One group received 20 mL of 0.2% ropivacaine, and another group received 18 mL of 0.2% ropivacaine with 2 mL of dexmedetomidine (1 µg/kg). Pain scores, time to first rescue analgesia, sedation levels, hemodynamic parameters, and adverse events were monitored. Statistical evaluation was carried out with SPSS version 21, with significance set at $p < 0.05$.

Results: Patients who received dexmedetomidine showed lower pain scores at 4, 8, and 12 hours after surgery. Their average duration of postoperative analgesia was also longer (23.00 ± 4.33 hours) when compared with the control group (15.13 ± 1.74 hours). Sedation profiles and intraoperative hemodynamics were largely similar in both groups. No clinically important adverse effects, such as hypotension, bradycardia, or respiratory compromise, were observed.

Conclusion: Incorporating dexmedetomidine into a caudal epidural block with ropivacaine provides more effective postoperative pain relief without significant side effects.

Introduction

Pain is not simply a physical sensation but a complex, multidimensional phenomenon that includes both physiological and emotional components in response to actual or potential tissue damage. The International Association for the Study of Pain describes it as an unpleasant experience linked to actual or potential tissue injury, underscoring its subjective and multifaceted nature [1-2]. Despite

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significant advancements in perioperative care, severe postoperative pain stays one of the most distressing outcomes after surgical interventions [3]. Pain perception originates through nociception, wherein peripheral nociceptors are activated by noxious stimuli and send signals to the spinal cord via Aδ and C fibers. These impulses are then processed centrally in the brain, leading to conscious awareness of pain [4-5]. Pain may be classified based on duration and etiology as either acute and chronic type. Acute pain is typically nociceptive and self-limiting; chronic pain often involves persistent sensitization and psychological overlay [6-7]. Lumbar spine surgeries such as discectomy often induce acute postoperative pain through nerve root irritation and inflammatory mechanisms. Chronic postoperative pain may be associated with structural complications like epidural fibrosis and arachnoiditis [8]. During surgery, tissue injury leads to activation of dorsal horn neurons and central sensitization, which amplifies nociceptive signaling [9-10]. Poorly managed postoperative pain increases the likelihood of complications such as ileus, urinary retention, venous thromboembolism, and cardiopulmonary morbidity [8,11]. As a result, optimizing postoperative analgesia is essential for improved surgical outcomes and patient satisfaction. A multimodal approach, combining systemic and regional analgesic strategies, is now widely advocated to address this issue [12]. Within this framework, preemptive analgesia—the administration of analgesics prior to surgical incision—has gained attention for its ability to attenuate central sensitization and reduce postoperative analgesic requirements [13]. First conceptualized by Crile in 1913 and later supported by Woolf and Wall, this strategy has proven particularly effective in surgeries with high nociceptive input [14-15].

Among regional techniques, the caudal epidural block has remained a reliable and widely used method for surgeries involving the lower spine [16–18]. Originally introduced by Sicard in 1901 and further popularized by Campbell in 1933 [19-20], it involves delivering local anesthetics via the sacral canal and remains an integral part of multimodal pain protocols. Ropivacaine, a long-acting amide local anesthetic, has gained favor over bupivacaine due to its lower cardiotoxicity and better sensory-motor dissociation, making it especially appropriate for procedures involving the spine. Dexmedetomidine, which has a high affinity for the α2-adrenergic receptor, is increasingly employed as an adjuvant in regional anesthesia due to its analgesic and sympatholytic properties. When combined with ropivacaine in caudal blocks, dexmedetomidine has shown potential in enhancing analgesia, prolonging block duration, and providing greater hemodynamic stability.

The present study was designed to investigate whether adding dexmedetomidine to ropivacaine in a caudal epidural block offers measurable advantages over ropivacaine alone for patients undergoing lumbosacral spine surgery under general anesthesia. The primary endpoint was postoperative pain intensity measured using the Visual Analogue Scale (VAS). Secondary endpoints included the time to first rescue analgesia, intraoperative hemodynamic trends (heart rate, systolic and diastolic blood pressure, and mean arterial pressure), fentanyl requirements during surgery, and the incidence of adverse events.

Methods

This investigation was designed as a prospective, randomized, and double-blinded trial conducted in the Department of Anaesthesia at S.M.S. Medical College, Jaipur, with its affiliated hospitals. The study was carried out over a five-month period, from October 2020 through February 2021. Study conducted after receiving approval from the Institutional Ethics Committee (781/MC/EC/2020). All participants provided written informed consent, and the conduct of the study followed the ethical principles outlined in the Declaration of Helsinki.

Sixty adult patients scheduled for elective lumbosacral spine surgery under general anesthesia were recruited. Eligible subjects were between 20 and 50 years of age and belonged to ASA physical status I or II. Patients were excluded if they had any contraindications to caudal blocks or study medications, including known drug allergies, bleeding disorders, local infections, previous history of spine surgery, psychiatric or neurological illness, or significant cardiac disease. Random allocation into two equal groups (30 patients each) was performed using computer-generated sequencing. Allocation concealment was ensured via sealed, opaque envelopes. Group A was administered 0.2% ropivacaine, 18 ml with 2 mL of normal saline (total volume 20 mL), while Group B was administered 18 mL of 0.2% ropivacaine, 18 ml mixed with 2 mL of dexmedetomidine (1 µg/kg), making up the same volume. Drug preparation was handled by an independent anesthesiologist not involved in the procedure or outcome assessment to keep blinding.

All patients underwent standard preoperative fasting and were evaluated with a routine laboratory workup, including hematological test, liver and renal function tests, serum electrolytes, electrocardiography, and chest X-ray. After confirming adequate fasting, patients were shifted to the operating room where standard non-invasive monitoring (ECG, NIBP, SpO_2) was applied. An 18-gauge IV cannula was secured, and patients were preloaded with crystalloid solution (8 mL/kg). Premedication consisted of intravenous ranitidine (1 mg/kg), metoclopramide (0.15 mg/kg), glycopyrrolate (5 µg/kg), and midazolam (0.01 mg/kg). The induction of anesthesia was achieved with propofol (2 mg/kg) and fentanyl (2 µg/kg). Succinylcholine (1.5 mg/kg)

facilitated tracheal intubation, and atracurium (0.5 mg/kg) was administered for neuromuscular relaxation. Once the airway was secured, the patient was positioned prone for caudal block. Under aseptic conditions, a 20-gauge cannula was inserted through the sacral hiatus into the caudal epidural space. The correct placement of the needle was verified by the loss-of-resistance technique before giving the study drug. Hemodynamic variables—heart rate, systolic, diastolic, and mean arterial pressures—were noted at 15-minute intervals throughout surgery. A supplemental dose of intravenous fentanyl (30 µg) was administered if hemodynamic parameters increased by more than 20% from baseline. Maintenance of anesthesia was achieved using sevoflurane (1–2%) in a 60:40 ratio of nitrous oxide-oxygen. Intermittent doses of atracurium were given as needed. Postoperative pain was evaluated using the Visual Analogue Scale (VAS), and sedation was graded using the Ramsay Sedation Scale. Assessments were performed at predetermined intervals: immediately after surgery (0 hours), at 30 minutes, and at 1, 2, 4, 8, 12, and 24 hours. Rescue analgesia consisted of intravenous diclofenac (75 mg) when VAS reached or exceeded 4. The primary endpoint of the study was how much time postoperative analgesia achieved. Secondary outcomes included sedation levels, intraoperative fentanyl consumption, hemodynamic fluctuations, and adverse events such as nausea, vomiting, hypotension, bradycardia, respiratory depression, and shivering. All observations were documented in a structured case-record form. Statistical analysis was done using SPSS version 21.0 (IBM Corp., USA). Continuous variables were compared using the unpaired Student's t-test and categorical variables using the chi-square test. A p-value < 0.05 was considered statistically significant.

Results

A total of sixty patients scheduled for lumbosacral spine surgery were enrolled and evenly distributed to the two treatment groups (30 patients each). The baseline profile of participants was well balanced. The average age of patients was similar between the two groups (37.63 ± 8.03 years in Group A vs. 38.57 ± 9.78 years in Group B; p = 0.595). Body weight and gender distribution also showed no detectable difference (p=0.197 and p=0.600, respectively). ASA grading revealed that most patients in both groups were ASA Grade I, with no significant intergroup variation (p=0.182) (Table 1).

Table 1- Demographic variables (Mean ± SD), Age Distribution

	Group A		Group B	
	No.	%	No.	%
22-35	10	33.33	13	43.33
36-50	20	66.66	17	56.66
Total	30	100.00	30	100.00
Mean±SD	37.63±8.03		38.57±9.78	
Result (P value)	0.595 (NS)			

Preoperative vital signs such as heart rate, systolic and diastolic pressures, mean arterial pressure, and oxygen saturation were comparable. Intraoperatively, both groups displayed stable hemodynamics without any major fluctuations, and none of the recorded time points showed statistically significant differences. As expected, a brief rise in pulse rate was noted following intubation in both groups, although the change did not reach statistical significance.

Postoperatively, heart rate, SBP, and DBP remained largely comparable across both groups except at selected time points. Statistically significant differences were observed in heart rate at 2 hours (Group A: 85.96±12.95 bpm vs. Group B: 75.4±7.54 bpm; p=0.022), DBP at 4 hours (Group A: 80.73±5.00 mmHg vs. Group B: 78.00±4.39 mmHg; p=0.028), and MAP at 4 hours (Group A: 93.82±5.47 mmHg vs. Group B: 90.84±3.36 mmHg; p=0.013), indicating improved hemodynamic stability in Group B.

The mean pain score (VAS) as shown in (Figure1) was significantly lower in Group B at 4 hours (0.00±0.00 vs. 0.33±0.48), 8 hours (0.18±0.03 vs. 1.50±0.63), 12 hours (1.00±0.87 vs. 3.13±0.78), and 24 hours (2.37±1.79 vs. 0.53±0.51), with all comparisons yielding $p<0.001$. This shows a good improvement in postoperative analgesia with the addition of dexmedetomidine.

Patients who received dexmedetomidine experienced a markedly longer duration of pain relief, with the first request for additional analgesia as shown in (Table 2), occurring almost eight hours later than Group A. This difference was highly significant ($p < 0.001$), further supporting the prolonged analgesic action of the ropivacaine–dexmedetomidine combination.

Sedation levels, assessed throughout the postoperative period, remained within acceptable limits for all patients. Although fewer patients in Group B required supplemental fentanyl during surgery, as shown in (Table 3), the difference did not reach statistical significance (p = 0.166). However, the numerical trend aligns with the overall superior analgesic performance of Group B. Postoperative nausea and vomiting was low and similar in both groups (p=0.741). Serious adverse effects such as bradycardia, hypotension, or respiratory depression were not observed in either group.

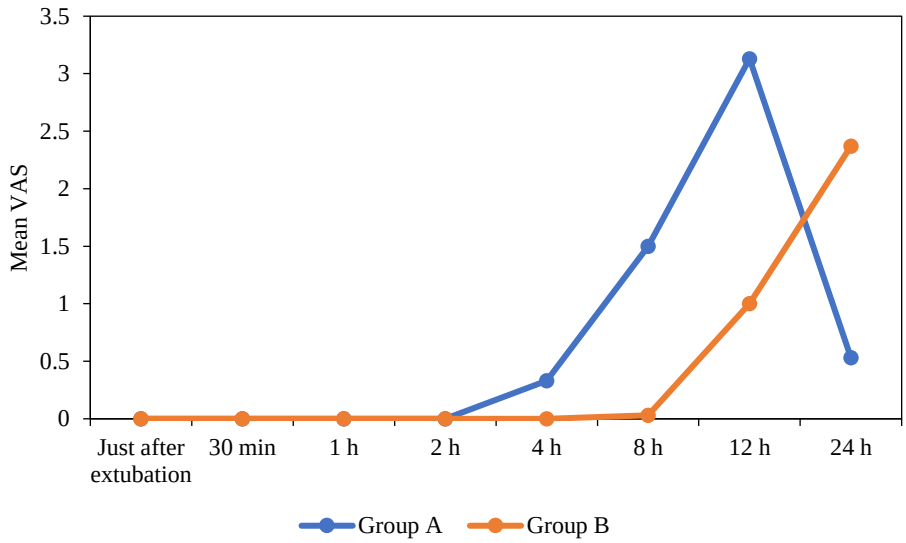

Figure 1- Comparison of postoperative VAS scores between Group A and Group B at multiple time intervals (0–24 hours).

Table 2- Time of rescue analgesia (hrs)

	Group A		**Group B**	
	Mean	SD	Mean	SD
Time of rescue analgesia (hrs)	15.13	1.74	23.00	4.33
Result (P value)	p<0.001 (S)			

Table 3- % Of patients requiring additional dose of fentanyl

	Group A		**Group B**	
	No.	%	No.	%
% Of patients requiring additional dose of fentanyl	4.00	13.33	1.00	3.33
Result (P value)	0.166 (NS)			

Discussion

Postoperative pain after laminectomy remains a challenge to recovery, often delaying ambulation and increasing reliance on postoperative physiotherapy. Poorly controlled pain not only prolongs hospital stays but may also lead to complications such as venous thromboembolism and pulmonary embolism. Ongoing inflammatory response and vascular congestion in the surgical site can result in fibrotic changes and chronic neuropathic pain. Effective analgesia is, therefore, very important for overall recovery and patient satisfaction. Among regional techniques, the caudal epidural block is considered a widely used approach for infraumbilical surgeries. When given after induction of general anesthesia, it attenuates intraoperative nociceptive responses and reduces the requirement for systemic opioids [21]. However, short duration of action is its limitation. To overcome this limitation, adjuvants such as opioids, ketamine, and α2-adrenergic agonists can be used [22]. Of these, dexmedetomidine has gained attention due to its unique ability to provide both analgesia and sedation by minimizing the risk of respiratory depression. In the present study, 0.2% ropivacaine was chosen as the primary local anesthetic for its favorable profile mainly sensory blockade, minimal motor impairment, and cardiovascular stability which is desirable in spine surgeries [23–26]. The dexmedetomidine is added to ropivacaine to prolong the duration of postoperative analgesia. This agent exerts its effects both centrally and peripherally, by inhibiting nociceptive transmission through hyperpolarization of Aδ and C fibers, increasing potassium conductance, and promoting local vasoconstriction via α2-receptor activation [27].

The dexmedetomidine and ropivacaine combination enhances analgesia without a proportional rise in adverse events. Kalso et al. and Kakiuchi et al. demonstrated that dexmedetomidine provides better neuraxial analgesia with a lower chance of side effects compared to other

adjuvants like clonidine or opioids [25-26]. Saravana Babu et al. also reported that a 1 μg/kg dose of dexmedetomidine administered epidurally produced better analgesia and hemodynamic stability—supporting the dosing used in our protocol [27]. Kamal et al. evaluated dexmedetomidine as an adjuvant to ropivacaine in pediatric caudal epidural block [28]. Esmaoglu et al. reported that adding dexmedetomidine to levobupivacaine prolonged axillary brachial plexus block [29]. The two study groups in our trial were demographically comparable in terms of age, sex, body weight, ASA classification, and duration of surgery, ensuring a fair comparison. Patients who received dexmedetomidine (Group B) required less fentanyl intraoperatively, a finding consistent with previous work by Shashwat Kumar et al. and Sandhya Kalappa et al., where combining dexmedetomidine who ropivacaine reduced opioid consumption [30-31]. Hemodynamic parameters remained stable in both study groups throughout the intraoperative period with no statistically meaningful differences in terms of heart rate, systolic blood pressure, diastolic blood pressure, or mean arterial pressure. These findings matched with previous studies by Vigya Goyal et al. and Jyotsna Kubre et al., who showed comparable cardiovascular stability when caudal or epidural techniques were combined with α_2-agonist adjuvants [32]. Postoperative pain assessment revealed a clear analgesic benefit in patients getting dexmedetomidine as an adjunct. Visual Analogue Scale (VAS) scores were significantly lower in Group B at 4, 8, and 12 hours following surgery. At the 12-hour assessment, patients in Group A reported a mean VAS score of 3.13 ± 0.78, whereas those in Group B demonstrated substantially lower pain scores of 1.00 ± 0.87 ($p < 0.001$), indicating superior pain control. These results are similar to studies conducted by Thimmappa et al., Saravana Babu et al., and Deming Xu et al., all of whom reported prolonged duration of analgesia and improved postoperative pain profiles with the use of dexmedetomidine as an adjuvant to local anesthetics in regional anesthesia techniques [33].

The duration of postoperative analgesia was longer in patients receiving dexmedetomidine as an adjuvant. Group B experienced longer pain relief for a mean duration of 23.00 ± 4.33 hours, which was significantly greater than the 15.13 ± 1.74 hours observed in group A, mirroring results seen in studies by Bajwa and Sandhya, who reported prolonged analgesia with α2-agonists [34]. As for adverse effects, both groups reported minimal and comparable incidences of nausea, vomiting, hypotension, and bradycardia. Notably, no patients in any group developed respiratory depression or major cardiovascular instability. This was observed in either group, reaffirming the safety profile of dexmedetomidine at the studied dose. Similar safety findings have been documented by Esmaoglu et al. and Neerja et al. in the context of regional anesthesia [35].

Conclusion

The findings of the present study indicate that adding dexmedetomidine (1 μg/kg) as an adjuvant to 0.2% ropivacaine through a single caudal epidural injection results in more effective and longer-lasting postoperative analgesia in patients undergoing lumbosacral spine surgery. Patients receiving the combination experienced better pain control compared with those receiving ropivacaine alone, without an associated increase in sedation or clinically relevant adverse effects during general anesthesia. These results suggest that dexmedetomidine, when used in appropriate doses, is a reliable and well-tolerated adjunct to ropivacaine for improving postoperative pain outcomes in lumbosacral spinal procedures.

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