Section: Critical Care Medicine & Anesthesiology

Original Research Article

COMPARISON OF INTRATHECAL VERSUS INTRAVENOUS DEXMEDETOMIDINE AS AN ADJUVANT TO HYPERBARIC BUPIVACAINE ON BLOCK CHARACTERISTICS AND DURATION OF POSTOPERATIVE ANALGESIA IN LOWER LIMB ORTHOPAEDIC SURGERIES

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ABSTRACT

Background: Dexmedetomidine is increasingly used as an adjuvant to hyperbaric bupivacaine in spinal anaesthesia to improve block quality and prolong postoperative analgesia in lower limb orthopaedic surgeries. However, the comparative efficacy of intrathecal and intravenous administration on block characteristics and postoperative pain relief remains clinically relevant. **Aim and Objective:** To compare intrathecal versus intravenous dexmedetomidine as an adjuvant to hyperbaric bupivacaine with respect to onset and duration of sensory and motor blockade, duration of postoperative analgesia, time to first rescue analgesia, and total 24-hour rescue analgesic requirement. **Materials and Methods:** This prospective, randomized, double-blinded comparative clinical study included 90 ASA I and II patients aged 18 to 60 years undergoing elective unilateral lower limb orthopaedic surgery under spinal anaesthesia. Patients were allocated into two groups of 45 each. Group A received intravenous dexmedetomidine 0.5 µg/kg before subarachnoid block, while Group B received intrathecal dexmedetomidine 5 µg with 12.5 mg hyperbaric bupivacaine. Sensory and motor block characteristics, visual analogue scale scores, time to first rescue analgesia, and 24-hour rescue tramadol requirement were recorded and analysed statistically. Rescue analgesia was administered as Inj. Tramadol 50 mg diluted in 100 mL normal saline intravenously whenever required. **Results:** Onset of sensory and motor blockade was comparable between groups. However, intrathecal dexmedetomidine produced significantly longer sensory and motor block duration, lower postoperative pain scores during the early and intermediate postoperative period, prolonged time to first rescue analgesia, and reduced 24-hour rescue analgesic requirement, with improved postoperative analgesic profile and patient comfort. **Conclusion:** Intrathecal dexmedetomidine was superior to intravenous dexmedetomidine as an adjuvant to hyperbaric bupivacaine, providing prolonged block characteristics and better postoperative analgesic efficacy in lower limb orthopaedic surgeries.

INTRODUCTION

Spinal anaesthesia remains the preferred anesthetic technique for lower limb orthopaedic surgeries due to its simplicity, rapid onset, reliable sensory–motor blockade, and avoidance of airway manipulation.[1] Among local anesthetic agents, hyperbaric bupivacaine is widely used because of its favourable pharmacodynamic profile, producing dense neural blockade by inhibiting voltage-gated sodium channels and thereby preventing impulse conduction along nerve fibers. However, a major limitation of spinal anaesthesia with bupivacaine alone is its relatively limited duration of postoperative analgesia, often necessitating early administration of rescue analgesics and contributing to suboptimal pain control in the immediate postoperative period.[2]

To overcome this limitation, various adjuvants such as opioids, clonidine, magnesium sulfate, and

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neostigmine have been incorporated into neuraxial anaesthesia.[3] While these agents can enhance block characteristics and prolong analgesia, their use is often associated with adverse effects including respiratory depression, nausea, vomiting, pruritus, and hemodynamic instability. These drawbacks have prompted the search for safer and more effective alternatives, leading to increasing interest in dexmedetomidine, a highly selective α2-adrenergic receptor agonist with sedative, analgesic, and sympatholytic properties.[4]

Dexmedetomidine exerts its analgesic effects through both central and spinal mechanisms. At the spinal level, it acts on presynaptic C-fibers and postsynaptic dorsal horn neurons, inhibiting the release of nociceptive neurotransmitters and enhancing hyperpolarization of interneurons. This results in potentiation of local anesthetic action and prolongation of sensory and motor blockade.[5] Additionally, its supraspinal action in the locus coeruleus contributes to sedation and analgesia without causing significant respiratory depression, making it particularly suitable for use in regional anaesthesia techniques.[6]

Intrathecal administration of dexmedetomidine as an adjuvant to bupivacaine has been extensively studied and has demonstrated significant improvements in block characteristics. Evidence indicates that intrathecal dexmedetomidine prolongs the duration of both sensory and motor blockade, delays regression of anaesthesia, and significantly extends the time to first request for postoperative analgesia.[7] Furthermore, studies have shown that its addition leads to reduced postoperative analgesic consumption and improved patient satisfaction, without a significant increase in adverse effects. These findings highlight its potential as a superior neuraxial adjuvant compared to conventional agents.[8]

In contrast, intravenous dexmedetomidine has emerged as an alternative route of administration that provides systemic analgesia and sedation.[9] Intravenous infusion produces dose-dependent sedation, anxiolysis, and analgesia through central α2-receptor activation, along with attenuation of the stress response to surgery. Unlike intrathecal administration, intravenous dexmedetomidine does not directly act on spinal cord receptors but enhances analgesia through descending inhibitory pathways and modulation of sympathetic activity. Its pharmacokinetic profile, characterized by rapid distribution and a relatively short elimination half-life, allows for titratable intraoperative use.[10]

Several studies have explored the comparative efficacy of intrathecal versus intravenous dexmedetomidine as adjuvants to bupivacaine. Intrathecal administration has been associated with a more pronounced prolongation of sensory and motor block due to its direct action on spinal receptors.[11] It also provides a longer duration of postoperative analgesia, which is particularly advantageous in orthopaedic procedures where postoperative pain is often severe and prolonged.[12] On the other hand, intravenous dexmedetomidine offers advantages such as ease of administration, avoidance of intrathecal drug preparation, and the ability to provide intraoperative sedation and hemodynamic stability. However, its effect on prolonging spinal block duration is comparatively less direct and may depend on systemic modulation of pain pathways.[13]

The impact of dexmedetomidine on block characteristics extends beyond analgesia. It has been shown to influence onset time, peak block height, and duration of motor block. Intrathecal dexmedetomidine often produces a faster onset and higher level of sensory block, along with prolonged motor blockade, which may be beneficial for prolonged surgical procedures but could delay early mobilization.[14] Conversely, intravenous dexmedetomidine tends to preserve motor function to a greater extent while still enhancing analgesia, making it potentially advantageous in settings where early postoperative ambulation is desired.

Hemodynamic stability is another critical consideration in the use of dexmedetomidine. Both intrathecal and intravenous routes can lead to bradycardia and hypotension due to sympatholytic effects, but these changes are generally mild and manageable when appropriate dosing is used. Studies have demonstrated that low-dose intrathecal dexmedetomidine does not significantly alter hemodynamic parameters compared to control groups, suggesting a favourable safety profile. Similarly, intravenous administration allows controlled titration, enabling maintenance of stable intraoperative conditions.[8]

In lower limb orthopaedic surgeries, effective postoperative analgesia is vital for patient comfort, early rehabilitation, shorter hospital stay, and prevention of complications such as deep vein thrombosis. The choice of adjuvant and its route significantly influence outcomes. Intrathecal dexmedetomidine prolongs spinal anaesthesia and analgesia, whereas intravenous administration provides sedation and stress attenuation. Comparative evaluation of these routes with hyperbaric bupivacaine is clinically important to optimize block characteristics, analgesia duration, and overall perioperative outcomes for evidence-based anesthetic selection.[15]

The aim of this study is to compare intrathecal versus intravenous dexmedetomidine as an adjuvant to hyperbaric bupivacaine in lower limb orthopaedic surgeries. It evaluates onset and duration of sensory and motor block, duration of postoperative analgesia using pain scores and time to first rescue analgesia, and total rescue analgesic requirement within the first 24 hours postoperatively.

MATERIALS AND METHODS

This hospital-based prospective, randomized, double-blinded comparative clinical study was

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conducted among 90 ASA I and II patients aged 18 to 60 years undergoing elective unilateral lower limb orthopaedic surgery under spinal anaesthesia at Vydehi Institute of Medical Sciences and Research Centre, Bengaluru. Patients were randomized into two groups of 45 each. Group A received intravenous dexmedetomidine 0.5 mcg/kg in 100 mL normal saline over 15 minutes before subarachnoid block, while Group B received intrathecal dexmedetomidine 5 mcg with 12.5 mg hyperbaric bupivacaine. Sensory block- onset and duration, motor block- onset and recovery, VAS scores, time to first rescue analgesia, and 24-hour rescue tramadol requirement were recorded. Rescue analgesia was Inj. Tramadol 50 mg in 100 mL normal saline IV.

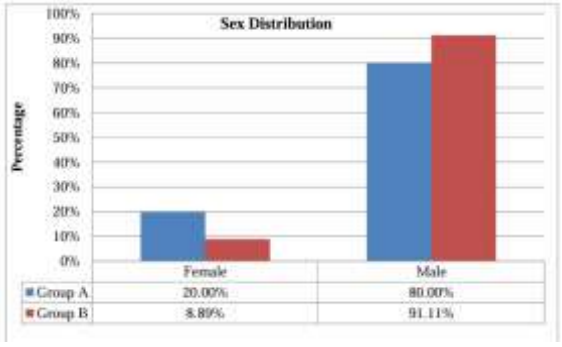
RESULTS

Table 1: Mean age comparison between two groups

	Group A		Group B		p value
	Mean	SD	Mean	SD	
Age	36.98	12.72	36.00	13.87	0.728

The mean age between Group A (36.98 ± 12.72 years) and Group B (36.00 ± 13.87 years) was comparable, with no statistically significant difference ($p > 0.05$). This indicates that both groups were demographically well matched at baseline. The similarity in age distribution minimizes confounding bias related to age-dependent variations in spinal block characteristics and analgesic response. Therefore, any observed differences in block profile and duration of postoperative analgesia can be reliably attributed to the route of dexmedetomidine administration rather than age differences.

The sex distribution between Group A (20% females, 80% males) and Group B (8.89% females, 91.11% males) shows male predominance in both groups. The difference in gender proportions between the groups is minimal and likely not statistically significant ($p > 0.05$). This indicates that both groups are comparable with respect to gender distribution. Hence, gender is unlikely to act as a confounding factor in influencing block characteristics or duration of postoperative analgesia.

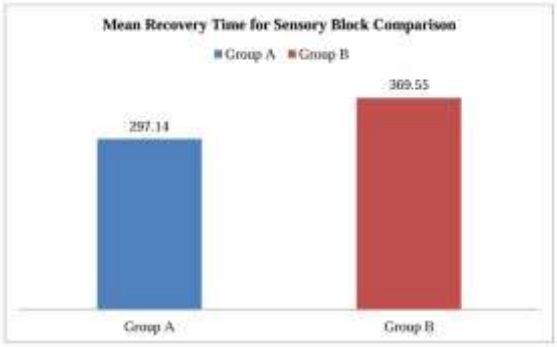


Graph 1: Bar diagram showing sex distribution between two groups

Table 2: Mean onset of sensory blockade comparison

	Group A		Group B		p value
	Mean	SD	Mean	SD	
Onset of sensory blockade	4.53	1.88	4.07	1.98	0.255

The mean onset of sensory blockade(minutes) was comparable between Group A (4.53 ± 1.88 min) and Group B (4.07 ± 1.98 min), with no statistically significant difference ($p = 0.255$). This suggests that the route of dexmedetomidine administration does not significantly influence the initiation time of sensory block. The similar onset profile indicates equivalent early spinal anesthetic action in both groups. Therefore, any differences observed in block duration or analgesic efficacy are unlikely to be related to onset characteristics.



Graph 2: Bar diagram showing mean recovery time (sensory) comparison between two groups

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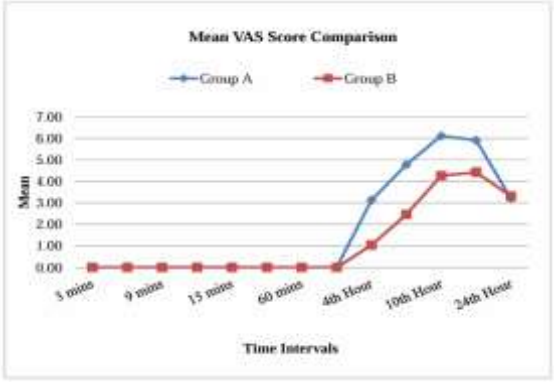
The mean recovery time of sensory block was higher in Group B (369.55 min) compared to Group A (297.14 min), indicating a prolonged duration of sensory blockade in Group B. This suggests that intrathecal Dexmedetomidine is associated with extended sensory block duration compared to the intravenous route. The observed difference reflects a clear advantage in terms of prolonged analgesic coverage. Hence, the route of administration significantly influences the duration of sensory blockade, with the intrathecal route providing superior prolongation when used with Bupivacaine.

Table 3: Mean recovery time (Motor) comparison between two groups

Time to Motor block recover(Bromage 1 from complete blockade (4))	Group A		Group B		p value
	Mean	SD	Mean	SD	
Recovery Time (Motor)	387.14	119.41	447.27	123.07	0.024*

The mean motor block recovery time was significantly higher in Group B (447.27 ± 123.07 min) compared to Group A (387.14 ± 119.41 min), with a statistically significant difference (p = 0.024). This indicates that intrathecal Dexmedetomidine produces a significantly prolonged duration of motor blockade compared to the intravenous route. The extended motor recovery reflects enhanced and sustained spinal action, although it may be associated with delayed postoperative mobilization. Hence, the route of administration significantly influences motor block duration, with the intrathecal route providing superior prolongation when used with Bupivacaine.



Graph 3: Line diagram means VAS score comparison between two groups at different intervals of time

The mean VAS scores were negligible and comparable in both groups during the early postoperative period up to 60 minutes, indicating effective initial analgesia. At later intervals (4th to 10th hour), VAS scores increased earlier and more markedly in Group A, whereas Group B consistently demonstrated lower VAS scores, indicating superior and prolonged analgesic effect. This suggests that intrathecal Dexmedetomidine provides better sustained postoperative analgesia compared to the intravenous route when used with Bupivacaine. By 24 hours, VAS scores in both groups became comparable, reflecting attenuation of the differential analgesic effect over time.

Table 4: Mean time to demand of 1st rescue analgesia

	Group A		Group B		
	Mean	SD	Mean	SD	P value
Time to Demand of 1st Rescue Analgesia (hours)	5.81	1.35	8.66	1.67	<0.001*

The mean time to first rescue analgesia was significantly longer in Group B (8.66 ± 1.67 hours) compared to Group A (5.81 ± 1.35 hours), and this difference was highly statistically significant (p < 0.001). This finding indicates that intrathecal Dexmedetomidine provides a more prolonged duration of postoperative analgesia than the intravenous route. The delayed requirement for rescue analgesia in Group B reflects superior and sustained analgesic efficacy. Therefore, the intrathecal route offers a clear advantage in extending postoperative pain relief when used with Bupivacaine.

Table 5: Total rescue analgesic doses in 24 hours

Each Dose = Inj. Tramadol (50mg) in 100ml Normal Saline		Group A		Group B	
Total rescue analgesic doses in 24 hours	No. of Doses	Patient Count	Column N%	Patient Count	Column N%
	0	0	0.00%	3	6.67%
	1	4	8.89%	18	40.00%
	2	5	11.11%	20	44.44%
	3	11	24.44%	4	8.89%

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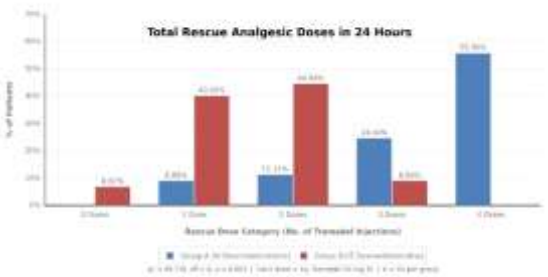
	4	25	55.56%	0	0.00%
$\chi^2 = 49.176$, df = 4, p = < 0.001					

In the present table, total rescue analgesic requirement within 24 hours was significantly higher in Group A than Group B, where each rescue dose was Inj. Tramadol 50 mg in 100 ml Normal Saline. Most patients in Group A required 4 doses [25 (55.56%)], while most patients in Group B required only 1 dose [18 (40%)] or 2 doses [20 (44.44%)]. No patient in Group B required 4 doses. The difference was statistically highly significant (χ^2 = 49.176, df = 4, p < 0.001), suggesting better analgesic efficacy in Group B.



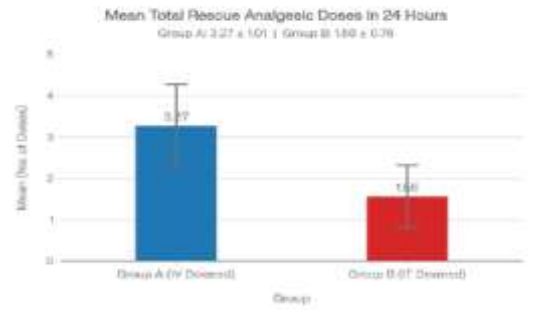
Graph 4: Bar diagram showing total rescue analgesic doses in 24 hours

The distribution of total rescue analgesic doses in 24 hours showed that Group A required higher tramadol consumption, with the majority of patients requiring 3 to 4 doses, 11 patients (24.44%) and 25 patients (55.56%), respectively. In contrast, Group B predominantly required only 1 to 2 doses, with 18 patients (40.00%) requiring 1 dose and 20 patients (44.44%) requiring 2 doses. Three patients (6.67%) in Group B did not require any rescue analgesia, while no patient in Group A remained rescue-analgesic free. Each rescue analgesic dose consisted of Inj. Tramadol 50 mg in 100 mL normal saline intravenously. This indicates that intrathecal dexmedetomidine provided more sustained postoperative analgesia with significantly lower rescue tramadol requirement compared with intravenous dexmedetomidine.

Table 6: Onset of motor blockade distribution

Motor Blockade (Time to Bromage 4)		Group A		Group B	
		Count	Column N%	Count	Column N%
Onset	3 min	13	28.89%	11	24.44%
	6 min	29	64.44%	25	55.56%
	9 min	3	6.67%	8	17.78%
	12 min	0	0.00%	1	2.22%
$\chi^2 = 3.736$, df = 3, p = 0.291					

The onset of motor blockade was comparable between the two groups, with the majority of patients achieving Bromage 4 at 6 minutes in both Group A (64.44%) and Group B (55.56%). Early onset at 3 minutes and delayed onset at 9–12 minutes showed minor variations between the groups. However, these differences were not statistically significant (χ^2 = 3.736, df = 3, p = 0.291). This indicates that the route of administration of Dexmedetomidine does not significantly influence the onset of motor blockade when used with Bupivacaine.



Graph 5: Bar diagram showing mean total rescue analgesic doses in 24 hours between two groups

The mean total number of rescue tramadol doses required within 24 hours was significantly higher in Group A (3.27 ± 1.01 doses) compared with Group B (1.56 ± 0.76 doses), indicating greater postoperative analgesic requirement in the intravenous dexmedetomidine group. Since each rescue dose consisted of Inj. Tramadol 50 mg in 100 mL normal saline intravenously, the lower dose requirement in Group B reflects superior and more sustained postoperative analgesia with intrathecal dexmedetomidine.

DISCUSSION

Spinal anaesthesia is widely preferred for lower limb orthopaedic surgeries due to its reliable intraoperative analgesia and favourable postoperative recovery profile. The addition of α2 agonists such as Dexmedetomidine has been extensively studied to enhance the duration and quality of neuraxial blockade. In the present study, demographic parameters including age and sex distribution were comparable between the two groups, indicating appropriate randomization and minimizing confounding bias. The onset of sensory and motor blockade did not show a statistically

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significant difference between intravenous and intrathecal groups, suggesting that the route of administration does not influence block initiation but primarily affects its duration. Similar findings were reported by Magdy et al (2015) and Gupta et al (2011).[16,17]

In contrast, duration-related parameters demonstrated clear superiority of the intrathecal route. Sensory block regression and motor block duration were significantly prolonged in the intrathecal group, indicating sustained spinal action. These findings are consistent with Afifi et al (2016) and Hamed et al (2014), who reported prolonged sensory and motor blockade with intrathecal administration due to direct spinal receptor action.[18,19]

Postoperative analgesic outcomes further reinforced these findings. In our study, VAS scores were significantly lower in the intrathecal group from the 4th to 10th postoperative hour, indicating improved pain control during the critical intermediate period. Additionally, time to first rescue analgesia was significantly prolonged, and the total 24-hour rescue tramadol requirement was markedly reduced in the intrathecal group. In the present study, each rescue analgesic dose consisted of Inj. Tramadol 50 mg in 100 mL normal saline intravenously; therefore, the lower number of rescue doses in Group B directly reflects reduced postoperative tramadol consumption and better sustained analgesic efficacy. Similar results were reported by Sharma et al (2020) and Afifi et al (2016), while Zhang et al. (2018) highlighted the opioid-sparing effect of dexmedetomidine, demonstrating a substantial reduction in cumulative postoperative narcotic requirements and lower pain scores without inducing respiratory depression.[18,20,21]

The underlying mechanism involves direct spinal action of intrathecal Dexmedetomidine on presynaptic C-fibers and postsynaptic dorsal horn neurons, resulting in inhibition of nociceptive transmission and enhanced analgesia. In contrast, intravenous administration primarily acts through supraspinal pathways, which may be less effective in sustaining localized neuraxial blockade.

Overall, although both routes are effective, intrathecal dexmedetomidine provides superior prolongation of sensory and motor blockade, improved postoperative analgesia, delayed rescue analgesia requirement, and reduced analgesic consumption. These findings support the intrathecal route as the more effective approach when used with bupivacaine in lower limb orthopaedic surgeries.

CONCLUSION

Intrathecal dexmedetomidine was more effective than the intravenous route as an adjuvant to bupivacaine in lower limb orthopaedic surgeries. Although the onset of sensory and motor blockade was comparable between the two groups, the intrathecal route produced significantly prolonged sensory and motor block duration, lower postoperative pain scores during the intermediate postoperative period, delayed requirement of first rescue analgesia and reduced 24-hour rescue tramadol consumption. These findings demonstrate that intrathecal dexmedetomidine provides superior block prolongation and postoperative analgesic efficacy, making it the preferred route when prolonged analgesia and reduced analgesic requirement are desired.

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