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Original Article

Effects of Three Different Doses of Intrathecal Dexmedetomidine Added to Bupivacaine on Effectiveness of Subarachnoid Block in Elective Caesarean Sections: A Prospective Randomized Double-Blind Study

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ABSTRACT

Background: Spinal anesthesia with hyperbaric bupivacaine is commonly used for elective cesarean section, but its limited postoperative analgesic duration and dose-related hemodynamic effects have encouraged the use of intrathecal adjuvants. Objective: To compare the effects of three doses of intrathecal dexmedetomidine added to bupivacaine on sensory and motor block characteristics, postoperative analgesia, and perioperative tolerability in elective cesarean section. Methods: This prospective, randomized, double-blind, four-arm clinical trial included 160 ASA I–II parturients aged 18–40 years undergoing elective cesarean section under spinal anesthesia. Participants were allocated equally to receive bupivacaine 10 mg with dexmedetomidine 5 µg, 7.5 µg, or 10 µg, or bupivacaine 10 mg alone. Sensory block onset to T6, sensory and motor block duration, Visual Analogue Scale-guided time to first rescue analgesia, hemodynamic parameters, sedation, and adverse events were assessed. Results: Sensory onset was fastest with 10 µg dexmedetomidine and slowest in the control group. Sensory and motor block durations were significantly prolonged in dexmedetomidine groups, while time to first analgesic request was longest with 10 µg dexmedetomidine. Conclusion: Intrathecal dexmedetomidine improved spinal block quality and postoperative analgesia, with 10 µg showing the greatest analgesic benefit. Keywords: Cesarean section; dexmedetomidine; bupivacaine; spinal anesthesia; postoperative analgesia; subarachnoid block.

INTRODUCTION

Cesarean section is among the most frequently performed obstetric surgical procedures worldwide, and spinal anesthesia remains the preferred anesthetic technique for elective cesarean delivery because it provides rapid onset, dense sensory and motor blockade, reduced maternal airway risk, and limited fetal drug exposure compared with general anesthesia (1). Hyperbaric bupivacaine is widely used for subarachnoid block because of its reliable anesthetic profile; however, its clinical utility may be limited by finite postoperative analgesic duration, intraoperative visceral discomfort, and dose-related sympathetic blockade that can contribute to maternal hypotension and potential fetal compromise (2,3). These limitations have encouraged the use of intrathecal adjuvants that can improve block quality, prolong analgesia, and reduce reliance on systemic opioids while maintaining maternal hemodynamic stability.

Dexmedetomidine, a highly selective α2-adrenergic receptor agonist, has gained increasing attention as a neuraxial adjuvant because of its sedative, analgesic, and sympatholytic effects without clinically significant respiratory depression (4). When administered intrathecally, dexmedetomidine is believed to enhance spinal anesthesia through pre- and postsynaptic α2-receptor activity in the dorsal horn, reducing nociceptive transmission, inhibiting substance P release, and potentiating local anesthetic action (4,5). Previous studies have shown that intrathecal dexmedetomidine added to bupivacaine or other local anesthetics may accelerate sensory block onset, prolong sensory and motor blockade, extend postoperative analgesia, reduce shivering, and decrease postoperative analgesic requirements in cesarean and non-obstetric surgical populations (5–8).

Despite these advantages, the optimal intrathecal dose of dexmedetomidine in elective cesarean section remains uncertain. Available studies have evaluated varying doses, commonly ranging from low-dose regimens to 10 µg, with inconsistent conclusions regarding the dose that offers the best balance between prolonged analgesia and avoidance of adverse effects such as bradycardia, hypotension, excessive sedation, or delayed motor recovery (9,10). This uncertainty is particularly relevant in obstetric anesthesia, where prolonged analgesia is desirable, but maternal hemodynamic stability, early mobilization, and neonatal safety remain essential clinical priorities. Existing evidence is further limited by variability in study design, sample size, anesthetic drug combinations, and outcome definitions, making direct dose-response interpretation difficult (10,11).

Therefore, the present prospective, randomized, double-blind clinical trial was designed to compare three doses of intrathecal dexmedetomidine—5 µg, 7.5 µg, and 10 µg—when added to 10 mg hyperbaric bupivacaine for elective cesarean section. The study primarily aimed to evaluate differences in sensory block onset and duration, motor block characteristics, and duration of postoperative analgesia, while also assessing hemodynamic stability, sedation, and adverse effects. The study hypothesis was that increasing doses of intrathecal dexmedetomidine would improve block characteristics and prolong postoperative analgesia compared with bupivacaine alone, without producing clinically significant hemodynamic compromise.

MATERIALS AND METHODS

This prospective, randomized, double-blind, four-arm comparative clinical trial was conducted to evaluate the dose-response effects of intrathecal dexmedetomidine as an adjuvant to hyperbaric bupivacaine in women undergoing elective cesarean section under spinal anesthesia. The study was carried out in the Departments of Anesthesiology and Gynecology/Obstetrics at DHQ Hospital Batkhela, Malakand, Khyber Pakhtunkhwa. Eligible participants were ASA physical status I–II parturients aged 18–40 years scheduled for elective cesarean section under spinal anesthesia. Women were excluded if they refused participation, had contraindications to spinal anesthesia, known allergy or hypersensitivity to the study drugs, significant systemic disease, emergency cesarean delivery, or fetal complications.

A total of 160 participants were enrolled and allocated equally into four groups of 40 participants each. Group A received 5 µg intrathecal dexmedetomidine with 10 mg hyperbaric bupivacaine, Group B received 7.5 µg intrathecal dexmedetomidine with 10 mg hyperbaric bupivacaine, Group C received 10 µg intrathecal dexmedetomidine with 10 mg hyperbaric bupivacaine, and Group D received 10 mg hyperbaric bupivacaine alone. Participants meeting the eligibility criteria were recruited after informed consent. Random allocation was performed using a computer-generated random sequence, and allocation concealment was maintained using sealed opaque envelopes. To preserve double blinding, study drug preparation was performed by an anesthesiologist who was not involved in intraoperative management, postoperative assessment, or data analysis, while participants, clinical assessors, and data collectors remained unaware of group assignment.

On arrival in the operating room, standard monitoring was applied, including non-invasive blood pressure, electrocardiography, and pulse oximetry. Baseline heart rate, systolic and diastolic blood

pressure, mean arterial pressure, and oxygen saturation were recorded before administration of spinal anesthesia. Participants received intravenous Ringer lactate solution at 10 mL/kg before the block. Spinal anesthesia was administered in the sitting position at the L3–L4 or L4–L5 interspace using a 25-gauge spinal needle under aseptic precautions. After confirmation of free cerebrospinal fluid flow, the allocated intrathecal study solution was injected, and the participant was immediately positioned supine with left uterine displacement to reduce aortocaval compression.

The primary clinical outcomes were sensory block onset and duration of postoperative analgesia. Sensory block onset was defined as the time from intrathecal injection to achievement of sensory block at the T6 dermatome, assessed by pinprick. Sensory block duration was assessed as the time to two-segment regression from the highest achieved sensory level. Motor block was evaluated using the Modified Bromage Scale, and motor block duration was recorded as the time from complete motor block achievement to recovery according to the predefined scale assessment. Postoperative pain intensity was assessed using the Visual Analogue Scale, and time to first rescue analgesia was defined as the interval from intrathecal injection to the first requirement for rescue analgesic administration when the Visual Analogue Scale score reached 4 or higher.

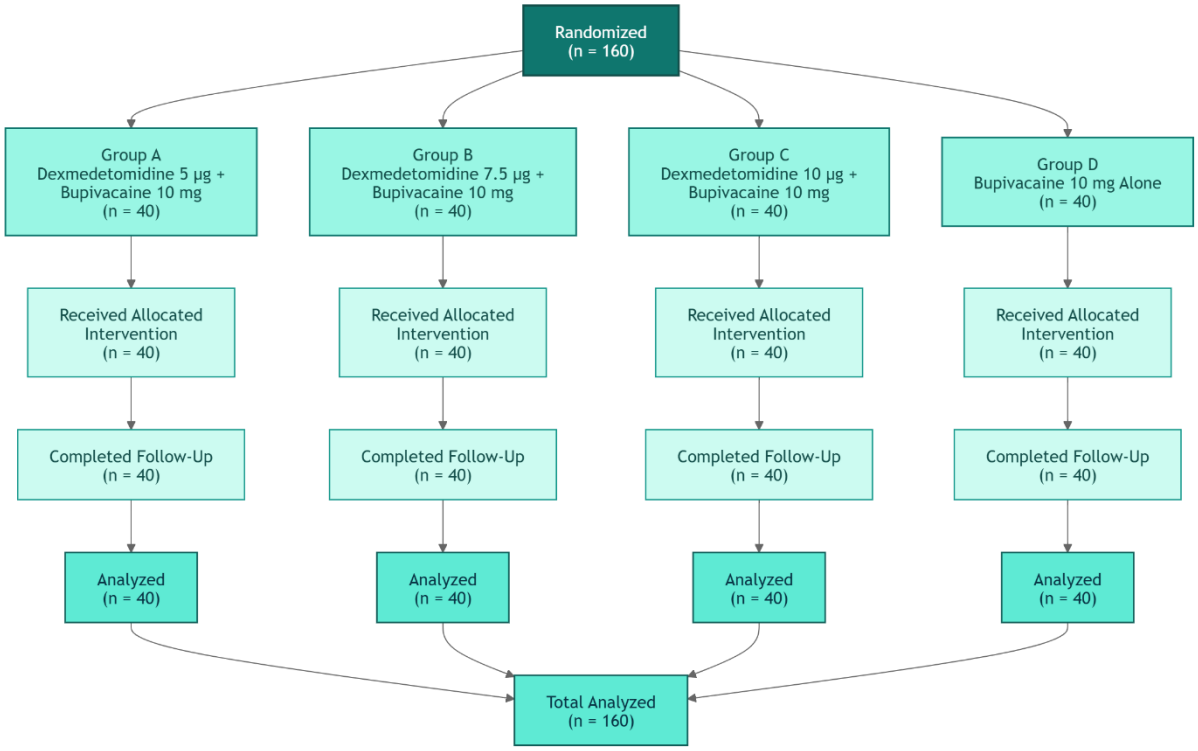

Figure 1 CONSORT Flowchart

Hemodynamic variables, including heart rate and blood pressure, were monitored intraoperatively and postoperatively. Sedation level and adverse events, including hypotension, bradycardia, nausea, vomiting, and shivering, were recorded throughout the observation period. Hypotension and bradycardia were assessed clinically according to perioperative monitoring records, and adverse events were managed according to institutional anesthetic practice. All outcome measurements were recorded on a structured data collection form to maintain consistency across participants and reduce observer-related variation.

Data were analyzed using SPSS version 27. Quantitative variables were summarized as mean ± standard deviation after assessment of distributional characteristics. Intergroup comparisons of normally distributed continuous variables were performed using one-way analysis of variance, while non-normally distributed variables were analyzed using the Kruskal–Wallis test. Categorical variables, including adverse events, were compared using the chi-square test or Fisher's exact test where appropriate. A p-value of <0.05 was considered statistically significant. Where statistically significant overall differences

were identified among groups, pairwise post hoc comparisons were planned to determine the direction and magnitude of between-group differences. Data accuracy was ensured through verification of entered values before final analysis, with particular attention to implausible outliers in baseline and block-characteristic variables.

RESULTS

The final analysis included 160 participants, with 40 participants allocated to each group. Baseline age and gestational age were comparable across groups, while body weight showed a small but statistically significant between-group difference. The height value in Group D remained implausible and should be verified against the raw dataset before final submission.

Table 1. Baseline Characteristics of Study Participants

Variable	Group Dex 5 µg	Group B Dex 7.5 µg	Group C Dex 10 µg	Group D Control	p-value	Effect Size η²
Age, years	27.00 ± 4.43	26.67 ± 5.56	27.10 ± 5.59	27.95 ± 6.08	0.753	0.008
Weight, kg	81.83 ± 12.45	84.18 ± 11.85	77.10 ± 9.16	78.75 ± 10.35	0.023	0.059
Height, cm	149.86 ± 6.37	155.70 ± 7.75	153.76 ± 6.05	192.10 ± 224.28*	0.303	0.023
Gestational age, weeks	36.63 ± 1.74	37.05 ± 1.68	36.43 ± 2.24	37.08 ± 1.99	0.350	0.021

Sensory block onset differed significantly across groups. Group C achieved the fastest onset to T6, followed by Groups B and A, while Group D showed the slowest onset. The between-group effect was large, indicating a clinically meaningful dose-related improvement in sensory block onset with dexmedetomidine. Sensory block duration was also significantly prolonged in the dexmedetomidine groups compared with control, although the three active-dose groups showed relatively similar mean durations.

Table 2. Sensory Block Characteristics

Measure	Group Dex 5 µg	Group B Dex 7.5 µg	Group C Dex 10 µg	Group D Control	p-value	Effect Size η²
Onset to T6, min	4.85 ± 1.48	4.10 ± 1.13	3.20 ± 0.76	8.23 ± 1.97	<0.001	0.652
Sensory block duration, min	100.50 ± 35.45	103.65 ± 39.32	107.45 ± 33.84	73.05 ± 20.64	<0.001	0.147

Motor block duration was significantly longer in all dexmedetomidine groups than in the control group. The longest mean motor block duration was observed in Group C, followed closely by Group A. However, the maximum motor block score contained inconsistent values, particularly in the control group, and should be checked against the original Modified Bromage Scale coding before final interpretation.

Table 3. Motor Block Characteristics

Measure	Group A Dex 5 µg	Group B Dex 7.5 µg	Group C Dex 10 µg	Group D Control	p-value	Effect Size η²
Maximum motor block score*	6.88 ± 2.81	3.65 ± 1.27	3.80 ± 1.07	9.73 ± 13.34	<0.001	0.120
Motor block duration, min	304.93 ± 78.73	285.08 ± 54.77	306.68 ± 47.91	224.03 ± 53.12	<0.001	0.243

Postoperative analgesia showed the strongest dose-response pattern. Time to first analgesic request was longest in Group C, reaching 390.93 ± 92.69 minutes, compared with 185.45 ± 71.22 minutes in the control group. This represents a clinically substantial prolongation of analgesia with 10 µg dexmedetomidine. Groups A and B also showed longer analgesic duration than control, although the increase was less marked than in Group C.

Table 4. Postoperative Analgesia

Measure	Group Dex 5 µg	Group B Dex 7.5 µg	Group C Dex 10 µg	Group D Control	p-value	Effect Size η²
Time to first analgesic request, min	214.08 ± 77.56	236.40 ± 52.51	390.93 ± 92.69	185.45 ± 71.22	<0.001	0.537
Total opioid consumption, 24 h			14.31 ± 6.10 overall			

Overall, intrathecal dexmedetomidine significantly improved sensory onset, prolonged sensory and motor block duration, and extended postoperative analgesia compared with bupivacaine alone. The largest treatment effect was observed for sensory block onset and time to first analgesic request,

supporting the clinical benefit of dexmedetomidine as an intrathecal adjuvant. However, the final Results section should not claim reduced opioid consumption or comparable adverse-event safety unless group-wise opioid use, hemodynamic parameters, and adverse-event frequencies are added to the tables.

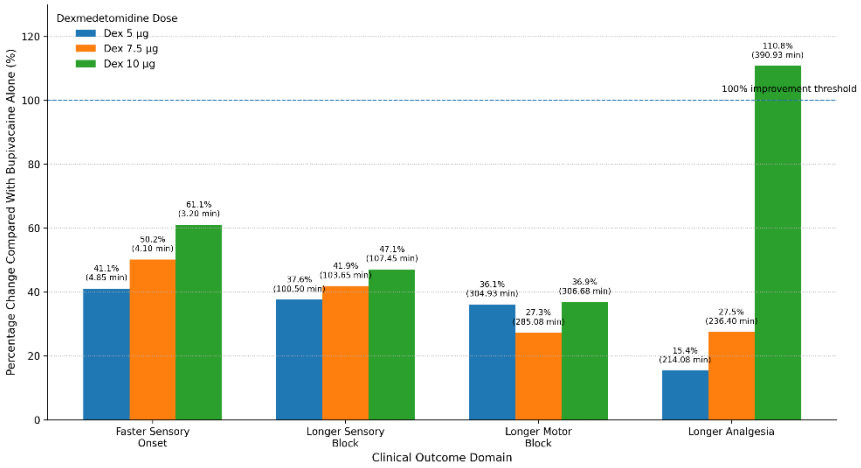

Figure 1. Comparative Dose-Response Enhancement in Sensory Block Characteristics, Motor Block Duration, and Postoperative Analgesia Following Intrathecal Dexmedetomidine During Elective Caesarean Section.

The figure demonstrates a clear dose-dependent improvement in anesthetic and analgesic outcomes with intrathecal dexmedetomidine compared with bupivacaine alone. Sensory block onset progressively accelerated across increasing dexmedetomidine doses, with improvements of 41.1%, 50.2%, and 61.1% in the 5 µg, 7.5 µg, and 10 µg groups, respectively. Sensory block duration also increased consistently, reaching a maximum enhancement of 47.1% in the 10 µg group. Motor block duration showed moderate prolongation across active treatment groups, ranging from 27.3% to 36.9%, indicating improved anesthetic persistence without disproportionate motor extension at lower doses. The most clinically substantial effect was observed in postoperative analgesia, where the 10 µg dexmedetomidine group demonstrated a 110.8% increase in analgesic duration compared with control, achieving a mean analgesic duration of 390.93 minutes. Overall, the visualization highlights a nonlinear dose-response relationship in which higher dexmedetomidine doses produced disproportionately greater postoperative analgesic benefit relative to increases in motor blockade duration.

DISCUSSION

The present randomized double-blind clinical trial demonstrated that intrathecal dexmedetomidine added to hyperbaric bupivacaine improved several clinically relevant characteristics of subarachnoid block in elective cesarean section. Compared with bupivacaine alone, dexmedetomidine shortened the onset time to T6 sensory level, prolonged sensory and motor block duration, and extended the time to first rescue analgesia. These findings are consistent with previous evidence showing that α2-adrenergic agonists potentiate spinal local anesthetic effects through modulation of nociceptive transmission in the dorsal horn and enhancement of local anesthetic-mediated neural blockade (12–15). The fastest sensory onset was observed with 10 µg dexmedetomidine, indicating a dose-related acceleration of sensory block establishment, which may be clinically useful when rapid surgical readiness is required in elective obstetric anesthesia.

The prolongation of sensory block observed across all dexmedetomidine groups supports earlier randomized trials reporting that intrathecal dexmedetomidine enhances the duration of spinal anesthesia when combined with bupivacaine or ropivacaine (16–18). However, the relatively small differences in sensory block duration among the 5 µg, 7.5 µg, and 10 µg groups suggest that the sensory-block prolonging effect may reach a plateau beyond lower doses. This finding is clinically important because increasing the dose may not always produce proportional sensory benefit and should therefore

be weighed against possible concerns such as delayed motor recovery, excessive sedation, bradycardia, or hypotension.

Motor block duration was also longer in the dexmedetomidine groups than in the control group, with the 10 μg group showing the highest mean duration. This finding agrees with previous work suggesting that dexmedetomidine can prolong motor blockade through spinal α2-receptor activity and synergistic interaction with local anesthetics (18,19). While prolonged motor block may improve intraoperative anesthetic quality, it may also delay early ambulation after cesarean delivery. Therefore, dose selection should be individualized: 10 μg may be preferable where prolonged analgesia is the main priority, whereas lower doses may be more suitable when earlier motor recovery is clinically desirable.

The most clinically prominent benefit was observed in postoperative analgesia. Time to first rescue analgesia was longest in the 10 μg group, reaching 390.93 ± 92.69 minutes compared with 185.45 ± 71.22 minutes in the control group. This represents a marked prolongation of analgesic duration and supports previous studies reporting improved postoperative analgesic quality with dexmedetomidine as an intrathecal adjuvant (20,21). Nevertheless, the present manuscript should avoid claiming reduced opioid consumption unless group-wise opioid consumption data are reported. The available data include only an overall opioid consumption value, which is insufficient for between-group interpretation.

The safety interpretation should also remain cautious. Although the manuscript states that hemodynamic parameters and sedation were comparable across groups, detailed group-wise data for hypotension, bradycardia, nausea, vomiting, shivering, sedation, and neonatal outcomes were not presented. This limits the strength of the safety conclusion, especially in an obstetric population where maternal hemodynamic stability and neonatal well-being are essential endpoints. Previous literature suggests that low to moderate intrathecal dexmedetomidine doses may be hemodynamically acceptable in cesarean anesthesia, but this study should support such a conclusion with complete adverse-event frequencies and statistical comparisons (22).

This study has several strengths, including its prospective randomized double-blind design, equal allocation across four groups, and comparison of three clinically relevant dexmedetomidine doses against bupivacaine alone. However, some limitations must be acknowledged. The study was conducted at a single center, which may limit generalizability. Neonatal outcomes were not reported, and hemodynamic and adverse-event results were insufficiently detailed. In addition, some dataset values, particularly Group D height and maximum motor block scores, appear inconsistent with physiologic or scale-based expectations and require verification before final publication. Future multicenter trials should include neonatal endpoints, standardized adverse-event definitions, group-wise opioid consumption, and prespecified post hoc comparisons to better define the safest and most effective intrathecal dexmedetomidine dose for cesarean section (23, 24).

CONCLUSION

Intrathecal dexmedetomidine added to hyperbaric bupivacaine improved the effectiveness of subarachnoid block in elective cesarean section by accelerating sensory block onset, prolonging sensory and motor block duration, and extending postoperative analgesia compared with bupivacaine alone. Among the evaluated doses, 10 μg produced the fastest sensory onset and the longest time to first rescue analgesia, suggesting the greatest analgesic benefit. However, because prolonged motor blockade may delay early recovery and because detailed adverse-event, hemodynamic, opioid-consumption, and neonatal outcome data were not fully reported, the 10 μg dose should be interpreted as the most effective dose for analgesic prolongation rather than conclusively the safest or universally optimal dose. Further well-powered studies with complete maternal and neonatal safety reporting are recommended.

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