RESEARCH PAPER

A Comparative Study of Intrathecal Dexmedetomidine and Fentanyl as Adjuvants to 0.5% Hyperbaric Bupivacaine in Spinal Anaesthesia for Infraumbilical surgeries

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ABSTRACT

Introduction: Intrathecal adjuvants are commonly used with hyperbaric bupivacaine to prolong spinal anaesthesia and improve postoperative analgesia. Dexmedetomidine, a selective α2-adrenergic agonist, has shown promising results as an alternative to opioids such as fentanyl in subarachnoid block. The present study aimed to compare the efficacy and safety of intrathecal dexmedetomidine and fentanyl as adjuvants to 0.5% hyperbaric bupivacaine in patients undergoing infraumbilical surgeries.

Materials and Methods: This prospective, randomized, double-blind controlled study was conducted in the Department of Anaesthesiology at Adichunchanagiri Institute of Medical Sciences, Adichunchanagiri University, between January 2025 and December 2025. Sixty ASA I and II patients aged 18–60 years undergoing elective infraumbilical surgeries under spinal anaesthesia were randomly allocated into two groups of 30 each. Group D received 12.5 mg of 0.5% hyperbaric bupivacaine with 2.5 µg dexmedetomidine, while Group F received 12.5 mg of 0.5% hyperbaric bupivacaine with 25 µg fentanyl. Sensory and motor block characteristics, postoperative analgesia, hemodynamic parameters, and adverse effects were assessed.

Results: Group D demonstrated significantly faster onset of sensory block at T10 (2.84 ± 0.68 min vs 3.62 ± 0.81 min; $p<0.001$) and prolonged duration of sensory block (521.8 ± 61.7 min vs 336.4 ± 48.2 min; $p<0.001$) compared to Group F. Time to first rescue analgesia was significantly longer in Group D (468.2 ± 58.4 min vs 284.6 ± 39.5 min; $p<0.001$), with lower NRS pain scores at 6 hours. Mean heart rate and MAP were lower in Group D during the intraoperative period but remained clinically manageable. Incidence of adverse effects was comparable between groups, with pruritus observed only in the fentanyl group.

Conclusion: Intrathecal dexmedetomidine as an adjuvant to hyperbaric bupivacaine provided superior sensory and motor blockade, prolonged postoperative analgesia, and reduced analgesic requirement compared to fentanyl with acceptable hemodynamic stability and minimal adverse effects.

Keywords: Dexmedetomidine; Fentanyl; Hyperbaric bupivacaine; Infraumbilical surgeries; Spinal anaesthesia

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INTRODUCTION

Spinal anaesthesia is one of the most commonly employed regional anaesthetic techniques for infraumbilical surgeries because of its rapid onset, reliable sensory and motor blockade, cost-effectiveness, and avoidance of airway manipulation [1]. Hyperbaric bupivacaine remains the most widely used local anaesthetic agent for subarachnoid block due to its favourable pharmacological profile and dense neural blockade [2]. However, the relatively limited duration of postoperative analgesia with bupivacaine alone often necessitates early administration of rescue analgesics, thereby increasing postoperative discomfort and analgesic consumption [3,4].

To improve the quality and duration of spinal anaesthesia, several intrathecal adjuvants have been investigated [5,6]. Opioids such as fentanyl are frequently added to local anaesthetics because of their synergistic analgesic effects mediated through opioid receptors in the dorsal horn of

the spinal cord [7]. Intrathecal fentanyl enhances intraoperative analgesia, improves patient comfort, and prolongs early postoperative pain relief without significantly increasing sympathetic blockade [8]. However, opioid-related adverse effects including pruritus, nausea, vomiting, urinary retention, and respiratory depression remain important concerns [9].

Dexmedetomidine, a highly selective α2-adrenergic receptor agonist, has emerged as a promising neuraxial adjuvant in recent years [10,11]. When administered intrathecally, dexmedetomidine produces analgesia by inhibiting the release of nociceptive neurotransmitters and by hyperpolarization of interneurons in the dorsal horn of the spinal cord [12]. Previous studies have demonstrated that dexmedetomidine prolongs both sensory and motor blockade, provides prolonged postoperative analgesia, and maintains better hemodynamic stability with minimal respiratory depression [13]. Owing to these properties, dexmedetomidine has gained increasing attention as a potential alternative to opioids in spinal anaesthesia [14].

Although several studies have compared dexmedetomidine and fentanyl as intrathecal adjuvants, limited data are available regarding their comparative efficacy and safety in patients undergoing infraumbilical surgeries in the Indian population. Hence, the present study aimed to compare the efficacy and safety of intrathecal dexmedetomidine and fentanyl as adjuvants to 0.5% hyperbaric bupivacaine in spinal anaesthesia for infraumbilical surgeries with respect to onset and duration of sensory and motor blockade, postoperative analgesia, hemodynamic parameters, and adverse effects.

MATERIALS AND METHODS

This prospective, randomized, double-blind controlled clinical trial was conducted in the Department of Anaesthesiology at Adichunchanagiri Institute of Medical Sciences, affiliated to Adichunchanagiri University, after obtaining approval from the Institutional Ethics Committee. The study was carried out between January 2025 and December 2025 and included 60 patients posted for elective infraumbilical surgeries under spinal anaesthesia. Adult patients aged between 18 and 60 years belonging to American Society of Anaesthesiologists (ASA) physical status I and II were enrolled after obtaining written informed consent. Patients with known allergy to study drugs, cardiovascular, hepatic, renal, neurological, or psychiatric illness, coagulation disorders, local infection at the puncture site, patients receiving anticoagulant therapy, pregnant women, and patients unable to comprehend pain scoring systems were excluded from the study.

All patients underwent detailed preanesthetic evaluation on the day prior to surgery. Patients were familiarized with the Numeric Rating Scale (NRS) for postoperative pain assessment. Standard fasting guidelines were followed, and all patients received oral ranitidine 150 mg and alprazolam 0.5 mg on the night before surgery. Eligible patients were randomly allocated into two groups of 30 patients each using computer-generated randomization. Allocation concealment was maintained using sequentially numbered opaque sealed envelopes. The study drug was prepared by an anaesthesiologist not involved in patient monitoring or data collection to maintain double blinding. Group D received 12.5 mg of 0.5% hyperbaric bupivacaine with 2.5 µg dexmedetomidine diluted with normal saline to a total volume of 3 mL, whereas Group F received 12.5 mg of 0.5% hyperbaric bupivacaine with 25 µg fentanyl adjusted to a total volume of 3 mL.

On arrival in the operating room, baseline heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, respiratory rate, and oxygen saturation were recorded. Intravenous access was secured with an 18G cannula, and all patients were preloaded with lactated Ringer's solution 10–15 mL/kg prior to administration of spinal anaesthesia. Under strict aseptic precautions, spinal anaesthesia was performed in the sitting position at the L3–L4 intervertebral space using a 25G Quincke spinal needle via midline approach. Following confirmation of free flow of cerebrospinal fluid, the study drug solution was injected intrathecally over 10–15 seconds. Patients were then immediately placed in the supine position and administered supplemental oxygen via face mask at 4–5 L/min throughout the procedure.

Sensory blockade was assessed using pinprick sensation with a 23G hypodermic needle along the midclavicular line bilaterally, while motor blockade was evaluated using the modified Bromage scale. Time to onset of sensory block at T10 dermatome, time to achieve Bromage grade 3 motor block, peak sensory level attained, time for two-segment regression, duration of sensory block until regression to S1 dermatome, duration of motor block until return to Bromage grade 0, and time to first rescue analgesia were recorded. Hemodynamic parameters including heart rate and mean arterial pressure were monitored at baseline, every 2–5 minutes intraoperatively, and at regular postoperative intervals. Hypotension was defined as a fall in systolic blood pressure greater than 20% from baseline or systolic blood pressure below 90 mmHg and was treated with intravenous fluids and mephentermine. Bradycardia was defined as heart rate below 50 beats/min and treated with intravenous atropine.

Postoperative pain assessment was performed using Numeric Rating Scale scores at regular intervals for 24 hours. Rescue analgesia in the form of intravenous paracetamol 1gm was administered when NRS score was ≥4, and the total analgesic requirement during the first 24 hours was documented. Adverse effects including

hypotension, bradycardia, nausea, vomiting, pruritus, shivering, sedation, and respiratory depression were recorded and managed appropriately. All collected data were entered systematically and analyzed statistically with SPSS v 26 using appropriate tests, with $p<0.05$ considered statistically significant.

RESULTS

The baseline demographic and clinical characteristics were comparable between Group D and Group F. The mean age was 41.8 ± 10.6 years in Group D and 42.4 ± 11.2 years in Group F. Male predominance was observed in both groups (60% vs 56.7%). Mean duration of surgery was also similar between the groups (94.6 ± 18.4 min vs 92.8 ± 17.6 min; p=0.69), indicating adequate comparability of study participants. (Table 1)

TABLE 1. Baseline Demographic and Clinical Characteristics

Variable	Group D (n=30)	Group F (n=30)	p-value
Age (years)	41.8 ± 10.6	42.4 ± 11.2	0.82
Male/Female	18/12	17/13	0.79
Weight (kg)	66.9 ± 8.5	68.1 ± 9.1	0.58
Height (cm)	164.5 ± 7.8	165.8 ± 6.9	0.49
BMI (kg/m²)	24.7 ± 2.8	24.9 ± 3.1	0.77
ASA I/II	19/11	18/12	0.79
Duration of surgery (min)	94.6 ± 18.4	92.8 ± 17.6	0.69

Patients in Group D demonstrated significantly faster onset and prolonged duration of spinal block characteristics compared to Group F. The time to achieve sensory block at T10 was significantly shorter in Group D (2.84 ± 0.68 min) compared to Group F (3.62 ± 0.81 min; $p<0.001$). Similarly, duration of sensory block was markedly prolonged in Group D (521.8 ± 61.7 min vs 336.4 ± 48.2 min; $p<0.001$). Time to first rescue analgesia was significantly longer in Group D (468.2 ± 58.4 min) than Group F (284.6 ± 39.5 min), with lower postoperative NRS pain scores at 6 hours (2.1 ± 0.9 vs 4.9 ± 1.2; $p<0.001$). (Table 2)

TABLE 2. Characteristics of Sensory and Motor Block

Parameter	Group D (n=30)	Group F (n=30)	p-value
Time to sensory block at T10 (min)	2.84 ± 0.68	3.62 ± 0.81	<0.001
Time to Bromage 3 motor block (min)	4.92 ± 1.12	5.74 ± 1.26	0.01
Time to peak sensory level (min)	6.34 ± 1.08	7.21 ± 1.14	0.003
Time for two-segment regression (min)	141.6 ± 18.4	92.8 ± 14.6	<0.001
Duration of motor block / Regression to Bromage 0 (min)	318.4 ± 42.5	198.6 ± 31.2	<0.001
Duration of sensory block / Regression to S1 (min)	521.8 ± 61.7	336.4 ± 48.2	<0.001
Time to first rescue analgesia (min)	468.2 ± 58.4	284.6 ± 39.5	<0.001
NRS score at 6 hours	2.1 ± 0.9	4.9 ± 1.2	<0.001

The majority of patients in both groups achieved a maximum sensory block level between T5 and T6 dermatomes. In Group D, 43.3% of patients attained T6 level and 30% attained T5 level, whereas in Group F, T6 was achieved in 53.3% and T5 in 23.3% of patients. A higher sensory level of T4 was observed more frequently in Group D (10%) compared to Group F (3.3%). (Table 3)

TABLE 3. Maximum Sensory Block Level Achieved

Highest Sensory Level	Group D (n=30)	Group F (n=30)
T4	3 (10%)	1 (3.3%)
T5	9 (30%)	7 (23.3%)
T6	13 (43.3%)	16 (53.3%)
T7	4 (13.3%)	5 (16.7%)
T8	1 (3.3%)	1 (3.3%)

Heart rate decreased progressively following spinal anesthesia in both groups during the intraoperative period. Group D showed lower mean heart rate values from 10 minutes onward, with statistically significant differences observed up to the 4th postoperative hour. At 30 minutes, the mean heart rate was 70.8 ± 5.5 beats/min in Group D compared to 75.4 ± 5.8 beats/min in Group F (p=0.003). By 24 hours, heart rate values in both groups approached baseline with no statistically significant difference (80.1 ± 6.5 vs 80.8 ± 6.4 beats/min; p=0.67). (Table 4)

TABLE 4. Heart Rate Changes During Perioperative and Postoperative Period

Time Interval	Group D (n=30)	Group F (n=30)	p-value
Baseline	84.2 ± 7.4	85.6 ± 6.9	0.44
2 min	82.8 ± 7.1	84.9 ± 6.8	0.23
4 min	80.6 ± 6.8	83.7 ± 6.5	0.06
5 min	78.6 ± 6.5	81.9 ± 7.1	0.05
10 min	74.2 ± 6.1	79.5 ± 6.8	0.002
15 min	72.4 ± 5.9	77.8 ± 6.2	0.001
20 min	71.8 ± 5.7	76.9 ± 6.0	0.001
25 min	71.2 ± 5.5	76.1 ± 5.8	0.001
30 min	70.8 ± 5.5	75.4 ± 5.8	0.003
45 min	70.2 ± 5.3	74.8 ± 5.6	0.002
60 min	69.6 ± 5.2	74.2 ± 5.4	0.002
90 min	69.2 ± 5.1	73.8 ± 5.2	0.001
120 min	68.8 ± 4.9	73.1 ± 5.0	0.001
150 min	69.4 ± 5.0	73.5 ± 5.1	0.002
180 min	70.1 ± 5.2	74.2 ± 5.3	0.003
4th hour	72.6 ± 5.5	75.9 ± 5.7	0.02
5th hour	74.8 ± 5.8	77.4 ± 5.9	0.08
6th hour	76.2 ± 6.1	78.1 ± 6.0	0.21
12th hour	78.4 ± 6.2	79.2 ± 6.1	0.61
24th hour	80.1 ± 6.5	80.8 ± 6.4	0.67

Mean arterial pressure declined after administration of spinal anesthesia in both groups, with a more pronounced reduction observed in Group D during the early intraoperative period. At 15 minutes, MAP was significantly lower in Group D (82.9 ± 4.9 mmHg) compared to Group F (88.1 ± 5.1 mmHg; p<0.001). Significant intergroup differences persisted up to 120 minutes postoperatively, following which MAP gradually stabilized in both groups and returned near baseline by 24 hours (93.8 ± 6.1 mmHg vs 94.2 ± 6.0 mmHg; p=0.80). (Table 5)

TABLE 5. Mean Arterial Pressure (MAP) Changes During Perioperative and Postoperative Period

Time Interval	Group D (n=30)	Group F (n=30)	p-value
Baseline	94.5 ± 6.2	95.1 ± 5.9	0.68
2 min	92.4 ± 6.0	94.2 ± 5.8	0.24
4 min	90.1 ± 5.9	92.8 ± 5.7	0.07
5 min	88.2 ± 5.8	90.6 ± 6.1	0.11
10 min	84.8 ± 5.2	89.9 ± 5.6	<0.001
15 min	82.9 ± 4.9	88.1 ± 5.1	<0.001
20 min	82.1 ± 4.8	87.2 ± 5.0	<0.001
25 min	81.8 ± 4.7	86.9 ± 4.9	<0.001
30 min	81.6 ± 4.6	86.4 ± 4.8	<0.001
45 min	81.9 ± 4.7	85.9 ± 4.8	0.001
60 min	82.4 ± 4.8	85.8 ± 4.9	0.006
90 min	83.2 ± 4.9	86.1 ± 5.0	0.02
120 min	84.1 ± 5.1	86.8 ± 5.2	0.04
150 min	84.8 ± 5.2	87.2 ± 5.3	0.06
180 min	85.4 ± 5.4	87.8 ± 5.5	0.08
4th hour	87.6 ± 5.5	88.9 ± 5.6	0.34
5th hour	89.1 ± 5.7	90.2 ± 5.8	0.45
6th hour	90.6 ± 5.8	91.4 ± 5.9	0.59
12th hour	92.2 ± 6.0	92.8 ± 5.9	0.69
24th hour	93.8 ± 6.1	94.2 ± 6.0	0.80

Adverse effects were minimal and comparable between the study groups. Hypotension occurred in 6.7% of patients in Group D and 10% in Group F, while bradycardia was observed in 10% and 3.3% of patients, respectively. Pruritus was reported only in Group F (10%). No cases of respiratory depression were observed in either group. However, none of these differences reached statistical significance. (Table 6)

TABLE 6. Adverse Effects and Complications

Side Effect	Group D (n=30)	Group F (n=30)	p-value
Hypotension	2 (6.7%)	3 (10%)	0.64
Bradycardia	3 (10%)	1 (3.3%)	0.30

Nausea	1 (3.3%)	2 (6.7%)	0.55
Vomiting	0	1 (3.3%)	0.31
Pruritus	0	3 (10%)	0.07
Respiratory depression	0	0	—
Shivering	1 (3.3%)	2 (6.7%)	0.55

Postoperative analgesic requirement was significantly lower in Group D compared to Group F. Only 13.3% of patients in Group D required rescue analgesia within the first 6 postoperative hours compared to 60% in Group F ($p<0.001$). Additionally, total paracetamol consumption over 24 hours was significantly lower in Group D (82.5 ± 21.4 mg) than Group F (146.8 ± 28.7 mg), indicating prolonged postoperative analgesia with dexmedetomidine. (Table 7)

TABLE 7. Postoperative Rescue Analgesic Requirement

Variable	Group D	Group F	p-value
Patients requiring rescue analgesia within 6 h	4 (13.3%)	18 (60%)	<0.001
Total paracetamol consumption in 24 h (mg)	82.5 ± 21.4	146.8 ± 28.7	<0.001

DISCUSSION

The present study demonstrated that intrathecal dexmedetomidine as an adjuvant to 0.5% hyperbaric bupivacaine produced earlier onset and significantly prolonged duration of sensory and motor blockade compared to intrathecal fentanyl. The onset of sensory block at T10 and attainment of Bromage grade 3 were faster in Group D, while duration of sensory block, motor block, and time to rescue analgesia were significantly prolonged. Similar findings were reported by Rajni Gupta and colleagues, who observed prolonged sensory regression time and motor blockade with dexmedetomidine compared to fentanyl [15]. Likewise, Poupak Rahimzadeh et al. demonstrated significantly prolonged postoperative analgesia and delayed regression of sensory and motor block in the dexmedetomidine group, which closely correlates with the findings of the present study [16]. The probable mechanism may be attributed to the action of dexmedetomidine on presynaptic C-fibers and postsynaptic dorsal horn neurons, resulting in inhibition of nociceptive neurotransmitter release and prolongation of spinal analgesia.

In the present study, postoperative analgesia was superior in the dexmedetomidine group, as evidenced by significantly prolonged time to first rescue analgesia, lower postoperative NRS scores, and reduced total paracetamol consumption over 24 hours. These findings are in accordance with studies by Vandana Mahendru et al. and Brijesh Gautam et al., who also reported enhanced postoperative analgesia and reduced analgesic requirements with dexmedetomidine compared to fentanyl [17,18]. Similar observations were further supported by a systematic review and meta-analysis demonstrating that intrathecal dexmedetomidine significantly prolongs analgesia duration without increasing major adverse effects [19,20]. The improved postoperative analgesic profile with dexmedetomidine may contribute to greater patient comfort and reduced need for supplemental analgesics in the postoperative period.

Hemodynamic changes observed in the present study revealed lower heart rate and mean arterial pressure values in the dexmedetomidine group during the early intraoperative period, although these changes remained clinically manageable. Bradycardia and hypotension were slightly more frequent in Group D, whereas pruritus was observed only in the fentanyl group. These findings are comparable with those reported by Gupta et al. and Rahimzadeh et al., who found better hemodynamic stability with dexmedetomidine despite occasional bradycardia and hypotension [15,16]. Similarly, Kalbande et al. observed that dexmedetomidine provided prolonged blockade with acceptable hemodynamic variations and minimal complications [20]. The absence of respiratory depression in both groups in the present study is consistent with previous literature, emphasizing the safety profile of intrathecal dexmedetomidine when used in low doses.

The present study supports the growing evidence favouring dexmedetomidine as an effective intrathecal adjuvant to hyperbaric bupivacaine for infraumbilical surgeries. Compared to fentanyl, dexmedetomidine provided prolonged sensory and motor blockade, superior postoperative analgesia, and reduced analgesic consumption with minimal and manageable adverse effects. These findings are consistent with multiple previous randomized controlled trials and meta-analyses, thereby reinforcing the utility of dexmedetomidine as a

reliable alternative to intrathecal opioids in spinal anaesthesia [17,20].

CONCLUSION

Intrathecal dexmedetomidine as an adjuvant to 0.5% hyperbaric bupivacaine provided faster onset and significantly prolonged duration of sensory and motor blockade, superior postoperative analgesia, delayed requirement of rescue analgesia, and reduced postoperative analgesic consumption compared to intrathecal fentanyl in patients undergoing infraumbilical surgeries. Although mild hemodynamic variations such as bradycardia and hypotension were observed, they were clinically manageable, and the overall incidence of adverse effects was comparable between the groups. Thus, dexmedetomidine appears to be an effective and safe alternative to fentanyl as an intrathecal adjuvant for spinal anaesthesia.

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