Section: Anesthesiology

Original Research Article

A COMPARATIVE STUDY OF HYPERBARIC ROPIVACAINE, ROPIVACAINE WITH DEXMEDETOMIDINE, AND ROPIVACAINE WITH FENTANYL IN SPINAL ANAESTHESIA FOR ADULT PATIENTS UNDERGOING INFRAUMBILICAL SURGERIES-A STUDY OF 90 CASES

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Received *: 10/02/2026*
Received in revised form *: 04/04/2026*
Accepted *: 22/04/2026*

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DOI: 10.70034/ijmedph.2026.2.222

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (2); 1313-1317

ABSTRACT

Background: Spinal anaesthesia using ropivacaine is widely employed for infraumbilical surgeries, and the use of intrathecal adjuvants like dexmedetomidine and fentanyl may improve block characteristics and postoperative analgesia. The aim is to compare the intraoperative and postoperative effects of intrathecal hyperbaric ropivacaine alone and in combination with dexmedetomidine and fentanyl.

Materials and Methods: A prospective randomized study was conducted on 90 patients divided into three groups of 30 each. Group RR received ropivacaine alone, Group RF received ropivacaine with fentanyl, and Group RD received ropivacaine with dexmedetomidine. Parameters assessed included onset and duration of sensory and motor block, duration of analgesia, hemodynamic changes, and adverse effects.

Results: The RD group showed the fastest onset of sensory (2.50 ± 0.85 min) and motor block (4.60 ± 0.86 min), longest duration of sensory block (294.00 ± 40.22 min), motor block (275.67 ± 42.97 min), and analgesia (313.00 ± 42.28 min) compared to RF and RR groups ($p < 0.001$). Hemodynamic parameters remained stable and adverse effects were minimal across all groups.

Conclusion: Dexmedetomidine is a superior intrathecal adjuvant to fentanyl when combined with hyperbaric ropivacaine, providing faster onset, prolonged block duration, and extended postoperative analgesia with stable hemodynamics.

Keywords: Ropivacaine, Dexmedetomidine, Fentanyl, Spinal Anaesthesia.

INTRODUCTION

Spinal anaesthesia is one of the most widely used regional anaesthetic techniques for infraumbilical surgeries due to its simplicity, rapid onset, and reliable sensory and motor blockade. It provides excellent intraoperative anaesthesia along with effective postoperative analgesia, thereby reducing the requirement for systemic analgesics and minimizing complications associated with general anaesthesia such as airway manipulation and postoperative nausea and vomiting.[1] Over the years, advancements in spinal anaesthesia have focused on optimizing drug selection and improving block characteristics while maintaining hemodynamic stability and patient safety.[2]

Among local anaesthetic agents, ropivacaine has gained significant attention due to its favorable

pharmacological profile. It is a long-acting amide local anaesthetic and a pure S(-) enantiomer, which exhibits less cardiotoxicity and neurotoxicity compared to bupivacaine.[3] Ropivacaine provides differential blockade with a greater degree of sensory block relative to motor block, making it particularly suitable for ambulatory and short-duration surgical procedures.[4] However, compared to bupivacaine, ropivacaine has a relatively shorter duration of action, which may limit its utility in prolonged surgeries unless supplemented with adjuvants.[5]

The concept of baricity plays a crucial role in determining the spread and effectiveness of intrathecal anaesthesia. Hyperbaric solutions, achieved by adding dextrose, enhance the predictability of drug distribution in cerebrospinal fluid, resulting in a more consistent and reliable block.[6] Hyperbaric ropivacaine has thus emerged as a promising alternative, offering better control over block height and duration while maintaining hemodynamic stability.[7]

To further enhance the quality and duration of spinal anaesthesia, various intrathecal adjuvants have been explored. Opioids such as fentanyl are commonly used due to their rapid onset and potent analgesic properties. Fentanyl, a highly lipophilic μ-opioid receptor agonist, provides synergistic analgesia when combined with local anaesthetics, prolonging sensory blockade without significantly affecting motor function.[8] However, opioid-related side effects such as pruritus, nausea, vomiting, and respiratory depression remain a concern.

Dexmedetomidine, a highly selective α2-adrenergic receptor agonist, has emerged as an effective alternative adjuvant in spinal anaesthesia. It exerts its analgesic effects by inhibiting the release of nociceptive neurotransmitters and producing hyperpolarization of spinal neurons.[9] Intrathecal dexmedetomidine has been shown to prolong both sensory and motor blockade, enhance postoperative analgesia, and provide sedation without significant respiratory depression. Additionally, it is associated with a lower incidence of opioid-related adverse effects, making it an attractive option in modern anaesthetic practice.

Recent studies have demonstrated that the addition of dexmedetomidine to intrathecal local anaesthetics significantly prolongs the duration of analgesia and improves block characteristics compared to fentanyl.[10] However, variations in onset time, duration of sensory and motor block, and hemodynamic effects between these adjuvants necessitate further comparative evaluation.

Therefore, a comparative assessment of hyperbaric ropivacaine alone and in combination with dexmedetomidine and fentanyl is essential to determine the optimal intrathecal regimen for infraumbilical surgeries. Such studies contribute to refining anaesthetic techniques, improving patient outcomes, and enhancing perioperative care by balancing efficacy, safety, and recovery profiles.

MATERIALS AND METHODS

This prospective, randomized, comparative study was conducted in the Department of Anaesthesiology at a tertiary care teaching hospital after obtaining approval from the Institutional Ethics Committee and written informed consent from all participants. The study included a total of 90 adult patients scheduled to undergo elective infraumbilical surgeries under spinal anaesthesia.

Patients of either sex, aged between 18 and 60 years, belonging to American Society of Anesthesiologists (ASA) physical status I and II were included in the study. Patients with contraindications to spinal anaesthesia such as coagulopathy, infection at the injection site, known hypersensitivity to study drugs, severe cardiac or respiratory disease, neurological disorders, or refusal to participate were excluded from the study.

The selected patients were randomly allocated into three equal groups of 30 each using a computer-generated randomization method. Group R received intrathecal hyperbaric ropivacaine 0.75% (3.5 ml) alone. Group RF received intrathecal hyperbaric ropivacaine 0.75% (3.5 ml) combined with fentanyl 25 μg. Group RD received intrathecal hyperbaric ropivacaine 0.75% (3.5 ml) combined with dexmedetomidine 5 μg.

All patients were evaluated preoperatively with detailed history, physical examination, and routine investigations. Patients were kept nil per oral as per standard guidelines and premedicated as per institutional protocol. On arrival in the operating room, baseline parameters including heart rate, non-invasive blood pressure, oxygen saturation, and respiratory rate were recorded. Intravenous access was secured, and all patients were preloaded with appropriate crystalloid solution prior to administration of spinal anaesthesia.

Under strict aseptic precautions, spinal anaesthesia was administered in the sitting position at the L3–L4 or L4–L5 interspace using a standard midline approach with an appropriate spinal needle. After confirmation of free flow of cerebrospinal fluid, the study drug was injected intrathecally according to the group allocation. Patients were then immediately positioned supine.

Sensory blockade was assessed using pinprick method and the onset time was defined as the time taken to achieve the desired sensory level. The duration of sensory block was assessed by the time taken for regression to L1 dermatome. Motor blockade was evaluated using the Modified Bromage Scale, and onset and duration were recorded accordingly. The time taken for complete motor recovery, defined as return to Bromage grade 0, was also noted.

The total duration of analgesia was defined as the time from intrathecal injection to the first request for rescue analgesia. Hemodynamic parameters including heart rate and blood pressure were

monitored at regular intervals throughout the intraoperative period. Any occurrence of hypotension, bradycardia, or other adverse events was recorded and managed appropriately.

Postoperative monitoring included assessment of analgesia, motor recovery, and any side effects such as nausea, vomiting, pruritus, shivering, urinary retention, or respiratory depression. Rescue analgesia was administered when required.

All collected data were compiled and analyzed using appropriate statistical methods. Quantitative data were expressed as mean and standard deviation, while qualitative data were presented as proportions and percentages. Statistical significance was determined using suitable tests such as analysis of variance (ANOVA) and Chi-square test, with a p-value of less than 0.05 considered statistically significant.

RESULTS

Table 1: Onset of Sensory and Motor Blockade (n = 90)

Group	Sample Size (n)	Sensory Onset (min)	Motor Onset (min)	p value
RR	30	4.20 ± 1.50	7.80 ± 1.42	<0.001
RF	30	3.20 ± 1.10	5.90 ± 1.20	<0.001
RD	30	2.50 ± 0.85	4.60 ± 0.86	<0.001

Table 2: Duration of Sensory Block (Regression to L1) (n = 90)

Group	Sample Size (n)	Duration (min)	p value
RR	30	190.00 ± 22.50	<0.001
RF	30	245.00 ± 30.10	<0.001
RD	30	294.00 ± 40.22	<0.001

Table 3: Duration of Motor Block (Time to Bromage 0) (n = 90)

Group	Sample Size (n)	Duration (min)	p value
RR	30	150.00 ± 14.38	<0.001
RF	30	222.00 ± 27.84	<0.001
RD	30	275.67 ± 42.97	<0.001

Table 4: Duration of Analgesia (n = 90)

Group	Sample Size (n)	Duration (min)	p value
RR	30	180.33 ± 17.12	<0.001
RF	30	246.33 ± 27.73	<0.001
RD	30	313.00 ± 42.28	<0.001

Table 5: Hemodynamic Parameters and Adverse Effects (n = 90)

Parameter	RR (n=30)	RF (n=30)	RD (n=30)	p value
Pulse Rate Trend	Comparable	Comparable	Comparable	0.259
SBP	Comparable	Comparable	Comparable	0.843
DBP	Comparable	Comparable	Comparable	0.172
Adverse Events (Yes)	8	5	4	0.090
Adverse Events (No)	22	25	26	0.090

Table 6: Comparison of Sensory Regression to L1 and Motor Recovery (n = 90)

Group	Sensory Regression to L1 (min)	Time to Bromage 0 (min)	p value
RR	190.00 ± 22.50	150.00 ± 14.38	<0.001
RF	245.00 ± 30.10	222.00 ± 27.84	<0.001
RD	294.00 ± 40.22	275.67 ± 42.97	<0.001

Table 7: Comparison of Hemodynamic Parameters (n = 90)

Parameter	RR (n=30)	RF (n=30)	RD (n=30)	p value
Pulse Rate Trend	Comparable	Comparable	Comparable	0.259
SBP	Comparable	Comparable	Comparable	0.843
DBP	Comparable	Comparable	Comparable	0.172

Table 8: Comparison of Adverse Effects (n = 90)

Outcome	RR (n=30)	RF (n=30)	RD (n=30)	p value
Adverse Events (Yes)	8	5	4	0.090
Adverse Events (No)	22	25	26	0.090

The onset of sensory blockade was fastest in Group RD with a mean value of 2.50 ± 0.85 minutes, followed by Group RF at 3.20 ± 1.10 minutes, while Group RR had the slowest onset at 4.20 ± 1.50 minutes. Similarly, motor blockade onset was earliest in Group RD at 4.60 ± 0.86 minutes, followed by Group RF at 5.90 ± 1.20 minutes and Group RR at 7.80 ± 1.42 minutes. The difference among all three

groups was highly significant ($p < 0.001$), clearly demonstrating that dexmedetomidine as an adjuvant provides a faster onset of both sensory and motor blockade compared to fentanyl and ropivacaine alone.

The duration of sensory block assessed by regression to L1 dermatome was significantly prolonged in Group RD with a mean duration of 294.00 ± 40.22 minutes, followed by Group RF at 245.00 ± 30.10 minutes, and shortest in Group RR at 190.00 ± 22.50 minutes. The difference was statistically highly significant ($p < 0.001$), indicating that dexmedetomidine markedly prolongs sensory blockade duration compared to fentanyl and plain ropivacaine.

The duration of motor blockade, measured as time to achieve Bromage grade 0, was longest in Group RD at 275.67 ± 42.97 minutes, followed by Group RF at 222.00 ± 27.84 minutes, and shortest in Group RR at 150.00 ± 14.38 minutes. The difference was statistically significant ($p < 0.001$), showing that dexmedetomidine prolongs motor recovery time more than fentanyl and ropivacaine alone.

The total duration of analgesia was maximum in Group RD with a mean duration of 313.00 ± 42.28 minutes, followed by Group RF at 246.33 ± 27.73 minutes, while Group RR had the shortest duration at 180.33 ± 17.12 minutes. This difference was statistically highly significant ($p < 0.001$), confirming superior postoperative analgesia with dexmedetomidine as an adjuvant.

The hemodynamic parameters including pulse rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP) remained comparable across all three groups. The variation in pulse rate over time was not statistically significant ($p = 0.259$), and there was no significant difference in SBP ($p = 0.843$) or DBP ($p = 0.172$) among the groups. A total of 17 out of 90 patients experienced adverse events, whereas 73 patients did not show any adverse effects, with slightly higher incidence in Group RR compared to Groups RF and RD. The difference in adverse events was statistically insignificant ($p = 0.090$), indicating that all three regimens maintained overall hemodynamic stability and safety profile.

The comparison of sensory regression to L1 dermatome and motor recovery, as shown in Table 6, further reinforces the prolonged action of dexmedetomidine as an intrathecal adjuvant. The mean time for sensory regression to L1 was maximum in Group RD with 294.00 ± 40.22 minutes, followed by Group RF with 245.00 ± 30.10 minutes, while Group RR showed the shortest duration at 190.00 ± 22.50 minutes. Similarly, the time required to achieve complete motor recovery (Bromage grade 0) was longest in Group RD at 275.67 ± 42.97 minutes, followed by Group RF at 222.00 ± 27.84 minutes and shortest in Group RR at 150.00 ± 14.38 minutes. The differences in both sensory regression and motor recovery among the groups were statistically highly significant ($p < 0.001$), clearly indicating that dexmedetomidine significantly prolongs both sensory and motor blockade compared to fentanyl and ropivacaine alone.

The intraoperative hemodynamic parameters, including pulse rate, systolic blood pressure (SBP), and diastolic blood pressure (DBP), remained stable across all three groups, as shown in Table 7. The trend of pulse rate over time showed no statistically significant difference among the groups ($p = 0.259$). Similarly, SBP values were comparable across RR, RF, and RD groups with no significant difference ($p = 0.843$), and DBP values also remained stable with no significant variation over time or between groups ($p = 0.172$). These findings indicate that the addition of dexmedetomidine and fentanyl to ropivacaine does not adversely affect hemodynamic stability.

The incidence of adverse effects was low and comparable among all groups, as depicted in Table 8. Out of 90 patients, 17 experienced at least one adverse event, while 73 patients had no adverse effects. Group RR had the highest number of adverse events (8 cases), followed by Group RF (5 cases) and Group RD (4 cases). However, this difference was statistically insignificant ($p = 0.090$), indicating that all three regimens are relatively safe with minimal side effects.

DISCUSSION

The present comparative study evaluated the efficacy of hyperbaric ropivacaine alone and in combination with dexmedetomidine and fentanyl in spinal anaesthesia for infraumbilical surgeries, and the findings clearly demonstrate that the addition of dexmedetomidine significantly enhances block characteristics and postoperative analgesia. The onset of sensory and motor blockade was fastest in the ropivacaine with dexmedetomidine group, followed by the fentanyl group and then ropivacaine alone, which correlates with the observations of Sun et al,[11] who reported that dexmedetomidine as an intrathecal adjuvant significantly hastens the onset of spinal anaesthesia due to its synergistic action at the dorsal horn of the spinal cord. Similarly, Ravipati et al,[12] observed earlier onset of both sensory and motor blockade with dexmedetomidine compared to fentanyl when used with ropivacaine, supporting the present findings. This faster onset can be explained by the action of dexmedetomidine on presynaptic C-fibers and postsynaptic neurons, enhancing the effect of local anaesthetics and facilitating rapid conduction blockade.

The duration of sensory blockade, as reflected by regression to L1 dermatome, was significantly prolonged in the dexmedetomidine group compared to fentanyl and ropivacaine alone, which is in agreement with Bi et al,[13] who demonstrated that intrathecal dexmedetomidine prolongs sensory block duration without increasing adverse effects. Similarly, Kumar et al,[14] reported that dexmedetomidine significantly prolongs both sensory and motor blockade compared to fentanyl,

owing to its inhibitory effect on nociceptive transmission and hyperpolarization of interneurons in the spinal cord. The present study also showed prolonged motor blockade in the dexmedetomidine group, with delayed recovery to Bromage grade 0, which aligns with these findings. Although prolonged motor block may delay early ambulation, it provides superior intraoperative conditions and prolonged postoperative comfort.

The total duration of analgesia was maximum in the dexmedetomidine group, followed by fentanyl and ropivacaine alone, indicating a clear advantage of dexmedetomidine as an adjuvant. This observation is strongly supported by Mishra et al,[15] who reported significantly prolonged postoperative analgesia with dexmedetomidine compared to fentanyl when used with ropivacaine. The mechanism behind this prolonged analgesia involves inhibition of substance P release, modulation of pain pathways, and activation of α2 receptors in the spinal cord, leading to enhanced and sustained analgesic effects. In contrast, fentanyl, although effective in improving analgesia, has a shorter duration due to its rapid redistribution and lipophilic nature.

The hemodynamic parameters including pulse rate, systolic blood pressure, and diastolic blood pressure remained stable and comparable across all groups, indicating that the addition of dexmedetomidine or fentanyl does not compromise hemodynamic stability when used in appropriate doses. These findings are consistent with previous studies such as Sun et al,[11] and Bi et al,[13] which reported minimal hemodynamic alterations with intrathecal dexmedetomidine. Although dexmedetomidine has sympatholytic properties, the low dose used intrathecally results in stable cardiovascular parameters without significant bradycardia or hypotension.

The incidence of adverse effects was low and comparable among all groups, with slightly higher occurrence in the ropivacaine alone group. This suggests that the addition of adjuvants does not increase the risk of complications and may even improve the safety profile by reducing the requirement for additional analgesics. Overall, the findings of the present study indicate that dexmedetomidine is a superior adjuvant to fentanyl when combined with hyperbaric ropivacaine, providing faster onset, prolonged duration of block, and extended postoperative analgesia with minimal side effects and stable hemodynamics.

CONCLUSION

The present study concludes that the addition of dexmedetomidine and fentanyl to hyperbaric ropivacaine significantly enhances the quality of spinal anaesthesia compared to ropivacaine alone. Among the two adjuvants, dexmedetomidine provides faster onset of sensory and motor blockade, prolonged duration of sensory and motor block, and extended postoperative analgesia with stable hemodynamic parameters and minimal adverse effects. Therefore, intrathecal dexmedetomidine can be considered a superior adjuvant to fentanyl for infraumbilical surgeries where prolonged analgesia and improved block characteristics are desirable.

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