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Dexmedetomidine Versus Sodium Bicarbonate as Adjuvants to Bupivacaine in Ultrasound-Guided Erector Spinae Plane Block: A Randomized Controlled Trial

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Abstract

The erector spinae plane (ESP) block has emerged as a safe, effective, and versatile regional anesthesia technique for providing postoperative analgesia in a wide range of surgical procedures, including thoracic, abdominal, and breast surgeries. Its popularity has increased due to its ease of administration under ultrasound guidance and lower risk of complications compared to neuraxial techniques such as epidural and paravertebral blocks. Despite these advantages, one of the key limitations of the ESP block is the relatively delayed onset and limited duration of analgesia when performed using local anesthetics alone.To overcome these limitations, various adjuvants have been incorporated with local anesthetics to enhance block characteristics. Among these, Dexmedetomidine and Sodium bicarbonate represent two pharmacologically distinct approaches. Dexmedetomidine, a highly selective α2-adrenergic receptor agonist, prolongs analgesia by inhibiting nociceptive transmission and enhancing the effect of local anesthetics. It has also been shown to reduce postoperative opioid consumption and improve the quality of analgesia. In contrast, sodium bicarbonate acts by alkalinizing the local anesthetic solution, thereby increasing the non-ionized fraction of the drug and facilitating faster penetration across nerve membranes, leading to a more rapid onset of action.Although both agents are used to improve block characteristics, they differ significantly in their mechanisms and clinical effects. While dexmedetomidine is known for prolonging analgesia, sodium bicarbonate primarily enhances the onset of block. There is a paucity of studies directly comparing these two adjuvants in fascial plane blocks, particularly the ESP block, and even fewer studies in the Indian population. Therefore, a comparative evaluation of these agents is essential to determine their relative efficacy and clinical utility.

Aim and Objectives

The aim of this study is to compare Dexmedetomidine and Sodium bicarbonate as adjuvants to bupivacaine in erector spinae plane block. Objectives include evaluating onset time, duration of analgesia, pain scores, opioid consumption, and adverse effects to determine the more effective adjuvant.

Methods

This prospective, randomized, double-blind controlled trial was conducted on 80 patients aged between 18 and 65 years, belonging to American Society of Anesthesiologists (ASA) physical status I and II, undergoing elective abdominal surgeries under general anesthesia. After obtaining institutional ethical committee approval and informed consent, patients were randomly allocated into two equal groups using a computer-generated randomization method.

Group DEXM received 20 ml of 0.25% bupivacaine combined with dexmedetomidine at a dose of 0.5 μg/kg.

Group SB received 20 ml of 0.25% bupivacaine with sodium bicarbonate in a concentration of 1 mEq per 10 ml of local anesthetic.
Ultrasound-guided ESP block was performed at the T7 vertebral level using a high-frequency linear probe and an in-plane technique.
The onset of analgesia was defined as the time from completion of injection to the loss of pinprick sensation in the targeted dermatomes. Duration of analgesia was defined as the time from block administration to the first request for rescue analgesia or when VAS score reached ≥4. Pain scores were recorded at 0, 2, 4, 6, 12, and 24 hours postoperatively. Total opioid consumption in the first 24 hours was documented. Hemodynamic parameters including heart rate and blood pressure were monitored, and any adverse effects such as hypotension, bradycardia, sedation, nausea, or vomiting were recorded.Statistical analysis was performed using appropriate tests, with continuous variables expressed as mean ± standard deviation and a p-value < 0.05 considered statistically significant.

Results

The demographic characteristics of patients in both groups were comparable and showed no statistically significant differences. The onset of analgesia was significantly faster in Group SB compared to Group DEXM. The mean onset time in the sodium bicarbonate group was 8.2 ± 1.5 minutes, whereas in the dexmedetomidine group it was 13.4 ± 2.2 minutes (p < 0.001), indicating a clear advantage of sodium bicarbonate in accelerating block onset.However, the duration of analgesia was significantly longer in the dexmedetomidine group. Group DEXM demonstrated a mean duration of analgesia of 12.8 ± 2.0 hours compared to 6.9 ± 1.6 hours in Group SB (p < 0.001). The time to first rescue analgesia was also prolonged in the dexmedetomidine group, reflecting improved analgesic efficacy.Postoperative pain scores assessed using VAS were comparable in the immediate postoperative period but were significantly lower in the dexmedetomidine group at 4, 6, and 12 hours (p < 0.05). Total opioid consumption within the first 24 hours was significantly reduced in Group DEXM (80 ± 18 mg) compared to Group SB (125 ± 22 mg) (p < 0.01), highlighting the opioid-sparing effect of dexmedetomidine.Hemodynamic parameters remained stable in both groups, although mild sedation was observed in patients receiving dexmedetomidine. No major adverse effects or complications were reported in either group.

Conclusion

Dexmedetomidine and sodium bicarbonate both enhance the characteristics of ESP block but through different mechanisms. Sodium bicarbonate significantly improves the onset of analgesia, making it useful in situations where rapid block onset is required. In contrast, dexmedetomidine provides a markedly prolonged duration of analgesia, superior pain control, and reduced opioid consumption, making it a more effective adjuvant for sustained postoperative analgesia.Thus, the choice of adjuvant may be tailored according to clinical requirements, with dexmedetomidine preferred for prolonged analgesia and sodium bicarbonate for rapid onset. Further large-scale studies are recommended to validate these findings and explore their applicability across different surgical populations.

Keywords: Erector Spinae Plane Block ,Dexmedetomidine ,Sodium Bicarbonate, Bupivacaine, Regional Anesthesia, Ultrasound-Guided Block, Postoperative Analgesia,Adjuvants in Nerve Blocks,Onset of Block,Duration of Analgesia,Opioid Consumption,Pain Management

Introduction

The erector spinae plane (ESP) block is a relatively recent advancement in regional anesthesia that has gained significant popularity due to its simplicity, safety, and effectiveness in providing postoperative analgesia. First described by M. Forero in 2016, the ESP block involves the injection of local anesthetic into the fascial plane deep to the erector spinae muscle. This facilitates widespread cranio-caudal spread of the drug, resulting in multi-dermatomal analgesia involving both dorsal and ventral rami of spinal nerves. Owing to its superficial location and ultrasound-guided approach, the ESP block is associated with a lower risk of complications compared to traditional neuraxial techniques such as epidural and paravertebral blocks.Over the past decade, the ESP block has been increasingly utilized in a variety of surgical procedures, including thoracic, abdominal, breast, and orthopedic surgeries. Its role has become particularly important in the context of multimodal analgesia and enhanced recovery after surgery (ERAS) protocols, where minimizing opioid consumption is a key objective. Despite its advantages, the ESP block has certain limitations, including delayed onset and relatively shorter duration of analgesia when administered with local anesthetics alone. These limitations can impact its overall effectiveness in the postoperative period.To address these concerns, various adjuvants have been added to local anesthetics to enhance the onset, prolong the duration, and improve the quality of analgesia. Among these, Dexmedetomidine and Sodium bicarbonate have gained attention due to their distinct mechanisms of action and clinical benefits. Dexmedetomidine is a highly selective α2-adrenergic receptor agonist that produces analgesia by inhibiting the release of norepinephrine and suppressing nociceptive transmission at both peripheral and central levels. It has been widely studied in peripheral nerve blocks and has been shown to significantly prolong the duration of analgesia, enhance block quality, and reduce postoperative opioid requirements.In contrast, sodium bicarbonate acts by alkalinizing the local anesthetic solution, thereby increasing the proportion of the non-ionized form of the drug. This facilitates faster diffusion across nerve membranes, leading to a more rapid onset of block. While sodium bicarbonate has been commonly used to hasten the onset of local anesthetics such as lignocaine, its role in fascial plane blocks like the ESP block remains less well defined. Although both dexmedetomidine and sodium bicarbonate are used as adjuvants in regional anesthesia, they differ fundamentally in their effects on block characteristics. Dexmedetomidine primarily enhances the duration and quality of analgesia, whereas sodium bicarbonate mainly improves the onset of action. Comparative data evaluating these two agents in the context of ESP block are limited, and there is a notable lack of studies conducted in the Indian population.Therefore, this study was designed to compare dexmedetomidine and sodium bicarbonate as adjuvants to bupivacaine in ultrasound-guided ESP block, with particular emphasis on onset of analgesia, duration of block, postoperative pain scores, and opioid consumption.

Aim and Objectives

The aim of this study is to compare the efficacy of Dexmedetomidine and Sodium bicarbonate as adjuvants to bupivacaine in ultrasound-guided erector spinae plane (ESP) block.

Primary objective

Evaluate the duration of analgesia.

Secondary objectives include

1. Comparison of onset time of block,
2. Postoperative pain scores (VAS)
3. Time to first rescue analgesia
4. Total opioid consumption in 24 hours, hemodynamic parameters
5. Incidence of adverse effects
6. To determine the more effective adjuvant for improving block characteristics and overall analgesic quality.

MATERIALS AND METHODS

This prospective, randomized, double-blind controlled study was conducted at a tertiary care hospital after obtaining approval from the institutional ethics committee and written informed consent from all participants. The study included 80 patients aged between 18 and 65 years, belonging to American Society of Anesthesiologists (ASA) physical status I and II, scheduled for elective abdominal surgeries under general anesthesia.

Inclusion Criteria

1. Patients aged 18–65 years

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2. ASA physical status I and II
3. Patients undergoing elective abdominal surgery
4. Patients providing informed written consent

Exclusion Criteria

1. Patient refusal
2. Known allergy to local anesthetics or study drugs
3. Coagulopathy or ongoing anticoagulant therapy
4. Infection at the site of block
5. Severe systemic illness (cardiac, renal, hepatic)
6. Body mass index (BMI) > 35 kg/m²
7. Pregnant or lactating patients

Study Design and Grouping

Patients were randomly allocated into two groups of 40 each using a computer-generated randomization method. Allocation concealment was ensured using sealed opaque envelopes. Both the patient and the observer assessing outcomes were blinded to group allocation.

1. **Group DEXM**: Received 20 ml of 0.25% bupivacaine with Dexmedetomidine (0.5 µg/kg)
2. **Group SB:** Received 20 ml of 0.25% bupivacaine with Sodium bicarbonate (1 mEq per 10 ml)

The study drugs were prepared by an independent anesthesiologist not involved in the procedure or data collection to maintain blinding.

Procedure

All patients were kept nil per oral as per standard fasting guidelines and received standard premedication. In the operating room, routine monitoring including electrocardiography, non-invasive blood pressure, and pulse oximetry was applied. General anesthesia was administered using standard protocols.Following induction, patients were positioned appropriately, and under strict aseptic precautions, ultrasound-guided erector spinae plane (ESP) block was performed at the T7 vertebral level using a high-frequency linear probe. The probe was placed in a parasagittal orientation to identify the transverse process and erector spinae muscle. A block needle was inserted using an in-plane approach. After negative aspiration, hydrodissection with saline confirmed correct placement, and the study drug was injected into the fascial plane deep to the erector spinae muscle.

Outcome Measures

1. Primary Outcome:
    a. Duration of analgesia (time to VAS ≥ 4)
2. Secondary Outcomes:
    a. Onset time of block (loss of pinprick sensation)
    b. Postoperative pain scores (VAS at 0, 2, 4, 6, 12, and 24 hours)
    c. Time to first rescue analgesia
    d. Total opioid consumption in 24 hours
    e. Hemodynamic parameters
    f. Adverse effects (hypotension, bradycardia, sedation, nausea, vomiting)

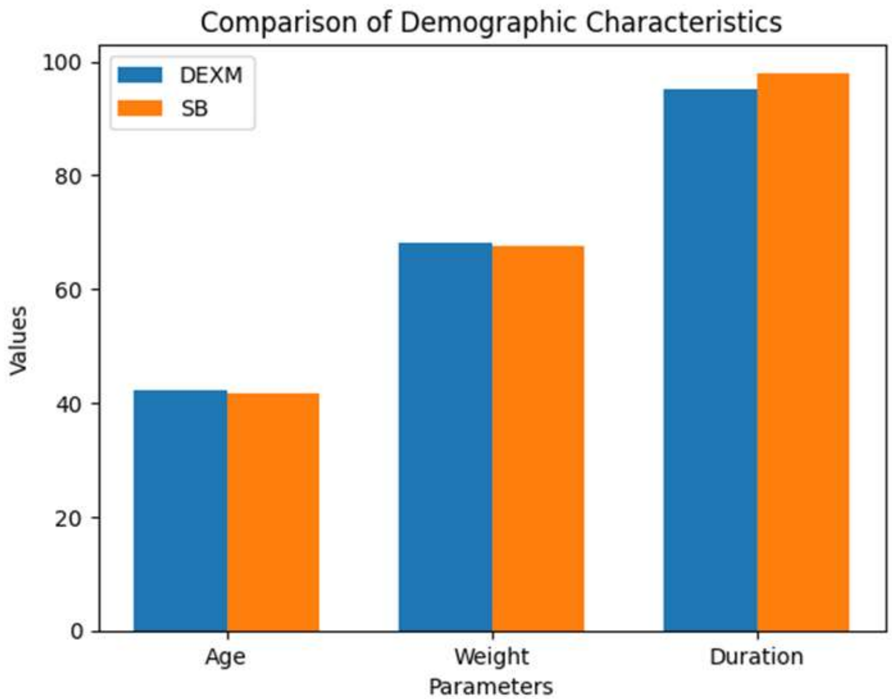
Statistical Analysis

Data were analysed using statistical software. Continuous variables were expressed as mean ± standard deviation and compared using the independent t-test. Categorical variables were analyzed using the chi-square test. A p-value of < 0.05 was considered statistically significant.

Result

Table 1: Demographic Characteristics

Parameter	Group DEXM (Mean ± SD)	Group SB (Mean ± SD)	p-value
Age (years)	42.3 ± 10.5	41.7 ± 9.8	>0.05
Weight (kg)	68.2 ± 8.6	67.5 ± 9.1	>0.05
Gender (M/F)	22/18	21/19	>0.05
Duration of surgery (min)	95 ± 20	98 ± 18	>0.05

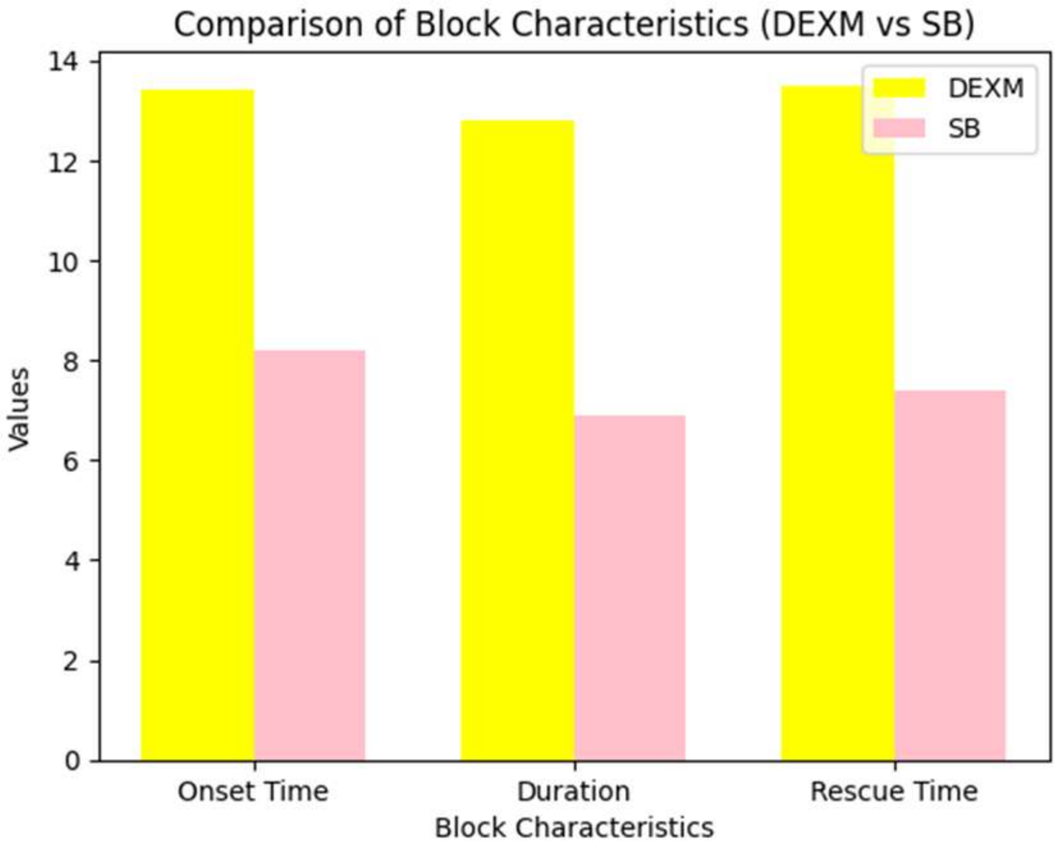


The bar graph demonstrates a comparison of baseline demographic parameters between Group DEXM and Group SB. The mean age of patients in both groups is nearly identical (42.3 ± 10.5 vs 41.7 ± 9.8 years), indicating no significant difference. Similarly, the mean body weight is comparable between the two groups (68.2 ± 8.6 kg vs 67.5 ± 9.1 kg).The duration of surgery also shows minimal variation (95 ± 20 minutes in Group DEXM vs 98 ± 18 minutes in Group SB). The gender distribution is balanced in both groups (22/18 vs 21/19).Overall, all parameters show $p > 0.05$, confirming that there is no statistically significant difference between the groups. This indicates that both groups are homogeneous and comparable at baseline, ensuring that any observed differences in outcomes can be attributed to the intervention rather than confounding demographic factors.

Table 2: Block Characteristics

Parameter	Group DEXM (Mean ± SD)	Group SB (Mean ± SD)	p-value
Onset time (min)	13.4 ± 2.2	8.2 ± 1.5	<0.001
Duration of analgesia (hrs)	12.8 ± 2.0	6.9 ± 1.6	<0.001

Parameter	Group DEXM (Mean ± SD)	Group SB (Mean ± SD)	p-value
Time to first rescue analgesia (hrs)	13.5 ± 2.3	7.4 ± 1.8	<0.001



The bar graph demonstrates a comparison of block characteristics between Group DEXM and Group SB. The onset time of block was significantly shorter in Group SB (8.2 ± 1.5 minutes) compared to Group DEXM (13.4 ± 2.2 minutes), indicating a faster onset with sodium bicarbonate.In contrast, the duration of analgesia was significantly prolonged in Group DEXM (12.8 ± 2.0 hours) compared to Group SB (6.9 ± 1.6 hours). Similarly, the time to first rescue analgesia was markedly longer in Group DEXM (13.5 ± 2.3 hours) than in Group SB (7.4 ± 1.8 hours).All these differences were statistically highly significant ($p < 0.001$). These findings suggest that while sodium bicarbonate accelerates the onset of block, dexmedetomidine provides superior and longer-lasting analgesia with delayed requirement for rescue analgesics.

Table 3: Pain Scores (VAS)

Time Interval	Group DEXM (Mean ± SD)	Group SB (Mean ± SD)	p-value
0 hr	0	0	—
2 hr	1.5 ± 0.6	1.8 ± 0.7	>0.05
4 hr	2.1 ± 0.8	4.3 ± 1.0	<0.05
6 hr	2.8 ± 0.9	4.8 ± 1.2	<0.05
12 hr	3.5 ± 1.1	5.2 ± 1.3	<0.05
24 hr	4.2 ± 1.2	4.5 ± 1.3	>0.05

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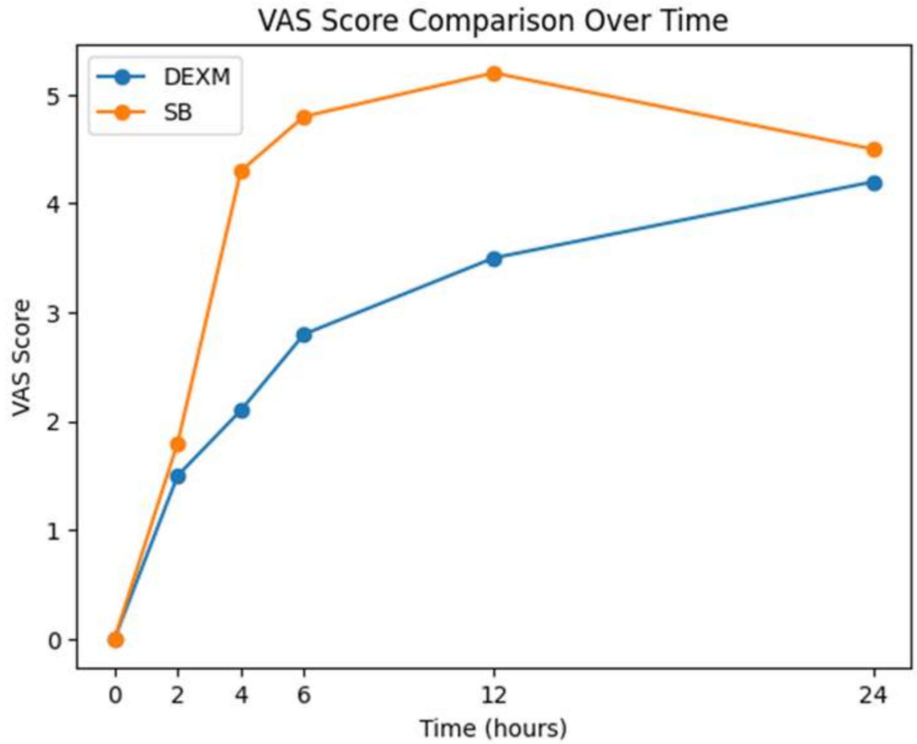


The line graph illustrates the trend of postoperative pain scores (VAS) over time in Group DEXM and Group SB. Both groups had comparable pain scores at 0 and 2 hours ($p > 0.05$), indicating similar immediate postoperative analgesia.However, from 4 to 12 hours, VAS scores were significantly lower in Group DEXM compared to Group SB ($p < 0.05$). This suggests that dexmedetomidine provides superior and more sustained analgesia during the critical postoperative period.At 24 hours, the difference between the groups was not statistically significant ($p > 0.05$), indicating convergence of analgesic effect over time.Overall, the graph demonstrates that dexmedetomidine offers better mid-term postoperative pain control compared to sodium bicarbonate.

Table 4: Opioid Consumption

Parameter	**Group DEXM (Mean ± SD)**	**Group SB (Mean ± SD)**	**p-value**
Total opioid consumption (mg)	80 ± 18	125 ± 22	<0.01

The bar graph demonstrates a comparison of total postoperative opioid consumption between Group DEXM and Group SB. The mean opioid requirement was significantly lower in Group DEXM (80 ± 18 mg) compared to Group SB (125 ± 22 mg).This difference was statistically significant ($p < 0.01$), indicating that patients receiving dexmedetomidine required less additional analgesia. The error bars (± SD) show some variability within groups but do not overlap substantially, supporting the significance of the findings.

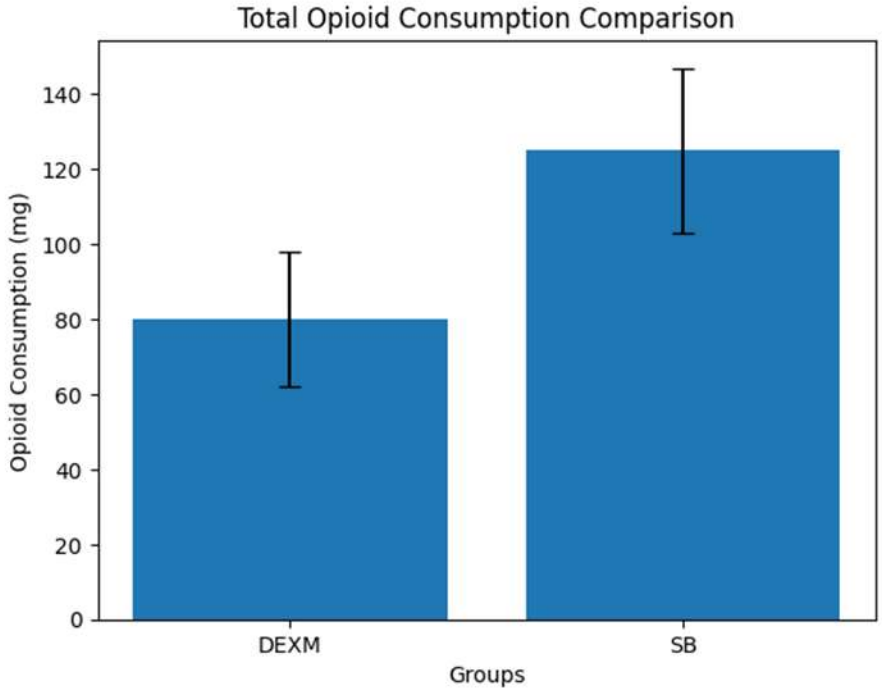
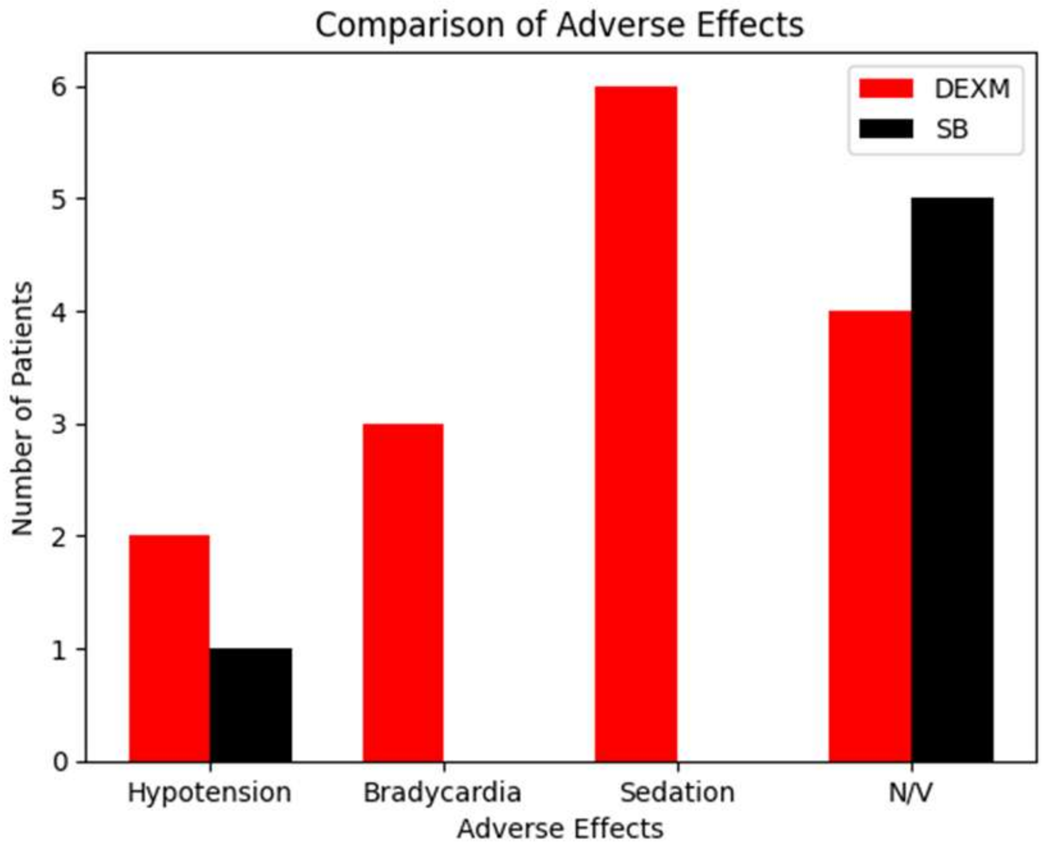


Table 5: Adverse Effects

Complication	Group DEXM	Group SB	p-value
Hypotension	2 (5%)	1 (2.5%)	>0.05
Bradycardia	3 (7.5%)	0	>0.05
Sedation	6 (15%)	0	<0.05
Nausea/Vomiting	4 (10%)	5 (12.5%)	>0.05



The bar graph compares the incidence of adverse effects between Group DEXM and Group SB. Hypotension and bradycardia were observed more frequently in Group DEXM (5% and 7.5%) compared to Group SB (2.5% and 0%), but these differences were not statistically significant ($p > 0.05$).Sedation was noted only in Group DEXM (15%) and was statistically significant ($p < 0.05$), indicating a higher sedative effect with dexmedetomidine.The incidence of nausea and vomiting was comparable between the two groups (10% vs 12.5%) and not statistically significant ($p > 0.05$).Overall, both groups demonstrated a similar safety profile, with the exception of increased sedation in the dexmedetomidine group.

Discussion

Pain control is not merely about relief,it is about recovery, comfort, and quality of care. In this study, we compared Dexmedetomidine and Sodium bicarbonate as adjuvants to bupivacaine in ultrasound-guided erector spinae plane (ESP) block, and the findings clearly highlight a striking contrast between speed and sustainability of analgesia.The onset of analgesia was significantly faster in the sodium bicarbonate group (8.2 ± 1.5 minutes) compared to the dexmedetomidine group (13.4 ± 2.2 minutes), with a highly significant difference ($p < 0.001$). This rapid onset reflects the pharmacological advantage of alkalinization, where an increased non-ionized fraction of the local anesthetic enhances nerve penetration. In essence, sodium bicarbonate acts as an "accelerator," delivering quicker analgesic onset when time is critical.However, speed alone does not define quality analgesia. The duration of analgesia was markedly prolonged in the dexmedetomidine group (12.8 ± 2.0 hours) compared to the sodium bicarbonate group (6.9 ± 1.6 hours) ($p < 0.001$). Similarly, the time to first rescue analgesia was significantly longer with dexmedetomidine (13.5 ± 2.3 hours vs 7.4 ± 1.8 hours; $p < 0.001$). If sodium bicarbonate is the sprinter, dexmedetomidine is clearly the marathon runner—sustaining analgesia long after the initial effect.Postoperative pain scores further reinforce this distinction. While VAS scores were comparable in the immediate postoperative period (0–2 hours; $p > 0.05$), a significant divergence was observed thereafter. At 4, 6, and 12 hours, VAS scores were significantly lower in the dexmedetomidine group (2.1 ± 0.8 vs 4.3 ± 1.0; 2.8 ± 0.9 vs 4.8 ± 1.2; 3.5 ± 1.1 vs 5.2 ± 1.3

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respectively; p < 0.05). By 24 hours, the difference diminished (4.2 ± 1.2 vs 4.5 ± 1.3; p > 0.05), suggesting eventual convergence of analgesic effects. This clearly illustrates that dexmedetomidine not only prolongs analgesia but also maintains superior pain control during the most critical postoperative period.A key clinical advantage observed in this study was the significant opioid-sparing effect of dexmedetomidine. Total opioid consumption over 24 hours was significantly lower in the dexmedetomidine group (80 ± 18 mg) compared to the sodium bicarbonate group (125 ± 22 mg) (p < 0.01). In the era of opioid minimization, this reduction is not just statistically significant—it is clinically transformative. Reduced opioid requirement translates into fewer side effects, earlier mobilization, and improved patient satisfaction.Regarding safety, both adjuvants demonstrated an acceptable profile. Hypotension (5% vs 2.5%) and bradycardia (7.5% vs 0%) were more frequent in the dexmedetomidine group but were not statistically significant (p > 0.05). Sedation was observed only in the dexmedetomidine group (15% vs 0%) and was statistically significant (p < 0.05), which is consistent with its known sedative properties. However, this sedation was mild and did not require intervention. The incidence of nausea and vomiting was comparable between the groups (10% vs 12.5%; p > 0.05). Thus, dexmedetomidine trades mild sedation for superior analgesia—a compromise that is often clinically acceptable.In summary, this study highlights a clear dichotomy: sodium bicarbonate enhances the speed of block onset, while dexmedetomidine enhances the strength and duration of analgesia. When rapid onset is desired, sodium bicarbonate is advantageous; however, when prolonged and superior analgesia is the goal, dexmedetomidine emerges as the more effective adjuvant.

Conclusion

The present study highlights a clinically meaningful distinction between dexmedetomidine and Sodium bicarbonate in enhancing ESP block characteristics. Sodium bicarbonate accelerates onset, making it beneficial in time-sensitive settings. However, dexmedetomidine significantly prolongs analgesia, reduces postoperative pain scores, and demonstrates a notable opioid-sparing effect.In pain management, speed may impress—but duration defines excellence.The prolonged analgesia observed with dexmedetomidine (12.8 ± 2.0 hours vs 6.9 ± 1.6 hours; p < 0.001) and reduced opioid requirement establish its superiority as an adjuvant.Thus, dexmedetomidine aligns well with modern anesthetic goals of enhanced recovery, improved patient comfort, and reduced opioid dependence.Ultimately, the choice of adjuvant should be guided by clinical priorities—but when durability matters, dexmedetomidine clearly leads.

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