Section: Anesthesia & Critical Care

Original Research Article

COMPARISON OF POST OPERATIVE ANALGESIC EFFICACY OF INTRAVENOUS VS EPIDURAL TRAMADOL VIA PCA INFUSION– A RETROSPECTIVE CLINICAL STUDY

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ABSTRACT

Background: Effective postoperative analgesia after caesarean section is essential for maternal comfort, early mobilisation, breastfeeding and neonatal care. Tramadol can be administered through different routes, including intravenous and epidural patient-controlled analgesia. However, direct comparison of intravenous and epidural tramadol through PCA infusion after caesarean section remains limited. **Aim:** To compare the postoperative analgesic efficacy of intravenous tramadol versus epidural tramadol administered through PCA infusion in patients undergoing caesarean section.

Materials and Methods: This retrospective comparative clinical study was conducted in the Department of Anesthesia & Critical Care, Al Ahli Hospital, Doha, Qatar, from March 2023 to November 2023. A total of 60 patients undergoing elective or emergency caesarean section were included and divided into two groups of 30 patients each. Group A received intravenous tramadol PCA after spinal anaesthesia, while Group B received epidural tramadol PCA after combined spinal epidural anaesthesia. Postoperative pain was assessed using the Visual Analogue Scale. Hemodynamic parameters, respiratory parameters and adverse effects were recorded and compared between the two groups.

Results: The mean VAS pain score was 1.60 ± 1.30 in the intravenous tramadol group and 1.67 ± 1.03 in the epidural tramadol group, with no statistically significant difference. Mean heart rate, diastolic blood pressure and respiratory rate were significantly higher in the intravenous tramadol group, while SpO_2 was significantly higher in the epidural tramadol group. Systolic blood pressure was comparable between the two groups. Adverse effects were broadly similar. Nausea and vomiting was the most common adverse effect in both groups. Urinary retention and headache/PDPH were observed only in the epidural group, while respiratory depression was observed in one patient in the intravenous group; however, these differences were not statistically significant.

Conclusion: Intravenous tramadol PCA and epidural tramadol PCA provided comparable postoperative analgesia after caesarean section. Epidural tramadol did not show statistically superior analgesic efficacy compared with intravenous tramadol. Both routes showed acceptable clinical safety profiles.

Keywords: Caesarean section; Tramadol; Patient-controlled analgesia; Epidural analgesia; Intravenous analgesia; Postoperative pain; Visual Analogue Scale.

INTRODUCTION

Postoperative pain following caesarean section is an important clinical concern because inadequate analgesia can delay early mobilisation, impair maternal comfort, interfere with breastfeeding and neonatal care, and increase postoperative stress response. Effective pain relief after caesarean delivery should therefore provide adequate analgesia while maintaining maternal alertness, respiratory safety, hemodynamic stability and minimal adverse effects.[1]

Tramadol is a synthetic opioid analgesic that acts through both opioid and non-opioid mechanisms. It has weak μ-opioid receptor agonist activity and also inhibits the reuptake of serotonin and noradrenaline, thereby contributing to analgesia through central pain-modulating pathways. Because of its relatively lower risk of respiratory depression compared with stronger opioids, tramadol has been used as a postoperative analgesic in different surgical settings, including obstetric and lower abdominal surgeries.[2]

Patient-controlled analgesia is an established method of postoperative pain management. It allows the patient to self-administer small doses of analgesic according to individual pain requirement, thereby reducing delay in analgesic delivery and avoiding wide fluctuations in plasma drug concentration. PCA also improves patient participation in pain control and may reduce unnecessary overdosage when appropriate lockout intervals and dose limits are used.[3]

Intravenous PCA tramadol has been evaluated for postoperative analgesia after caesarean section and other lower abdominal surgeries. Demirel et al. compared patient-controlled analgesia with continuous infusion of tramadol after caesarean section and reported that IV PCA tramadol was an effective technique for postoperative pain management.[2] Chi et al. also evaluated intravenous patient-controlled analgesia with tramadol after caesarean section and supported its usefulness as a postoperative analgesic modality.[4]

Epidural analgesia is another effective route for postoperative pain control, especially when neuraxial access is already established during anaesthesia. Epidural administration may provide segmental analgesia and may reduce systemic opioid requirement. Siddik-Sayyid et al. studied epidural tramadol for postoperative pain after caesarean section and reported adequate postoperative analgesia without significant respiratory depression.[1] Pan et al. also reported the role of epidural tramadol in postoperative pain relief after caesarean delivery and observed satisfactory analgesic effect with stable hemodynamic parameters.[3]

Several studies comparing epidural analgesia with intravenous PCA in other surgical populations have reported favourable outcomes with epidural techniques. Meng et al., in a meta-analysis of randomized trials in major spine surgery, reported that epidural analgesia provided superior pain relief, higher patient satisfaction and reduced opioid consumption compared with IV-PCA.[14] Similarly, Wu and Zhi reported better postoperative analgesia, improved comfort scores, faster recovery and fewer adverse reactions with patient-controlled epidural analgesia compared with IV-PCA in total hip arthroplasty patients.[17]

However, the superiority of epidural analgesia reported in non-obstetric surgeries cannot be directly applied to caesarean-section patients because the surgical population, pain characteristics, anaesthetic technique and analgesic drugs differ considerably. Many studies comparing epidural and intravenous analgesia have used local anaesthetic-opioid combinations rather than the same analgesic drug through both routes. Therefore, the observed superiority of epidural analgesia in such studies may reflect the drug combination and surgical context rather than the epidural route alone.[14,15,17]

Studies involving tramadol-based PCA also show that tramadol is useful but has tolerability concerns, especially nausea and vomiting. Kavishvar and Prajapati compared intravenous PCA tramadol alone with tramadol plus dexmedetomidine in major lower abdominal surgery and found that tramadol PCA provided effective analgesia, while addition of dexmedetomidine reduced tramadol requirement without significantly increasing adverse effects.[16] This supports the clinical usefulness of IV PCA tramadol, but it does not answer whether epidural tramadol is superior to IV tramadol when both are delivered through PCA.

Available literature therefore supports both intravenous tramadol PCA and epidural tramadol for postoperative pain relief, but direct evidence comparing intravenous versus epidural tramadol administered through PCA infusion after caesarean section remains limited. This gap is clinically relevant because IV tramadol PCA is easier to administer and avoids neuraxial catheter-related complications, whereas epidural tramadol may offer segmental analgesia but requires catheter placement and monitoring for neuraxial adverse effects such as urinary retention, pruritus and headache/PDPH.[1-6,14-17]

Hence, the present study was undertaken to compare the postoperative analgesic efficacy of intravenous tramadol versus epidural tramadol administered through PCA infusion in patients undergoing caesarean section. The study also assessed hemodynamic parameters, respiratory parameters and adverse effects in both groups, so that the clinical efficacy and safety of both routes could be evaluated in a practical obstetric anaesthesia setting.

Aim

To compare the postoperative analgesic efficacy of intravenous tramadol versus epidural tramadol administered through PCA infusion in patients undergoing caesarean section.

Objectives

1. To compare postoperative pain relief between intravenous tramadol PCA and epidural tramadol PCA using the Visual Analogue Scale pain score.
2. To compare the hemodynamic parameters, respiratory parameters, and adverse-effect profile between intravenous tramadol PCA and epidural tramadol PCA in postoperative caesarean-section patients.

MATERIALS AND METHODS

Study design

This was a retrospective comparative clinical study conducted to compare the postoperative analgesic efficacy of intravenous tramadol versus epidural tramadol administered through PCA infusion in patients undergoing caesarean section.

The original protocol document describes the study as a retrospective randomized controlled study, with 60 patients divided into two groups of 30 each. However, for manuscript clarity, the safer standard wording is retrospective comparative clinical study, unless prospective randomization records are available.

Place of study

The study was conducted in the Department of Anesthesia & Critical Care, Al Ahli Hospital, Doha, Qatar.

Duration of study

The study was conducted from March 2023 to November 2023.

Study population

The study included patients who underwent elective or emergency caesarean section under neuraxial anaesthesia and received postoperative tramadol through PCA infusion.

A total of 60 patients were included in the study. Patients were divided into two groups of 30 patients each.

Sample size

The total sample size was 60 patients.

Group	Analgesic technique	Number of patients
Group A	Intravenous tramadol PCA	30
Group B	Epidural tramadol PCA	30
Total	—	60

Inclusion criteria

Patients were included if they fulfilled the following criteria:

1. Patients undergoing elective or emergency caesarean section.
2. Patients belonging to ASA physical status I or II.

Exclusion criteria

Patients were excluded if any of the following were present:

1. Deranged coagulation profile.
2. Spinal deformities or spinal pathologies.
3. Patient refusal.
4. History of allergy to tramadol or other opioids.

Group allocation

Patients were divided into two groups.

Group A: Intravenous Tramadol Group

Patients who underwent caesarean section under spinal anaesthesia and received intravenous tramadol through PCA infusion postoperatively were included in Group A.

Group B: Epidural Tramadol Group

Patients who underwent caesarean section under combined spinal epidural anaesthesia and received epidural tramadol through PCA infusion postoperatively were included in Group B.

Anaesthetic technique and intervention

Group A: Intravenous Tramadol Group

Patients in Group A underwent caesarean section under spinal anaesthesia. Under strict aseptic precautions, subarachnoid block was administered using 10 mg of heavy bupivacaine. Adequate sensory and motor blockade were assessed. Vital parameters were continuously monitored intraoperatively.

In the post-anaesthesia care unit, intravenous tramadol was initiated through a PCA pump for postoperative analgesia. Tramadol was loaded at a concentration of 10 mg/mL and administered at a basal rate of 20 mg/hour. The bolus dose was 15 mg per push, with a lockout period of 30 minutes.

Group B: Epidural Tramadol Group

Patients in Group B underwent caesarean section under combined spinal epidural anaesthesia. Under strict aseptic precautions, combined spinal epidural anaesthesia was performed using a needle-through-needle technique. 10 mg of heavy bupivacaine was injected into the cerebrospinal fluid. Adequate sensory and motor blockade were assessed.

An epidural catheter was inserted aseptically into the epidural space. An adrenaline test dose was administered and documented. Vital parameters were continuously monitored intraoperatively.

In the post-anaesthesia care unit, tramadol was administered epidurally through a PCA pump for postoperative analgesia. Tramadol was loaded at a concentration of 10 mg/mL and administered at a basal rate of 20 mg/hour. The bolus dose was 15 mg per push, with a lockout period of 30 minutes.

Pain assessment

Postoperative pain was assessed using the Visual Analogue Scale.

The VAS score ranged from 0 to 10, where 0 indicated no pain and 10 indicated the worst imaginable pain.

For interpretation, VAS scores were classified as follows:

VAS score	Interpretation
0	No pain
1–3	Mild pain
4–6	Moderate pain
7–10	Severe pain

Outcome measures

Primary outcome

The primary outcome was postoperative analgesic efficacy, assessed by comparing the **VAS pain score** between the intravenous tramadol PCA group and the epidural tramadol PCA group.

Secondary outcomes

The secondary outcomes were:

1. Comparison of hemodynamic parameters between the two groups, including mean heart rate, systolic blood pressure and diastolic blood pressure.
2. Comparison of respiratory parameters between the two groups, including respiratory rate and SpO_2.
3. Comparison of adverse effects between the two groups, including hypotension, nausea and vomiting, pruritus, urinary retention, respiratory depression, shivering and headache/PDPH.

Statistical analysis

Data were entered and analysed group-wise.

Continuous variables such as age, heart rate, systolic blood pressure, diastolic blood pressure, respiratory rate, SpO_2 and VAS pain score were expressed as mean ± standard deviation. Categorical variables such as hypotension, nausea and vomiting, pruritus, urinary retention, respiratory depression, shivering and headache/PDPH were expressed as frequency and percentage.

Comparison of continuous variables between the two groups was performed using the independent-samples t-test. Comparison of categorical variables was performed using the Chi-square test or Fisher's exact test, as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 60 patients undergoing caesarean section were included in the study. Thirty patients received intravenous tramadol through PCA infusion and thirty patients received epidural tramadol through PCA infusion. The main objective was to compare postoperative analgesic efficacy, assessed by VAS pain score, along with hemodynamic parameters, respiratory parameters, and adverse effects.

Table 1: Baseline demographic comparison

Variable	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30	p-value
Age, years	31.23 ± 3.31	33.10 ± 2.51	0.017
Minimum age, years	26	28	—
Maximum age, years	38	36	—
Median age, years	31.0	33.5	—

The epidural tramadol group had a slightly higher mean age compared with the IV tramadol group, and the difference was statistically significant.

Table 2: Age distribution of study participants

Age group, years	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30
25–29	8	3
30–34	16	14
35–39	6	13
Total	30	30

Most patients in the IV tramadol group were between 30–34 years, whereas the epidural tramadol group had a higher number of patients in the 35–39 years age group.

Table 3: Comparison of hemodynamic parameters

Parameter	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30	Mean difference	p-value
Mean heart rate, beats/min	84.00 ± 12.71	76.80 ± 10.63	7.20	0.021
Mean systolic BP, mmHg	119.37 ± 11.09	116.63 ± 11.91	2.74	0.361
Mean diastolic BP, mmHg	84.67 ± 4.50	79.50 ± 5.60	5.17	0.0002

Mean heart rate and mean diastolic blood pressure were significantly higher in the IV tramadol group. Mean systolic blood pressure was comparable between both groups.

Table 4: Comparison of respiratory parameters

Parameter	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30	Mean difference	p-value
Respiratory rate, breaths/min	12.00 ± 1.58	10.73 ± 1.46	1.27	0.002
SpO_2, %	97.10 ± 1.94	98.47 ± 1.20	-1.37	0.002

Respiratory rate was significantly higher in the IV tramadol group, whereas SpO_2 was significantly higher in the epidural tramadol group. However, the values in both groups remained within clinically acceptable postoperative limits.

Table 5: Primary analgesic outcome: VAS pain score

Pain outcome	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30	p-value
Mean VAS pain score	1.60 ± 1.30	1.67 ± 1.03	0.827
Median VAS pain score	1.5	2.0	—
Minimum VAS score	0	0	—
Maximum VAS score	4	3	—
Patients with VAS ≤3	28, 93.3%	30, 100.0%	—
Patients with VAS ≥4	2, 6.7%	0, 0.0%	—

The mean VAS pain score was comparable between the two groups. Epidural tramadol did not show statistically superior analgesic efficacy compared with IV tramadol. However, no patient in the epidural group had a VAS score of 4 or more.

Table 6: Distribution of VAS pain scores

VAS pain score	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30
0	8	6
1	7	4
2	6	14
3	7	6
4	2	0
Total	30	30

Most patients in both groups had low postoperative VAS pain scores. In the epidural tramadol group, all patients had VAS scores of 3 or less, whereas 2 patients in the IV tramadol group had a VAS score of 4.

Table 7: VAS pain score severity grading

VAS category	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30
No pain, VAS 0	8, 26.7%	6, 20.0%
Mild pain, VAS 1–3	20, 66.7%	24, 80.0%
Moderate pain, VAS 4–6	2, 6.7%	0, 0.0%
Severe pain, VAS 7–10	0, 0.0%	0, 0.0%

Both routes provided effective postoperative analgesia. No patient in either group had severe pain. Moderate pain was seen only in the IV tramadol group, but in a small number of patients.

Table 8: Adverse-effect profile

Adverse effect	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30	p-value
Hypotension	2, 6.7%	2, 6.7%	1.000
Nausea and vomiting	5, 16.7%	6, 20.0%	1.000
Pruritus	1, 3.3%	2, 6.7%	1.000
Urinary retention	0, 0.0%	4, 13.3%	0.112
Respiratory depression	1, 3.3%	0, 0.0%	1.000
Shivering	3, 10.0%	2, 6.7%	1.000
Headache / PDPH	0, 0.0%	3, 10.0%	0.237

The adverse-effect profile was broadly comparable between both groups. Nausea and vomiting was the most common adverse effect in both groups. Urinary retention and headache/PDPH were observed only in the epidural group, while respiratory depression was observed only in the IV group. None of these differences were statistically significant.

Table 9: Overall adverse-event burden

Overall safety outcome	Group A: IV Tramadol, n=30	Group B: Epidural Tramadol, n=30	p-value
No adverse event	18, 60.0%	16, 53.3%	0.795
At least one adverse event	12, 40.0%	14, 46.7%	0.795

The proportion of patients with at least one adverse event was slightly higher in the epidural tramadol group, but this difference was not statistically significant.

Table 10: Summary comparison of major study outcomes

Outcome domain	Group A: IV Tramadol	Group B: Epidural Tramadol	Interpretation
Analgesic efficacy	Mean VAS 1.60 ± 1.30	Mean VAS 1.67 ± 1.03	Comparable analgesia

VAS ≤3	93.3%	100.0%	All epidural patients had mild/no pain
VAS ≥4	6.7%	0.0%	Seen only in IV group
Heart rate	Higher	Lower	Difference statistically significant
Systolic BP	Comparable	Comparable	No significant difference
Diastolic BP	Higher	Lower	Difference statistically significant
Respiratory rate	Higher	Lower	Difference statistically significant
SpO_2	Lower	Higher	Difference statistically significant
Nausea and vomiting	16.7%	20.0%	Comparable
Urinary retention	0.0%	13.3%	Seen only in epidural group
Respiratory depression	3.3%	0.0%	Seen only in IV group
Headache/PDPH	0.0%	10.0%	Seen only in epidural group
Overall adverse events	40.0%	46.7%	Comparable

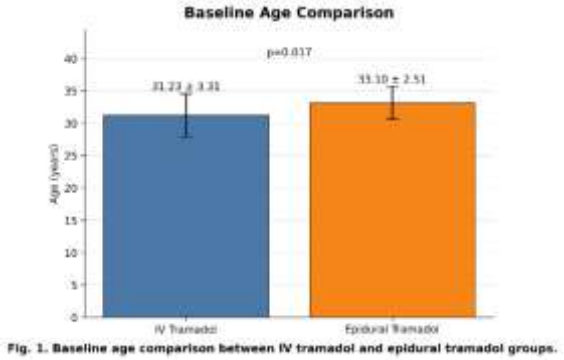

Figure 1: Baseline age comparison between IV tramadol and epidural tramadol groups

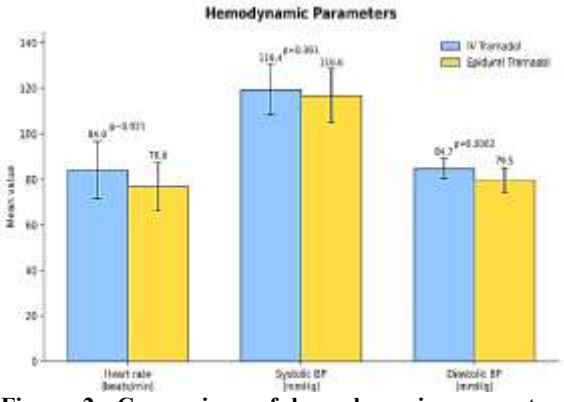

Figure 2: Comparison of hemodynamic parameters between IV tramadol and epidural tramadol groups

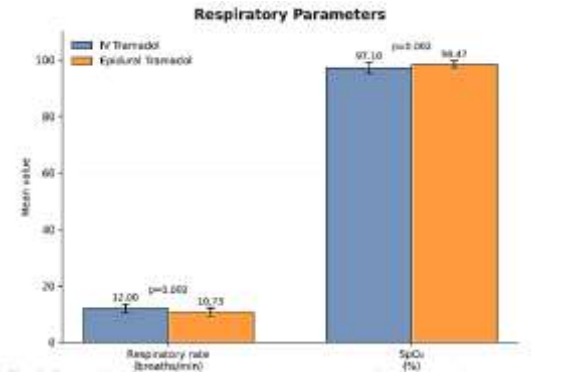

Figure 3: Comparison of respiratory rate and oxygen saturation between IV tramadol and epidural tramadol groups

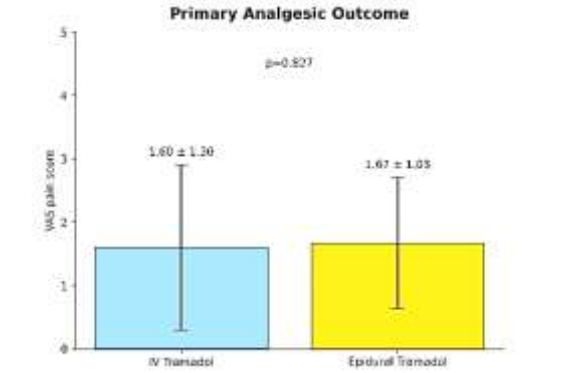

Figure 4: Comparison of mean VAS pain score between IV tramadol and epidural tramadol groups

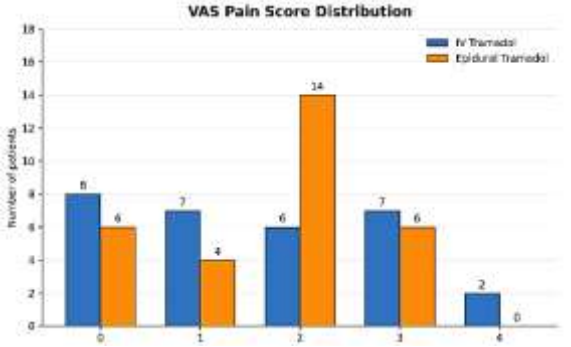

Figure 5: Distribution of VAS pain scores in IV tramadol and epidural tramadol groups

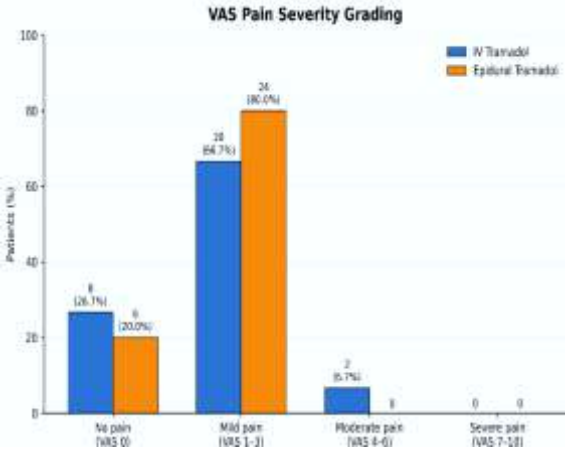

Figure 6: Grading of postoperative pain severity according to VAS score in both groups

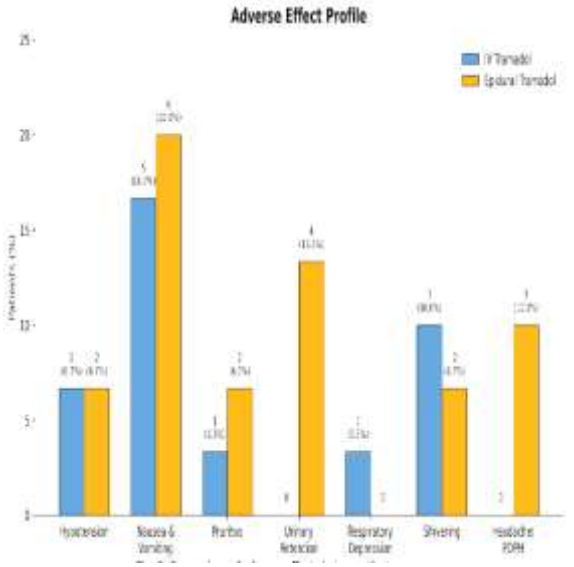

Figure 7: Comparison of adverse-effect profile between IV tramadol and epidural tramadol groups

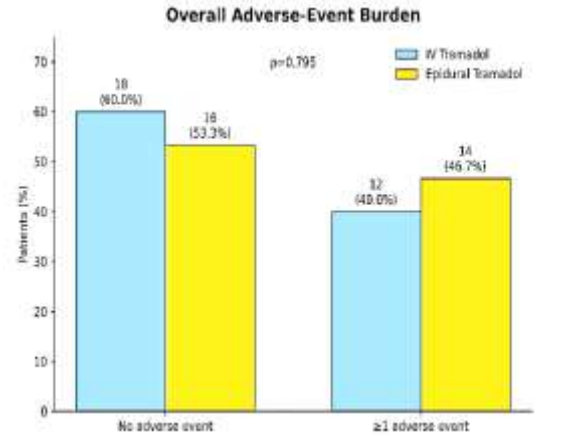

Figure 8: Overall adverse-event burden in IV tramadol and epidural tramadol groups

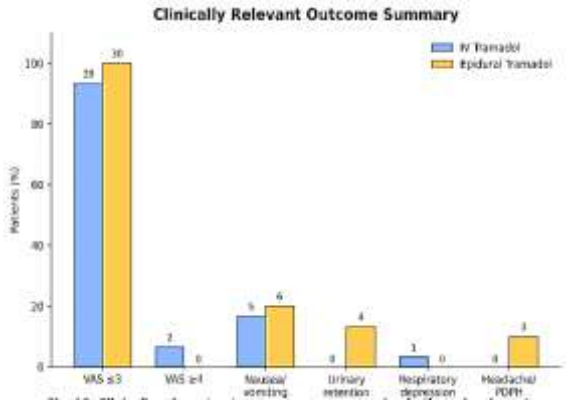

Figure 9: Clinically relevant outcome summary comparing IV tramadol and epidural tramadol groups.

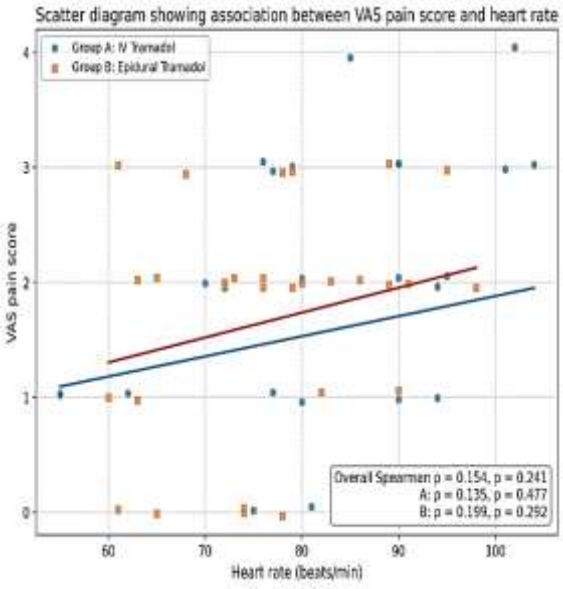

Figure 10: Scatter diagram showing association between VAS pain score and heart rate

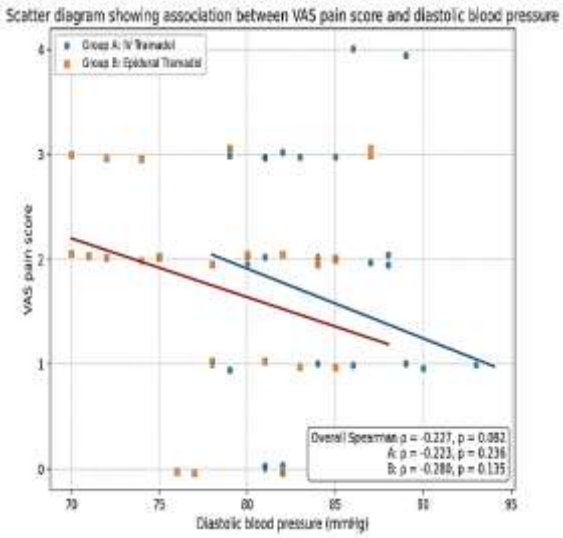

Figure 11: Scatter diagram showing association between VAS pain score and diastolic blood pressure

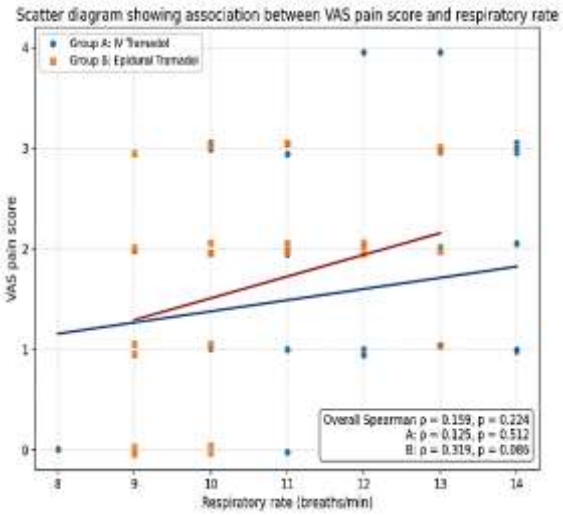

Figure 12: Scatter diagram showing association between VAS pain score and respiratory rate

DISCUSSION

The present study compared intravenous tramadol PCA with epidural tramadol PCA for postoperative analgesia following caesarean section. The main observation was that both routes provided effective postoperative pain relief, with low VAS pain scores in both groups. The mean VAS pain score was 1.60 ± 1.30 in the IV tramadol group and 1.67 ± 1.03 in the epidural tramadol group, with no statistically significant difference. Therefore, in the present study, epidural tramadol did not show statistically superior analgesic efficacy compared with IV tramadol.

This finding differs from broader literature comparing epidural analgesia with IV-PCA in other surgical settings. Meng et al. conducted a meta-analysis of 17 randomized trials involving 938 patients undergoing major spine surgery and reported that epidural analgesia provided better analgesia, higher patient satisfaction, and reduced opioid consumption compared with IV-PCA. However, their study population was different from the present caesarean-section cohort, and most epidural regimens included local anaesthetic-opioid combinations rather than tramadol alone.[14]

In contrast, the present study compared the same drug, tramadol, through two different routes. This may explain why the difference in analgesia was small. When the same analgesic molecule is used through both routes, the route-related advantage of epidural administration may be less pronounced than in studies where epidural local anaesthetic-opioid combinations are compared with systemic opioids.

Analgesic efficacy comparison

The primary outcome in the present study was postoperative VAS pain score. The mean VAS score was almost identical between the groups: 1.60 ± 1.30 in the IV tramadol group and 1.67 ± 1.03 in the epidural tramadol group. This indicates that both techniques provided satisfactory postoperative analgesia.

Meng et al. found epidural analgesia to be superior to IV-PCA after major spine surgery. On postoperative day 2, epidural analgesia was better than IV-PCA for lumbar surgery and scoliosis correction, and on postoperative day 3, epidural analgesia remained superior for scoliosis correction.[14] This contrasts with the present study, where epidural tramadol did not reduce mean VAS compared with IV tramadol.

Singh et al. found that continuous wound infiltration produced better analgesia than continuous epidural infusion and IV-PCA morphine at 12, 24, 36, and 48 hours after microdiscectomy.[15] This suggests that regional/local techniques may reduce pain more effectively in some surgical models, but the result cannot be directly transferred to caesarean patients receiving tramadol.

Kavishvar and Prajapati found that IV PCA tramadol produced effective analgesia in lower abdominal surgery. Their VRS pain scores were broadly comparable between tramadol alone and tramadol with dexmedetomidine, although dexmedetomidine reduced tramadol consumption.[16] This supports the present study finding that IV tramadol PCA itself is an effective postoperative analgesic method.

Wu and Zhi reported significantly lower VAS scores in the PCEA group compared with the IV-PCA group after total hip arthroplasty, including a 4-hour postoperative VAS of 1.2 in the PCEA group versus 2.7 in the IV-PCA group.[17] Their findings favour epidural analgesia, but they used a different surgical population and analgesic regimen.

Table 11: Primary analgesic outcome compared with uploaded studies

Study	Pain scale used	Present / reported pain result
Present study	VAS	IV tramadol: 1.60 ± 1.30; epidural tramadol: 1.67 ± 1.03; p=0.827
Meng et al.[14]	VAS / SMD	EA superior to IV-PCA overall; POD2 lumbar surgery SMD −0.93; scoliosis SMD −0.77
Singh et al.[15]	Static/dynamic VAS	CWI better than CEI and IV-PCA at 12, 24, 36, 48 h
Kavishvar and Prajapati[16]	VRS	VRS broadly comparable between tramadol and tramadol+dexmedetomidine; 24 h VRS: 1.66 ± 1.51 vs 0.63 ± 1.21
Wu and Zhi[17]	VAS	4 h VAS: PCEA 1.2 vs IV-PCA 2.7; PCEA lower at all time points

VAS distribution and pain severity

Although the mean VAS score was not significantly different, the VAS distribution showed a small clinical trend. In the IV tramadol group, 28 of 30 patients, 93.3%, had VAS ≤3, while 2 patients, 6.7%, had VAS score 4. In the epidural tramadol group, all 30 patients, 100%, had VAS ≤3 and no patient had VAS ≥4.

This suggests that epidural tramadol may have reduced the occurrence of moderate pain episodes, although the mean score was not statistically different. This finding is weaker than the epidural advantage seen by Meng et al. and Wu and Zhi, where epidural/PCEA techniques were clearly associated with lower postoperative pain scores.[14,17]

Table 12: VAS severity distribution compared with uploaded studies

Study	No pain / mild pain result	Moderate / higher pain result
Present study	IV: 28/30, 93.3% had VAS ≤3; epidural: 30/30, 100% had VAS ≤3	IV: 2/30, 6.7% had VAS 4; epidural: 0
Meng et al.[14]	Not presented as VAS severity categories	EA had lower pooled pain scores at several time points
Singh et al.[15]	Lower pain scores in CWI group at 12–48 h	IV-PCA morphine group had higher pain burden

Kavishvar and Prajapati[16]	VRS comparable between IV tramadol groups	Higher initial VRS in tramadol-only group at 1 h
Wu and Zhi[17]	PCEA had lower VAS at 4–48 h	IV-PCA had higher VAS

Hemodynamic comparison

In the present study, mean heart rate was significantly higher in the IV tramadol group compared with the epidural tramadol group. Mean heart rate was 84.00 ± 12.71 beats/min in the IV group and 76.80 ± 10.63 beats/min in the epidural group. Mean systolic blood pressure was comparable, while mean diastolic blood pressure was significantly higher in the IV group.

These findings may indicate better attenuation of postoperative pain-related sympathetic response in the epidural group. However, all values were within clinically acceptable limits. The uploaded studies did not provide directly comparable heart rate and blood pressure values for tramadol IV versus epidural tramadol. Kavishvar and Prajapati reported that pulse rate, systolic blood pressure, and diastolic blood pressure were not significantly different between IV PCA tramadol and IV PCA tramadol with dexmedetomidine.[16] Wu and Zhi also monitored hemodynamic stability in their hip arthroplasty cohort but focused mainly on recovery, sedation, VAS, comfort score, and adverse reactions.[17]

Table 13: Hemodynamic parameters compared with uploaded studies

Study	Heart rate / pulse finding	BP finding
Present study	IV: 84.00 ± 12.71; epidural: 76.80 ± 10.63; p=0.021	SBP comparable; DBP higher in IV group: 84.67 ± 4.50 vs 79.50 ± 5.60; p=0.0002
Meng et al.[14]	Not a primary extracted outcome	Not directly comparable
Singh et al.[15]	Not reported as directly comparable table for our outcome	Not directly comparable
Kavishvar and Prajapati[16]	Pulse rate not significantly different	SBP and DBP not significantly different
Wu and Zhi[17]	Standard monitoring used; recovery variables compared	Not directly comparable to our HR/DBP table

Respiratory parameter comparison

Respiratory safety is important when opioid analgesics are used. In the present study, respiratory rate was significantly higher in the IV tramadol group, while SpO_2 was significantly higher in the epidural tramadol group. Respiratory rate was 12.00 ± 1.58 breaths/min in the IV group and 10.73 ± 1.46 breaths/min in the epidural group. SpO_2 was 97.10 ± 1.94% in the IV group and 98.47 ± 1.20% in the epidural group.

Despite statistical significance, both values remained clinically acceptable. Respiratory depression was rare, occurring in only one patient in the IV group and none in the epidural group. This is consistent with the known safety profile of tramadol. Kavishvar and Prajapati specifically noted that tramadol is popular for postoperative analgesia because it has relatively low risk of respiratory depression, and no respiratory depression was observed in their tramadol PCA groups.[16]

Wu and Zhi reported fewer adverse reactions in the PCEA group compared with IV-PCA, including fewer respiratory-related adverse outcomes overall.[17]

Table 14: Respiratory parameters compared with uploaded studies

Study	Respiratory findings	SpO_2 / oxygenation	Respiratory depression
Present study	RR: IV 12.00 ± 1.58; epidural 10.73 ± 1.46; p=0.002	SpO_2: IV 97.10 ± 1.94%; epidural 98.47 ± 1.20%; p=0.002	IV: 1/30; epidural: 0/30
Meng et al.[14]	Not directly comparable	Not directly comparable	Side effects overall not significantly different between EA and IV-PCA
Singh et al.[15]	Not directly comparable	Not directly comparable	Minimal side effects reported with CWI
Kavishvar and Prajapati[16]	No major respiratory compromise reported	SpO_2 >97% in both groups	No respiratory depression in both groups
Wu and Zhi[17]	PCEA associated with better recovery profile	Not directly comparable	Fewer adverse events in PCEA group

Adverse-effect comparison

In the present study, the adverse-effect profile was broadly comparable between groups. Nausea and vomiting was the most common adverse effect, occurring in 5 patients, 16.7%, in the IV group and 6 patients, 20.0%, in the epidural group. This is consistent with the known emetogenic potential of tramadol.

Kavishvar and Prajapati also reported nausea in both tramadol PCA groups: 4 patients in the tramadol-only group and 5 patients in the tramadol+dexmedetomidine group, with no significant difference. They reported no vomiting, respiratory depression, bradycardia, hypotension, arrhythmia, or dry mouth.[16]

Meng et al. found no significant difference in nausea and vomiting between epidural analgesia and IV-PCA in their meta-analysis.[14] This supports the present finding that adverse effects were not significantly different between the IV and epidural tramadol groups.

In the present study, urinary retention and headache/PDPH occurred only in the epidural group. Although not statistically significant, this is clinically relevant because these effects may be related to neuraxial technique or epidural catheter use. Wu and Zhi reported fewer total adverse reactions in the PCEA group than in the IV-PCA group after hip arthroplasty, but their adverse-effect profile differs because the population and analgesic drugs were different.[17]

Overall adverse-event burden

The overall adverse-event burden in the present study was not significantly different. At least one adverse event was seen in 12/30 patients, 40.0%, in the IV tramadol group and 14/30 patients, 46.7%, in the epidural tramadol group. This supports the conclusion that both routes were clinically acceptable.

Meng et al. similarly found no difference in side effects between epidural analgesia and IV-PCA, although epidural analgesia had better analgesic efficacy in their meta-analysis.[14] Singh et al. reported continuous wound infiltration as effective with minimal side effects, but the comparison involved levobupivacaine and morphine rather than tramadol.[15] Kavishvar and Prajapati showed that tramadol PCA was generally safe, with nausea as the main adverse effect.[16] Wu and Zhi reported fewer adverse reactions in the PCEA group, which differs from the present study where epidural tramadol had a slightly higher but statistically non-significant adverse-event burden.[17]

Drug consumption and PCA demand comparison

The present study did not record total tramadol consumption or number of PCA demands. This is an important limitation because equal VAS scores may occur despite differences in drug consumption.

Singh et al. reported postoperative morphine consumption after 48 hours as 18 ± 12.82 mg in the continuous wound infiltration group, 22.92 ± 9.88 mg in the continuous epidural infusion group, and 41.56 ± 8.83 mg in the IV-PCA group, with $p<0.001$.[15] This shows that regional/local techniques can reduce systemic opioid requirement.

Kavishvar and Prajapati reported that total tramadol consumption over 24 hours was 182.4 ± 82.5 mg in the tramadol-only group and 137.66 ± 45.61 mg in the tramadol+dexmedetomidine group, showing approximately 25% reduction in tramadol requirement when dexmedetomidine was added.[16]

Regarding adverse effects, the present study found no statistically significant difference between groups. Nausea and vomiting was the most common adverse effect in both groups, consistent with the known adverse-effect profile of tramadol and with the findings of Kavishvar and Prajapati.[16] Urinary retention and headache/PDPH occurred only in the epidural tramadol group in the present study, although these differences were not statistically significant. This observation is clinically important because these complications may be route-related and should be monitored when epidural analgesia is used.

Overall, the present study suggests that both IV and epidural tramadol PCA are effective and safe for postoperative analgesia after caesarean section. Epidural tramadol showed a favourable distribution of pain scores, with no patient having VAS ≥4, but it did not significantly reduce mean VAS compared with IV tramadol. Therefore, based on the present data, epidural tramadol cannot be concluded to be superior to IV tramadol. Future studies should include larger sample sizes, serial VAS monitoring at defined postoperative intervals, total tramadol consumption, PCA demand frequency, maternal satisfaction, breastfeeding comfort, ambulation time, and neonatal safety outcomes.

CONCLUSION

In the present study, both intravenous tramadol PCA and epidural tramadol PCA provided effective postoperative analgesia following caesarean section. The mean VAS pain score was low in both groups, and there was no statistically significant difference between the IV tramadol group and the epidural tramadol group. Therefore, epidural tramadol did not demonstrate statistically superior analgesic efficacy compared with intravenous tramadol in this study.

Hemodynamic and respiratory parameters showed some statistically significant differences between the two groups, with lower heart rate, lower diastolic blood pressure, lower respiratory rate and higher SpO_2 in the epidural tramadol group. However, these values remained within clinically acceptable limits in both groups. The adverse-effect profile was also broadly comparable. Nausea and vomiting was the most common adverse effect in both groups. Urinary retention and headache/PDPH were observed only in the epidural tramadol group, while respiratory depression was observed only in one patient in the intravenous tramadol group; however, none of these differences reached statistical significance.

Based on the findings of this study, intravenous tramadol PCA can be considered an effective and practical alternative to epidural tramadol PCA for postoperative analgesia after caesarean section, especially when epidural catheter placement is not feasible or clinically preferred. Epidural tramadol may offer a favourable pain-score distribution, as no patient in the epidural group had a VAS score ≥4, but it cannot be concluded to be superior to intravenous tramadol based on the present data. Larger prospective randomized studies with serial VAS assessment, total tramadol consumption, PCA demand frequency, maternal satisfaction, breastfeeding outcomes and neonatal safety assessment are recommended.

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