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A Comparative Study on the Analgesic Efficacy of Ketorolac Versus Tramadol in Managing Postoperative Pain Following Median Sternotomy in Cardiac Surgery Patients

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Keywords

Postoperative pain, Sternotomy, Cardiac surgery, Ketorolac, Tramadol, Randomized controlled trial

ABSTRACT:

Background: Postoperative pain following median sternotomy remains a significant challenge despite advances in analgesic strategies. Effective pain control is crucial to prevent hemodynamic instability and enhance recovery after cardiac surgery.

Objective: To analyze the analgesic effects of Ketorolac and Tramadol injections on postoperative pain reduction at 12 and 24 hours following median sternotomy.

Methods: This was a prospective, double-blinded, randomized controlled trial conducted at a single tertiary care center in Puducherry, India, over a six-month period. Sixty patients undergoing cardiac surgery via sternotomy were randomized to receive either intravenous Ketorolac or Tramadol, and postoperative pain was assessed using VAS and Wong–Baker FACES scales at 12 and 24 hours.

Results: A total of 92 patients were assessed for eligibility, out of which 60 were enrolled and randomized equally into two groups: Group A (Ketorolac) and Group B (Tramadol). Baseline characteristics such as age, gender, comorbidities, diagnosis, and type of cardiac surgery were comparable between the groups. The mean age was 56.2 ± 13.4 years in the Ketorolac group and 51.7 ± 11.2 years in the Tramadol group. There was no significant difference in the duration of mechanical ventilation (11.5 hours in both groups), but patients in the Ketorolac group had significantly shorter ICU stays (3.1 ± 0.3 vs. 3.4 ± 0.5 days, $p = 0.002$) and hospital stays (6.5 ± 0.5 vs. 7.3 ± 0.9 days, $p < 0.001$). At 24 hours, the Ketorolac group showed significantly lower pulse rate and diastolic blood pressure. Pain scores were significantly lower in the Ketorolac group at both 12 and 24 hours based on VAS and Wong–Baker FACES scales ($p < 0.05$), indicating better analgesic efficacy.

Conclusion: Ketorolac demonstrated superior analgesic efficacy compared to Tramadol in managing postoperative pain following cardiac surgery via sternotomy. It was associated with lower pain scores, greater hemodynamic stability, and shorter ICU and hospital stays.

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Introduction

Median sternotomy remains the gold standard approach in cardiac surgery due to its excellent surgical exposure, technical ease, and favorable long-term outcomes, with minimal failure rates when compared to alternative access methods.(1, 2) However, postoperative pain following sternotomy continues to pose a significant clinical challenge. Despite advancements in perioperative care, achieving effective and sustained analgesia remains elusive in many patients, particularly in the early postoperative period.(3) Inadequate pain control after cardiac surgery can result in a cascade of physiological and psychological consequences. Uncontrolled pain leads to elevated catecholamine levels, which can trigger hemodynamic instability, myocardial ischemia, and increase the risk of postoperative bleeding.(4, 5) Moreover, insufficient pain relief negatively impacts pulmonary function by discouraging deep breathing and coughing, thus increasing the risk of atelectasis and pneumonia. Additionally, reduced mobility due to pain is associated with a higher incidence of thromboembolic events and delays in functional recovery. Psychologically, persistent pain contributes to sleep disturbances, anxiety, and delayed rehabilitation.(6)

Various analgesic strategies are employed to manage postoperative pain in cardiac surgical patients, including opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), sedatives, and multimodal analgesia protocols.(7) Among opioids, Tramadol is widely used due to its central mechanism of action and relatively safer profile. It acts as a weak μ-opioid receptor agonist and inhibits the reuptake of serotonin and norepinephrine, thereby modulating descending inhibitory pain pathways.(8, 9) Though effective, Tramadol is associated with side effects such as nausea, dizziness, somnolence, constipation, and pruritus, and its efficacy in the context of acute postoperative pain in high-intensity procedures like sternotomy remains debated.(10)

In contrast, Ketorolac, a non-selective NSAID, is commonly utilized for postoperative analgesia due to its anti-inflammatory, antipyretic, and analgesic properties. It exerts its effect through inhibition of cyclooxygenase (COX)-1 and COX-2 enzymes, thereby reducing prostaglandin synthesis at the site of injury and inflammation.(11) Ketorolac has shown promise in managing postoperative pain after cardiac surgery by reducing the need for opioids and improving patient comfort.(12) However, its use must be balanced against potential adverse effects, particularly gastrointestinal bleeding and renal impairment, especially at higher doses or prolonged use. Given the distinct mechanisms of action, efficacy profiles, and safety concerns of Tramadol and Ketorolac, it is imperative to establish evidence-based comparisons to guide clinical decision-making in postoperative pain management. Against this background, the objective of this study was to analyze the analgesic effects of Ketorolac and Tramadol injections on postoperative pain reduction at 12 and 24 hours following median sternotomy.

Materials and Methods

This was a single center, hospital-based, prospective, double blinded, randomized controlled trail conducted in the Department of Cardiothoracic and Vascular Surgery (CTVS), Mahatma Gandhi Medical College and Research Institute, Puducherry, India over a period of six months, between July 2023 and December 2023. The study was approved by the Institutional Human Ethics Committee (IHEC), and ethical principles outlined in the Declaration of Helsinki were strictly adhered to throughout the study period. Prior to enrolment, all participants were provided with a Participant Information Sheet (PIS) in a language they understood, and the contents were thoroughly explained. Informed and written consent was subsequently obtained from each participant. The study included patients 18 to 75 years of age, of both gender, undergoing cardiac surgeries through sternotomy. However, high risk emergent cardiac cases and patients with preexisting chronic kidney disease were excluded.

The sample size was calculated based on the ability to detect a clinically significant difference in postoperative pain scores between the Ketorolac and Tramadol groups at 12- and 24-hours following sternotomy. Assuming a two-sided significance level (α) of 0.05 and a power (1-β) of 80%, the minimum detectable difference in mean pain scores was estimated at 1.5 units on a Visual Analogue Scale (VAS), with a standard deviation of 2.0. Using the formula for comparing two independent means, the minimum required sample size was 28 participants per group. To account for possible dropouts or loss to follow-up, the sample size was increased to 30 participants in

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each group, resulting in a total sample size of 60 patients. Participants were randomized into two groups using a computer-generated block randomization list, ensuring equal allocation. The randomization sequence was maintained by a third party not involved in the study to preserve allocation concealment. Group assignments were placed in sequentially numbered, opaque, sealed envelopes and opened only after patient enrolment. The study followed a double-blinded design in which both the patients and the investigators assessing outcomes were unaware of the group allocations. The drugs were prepared and administered by nursing staff not involved in outcome assessment to maintain blinding integrity.

A total of 60 patients were enrolled and evenly distributed into two study arms, with 30 in each group. Group A received Injection Ketorolac 30 mg intravenously every 8 hours, while Group B received Injection Tramadol 50 mg intravenously every 8 hours. The first dose of the allocated analgesic was administered at the completion of surgery upon transfer to the postoperative intensive care unit. The analgesic efficacy of both drugs was assessed using two validated pain assessment tools: the Visual Analogue Scale (VAS) and the Wong–Baker Faces Pain Rating Scale. Pain scores were recorded at 12 and 24 hours postoperatively by a trained observer blinded to group allocation. Standardized instructions were provided to patients prior to pain assessment to ensure understanding and consistency. All other perioperative care, including anesthetic and surgical techniques, was standardized and adhered to institutional protocols. Data on demographic characteristics, clinical parameters, and pain scores were recorded in a structured case record form. Any adverse events or requirements for rescue analgesia were also documented.

Statistical analysis: Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as means and standard deviations (SD) for continuous variables, and frequencies with percentages for categorical variables. The normality of continuous variables was assessed using the Shapiro–Wilk test. Comparisons of baseline demographic and clinical variables between the Ketorolac and Tramadol groups were conducted using the independent samples t-test for normally distributed continuous data and the chi-square test (or Fisher's exact test where appropriate) for categorical variables. Repeated measures of continuous variables such as pulse rate, blood pressure, respiratory rate, SpO_2, VAS score, and Wong–Baker FACES Pain Rating Scale at 12 and 24 hours were compared between groups using independent samples t-tests. A p-value of less than 0.05 was considered statistically significant. All statistical tests were two-tailed. No imputation was performed for missing data, as there were no losses to follow-up or dropouts in this study.

Results

A total of 92 patients were assessed for eligibility, out of which 32 were excluded (26 did not meet inclusion criteria and 6 declined participation). Sixty patients were randomized equally into Group A (Ketorolac) and Group B (Tramadol), with all receiving their allocated interventions. There were no losses to follow-up, and all 60 participants were included in the final analysis. The baseline characteristics of the two study groups—Ketorolac (n = 30) and Tramadol (n = 30)—were largely comparable. The mean age in the Ketorolac group was 56.2 ± 13.4 years, while it was 51.7 ± 11.2 years in the Tramadol group ($p = 0.334$). The age distribution, gender ratio, and presence of comorbidities showed no significant differences between groups ($p > 0.05$). The majority of patients were male (70.0% in Ketorolac, 73.3% in Tramadol), and most had coronary artery disease (66.7% vs. 60.0%). The types of surgical procedures—CABG, MVR, and AVR—were similarly distributed across both groups. The mean duration of mechanical ventilation was identical (11.5 hours) in both groups ($p = 1.000$). However, statistically significant differences were observed in ICU stay and hospital stay durations. Patients in the Tramadol group had a longer ICU stay (3.4 ± 0.5 days) compared to the Ketorolac group (3.1 ± 0.3 days, $p = 0.002$), and a longer hospital stay (7.3 ± 0.9 days vs. 6.5 ± 0.5 days, $p < 0.001$).

The comparison of postoperative clinical parameters between the Ketorolac and Tramadol groups revealed significant differences in pain scores and selected hemodynamic variables. At 24 hours, the mean pulse rate was significantly lower in the Ketorolac group (88.3 ± 17.7 bpm) compared to the Tramadol group (99.5 ± 14.6 bpm; $p = 0.008$). Systolic blood pressure values at 12 and 24 hours were similar between groups ($p = 0.740$ and $p = 0.671$, respectively), though overall comparisons across

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time points indicated statistical significance ($p < 0.05$). Diastolic blood pressure at 24 hours was significantly lower in the Ketorolac group (63.5 ± 8.6 mmHg) than in the Tramadol group (71.5 ± 7.5 mmHg; $p = 0.002$). Respiratory rate and oxygen saturation (SpO_2) were comparable across groups at both time points ($p > 0.05$). Importantly, patients in the Ketorolac group reported significantly lower pain levels at both 12 and 24 hours, as evidenced by lower VAS scores (5.7 ± 1.1 vs. 6.3 ± 1.9 at 12 hours, $p = 0.009$; and 3.3 ± 1.2 vs. 4.1 ± 1.1 at 24 hours, $p = 0.004$) and Wong–Baker FACES scores (5.2 ± 1.4 vs. 5.8 ± 1.7 at 12 hours, $p = 0.034$; and 2.6 ± 1.0 vs. 4.0 ± 1.3 at 24 hours, $p < 0.001$), indicating superior analgesic efficacy of Ketorolac.

Discussion

This prospective, double-blinded, randomized controlled trial evaluated and compared the analgesic efficacy and associated clinical outcomes of intravenous Ketorolac and Tramadol in patients undergoing cardiac surgery via median sternotomy. The demographic and clinical characteristics of participants in both study groups were comparable at baseline, reducing the likelihood of confounding and thereby enhancing the internal validity of the observed treatment effects. Ketorolac demonstrated superior analgesic efficacy compared to Tramadol, as evidenced by significantly lower VAS and Wong–Baker FACES pain scores at both 12 and 24 hours postoperatively. These findings are consistent with Liu et al. (2024) and Saini et al. (2020) that underscores the potent analgesic properties of Ketorolac, a nonsteroidal anti-inflammatory drug (NSAID) that inhibits cyclooxygenase (COX) enzymes and reduces prostaglandin synthesis, thereby alleviating pain and inflammation.(13, 14) In contrast, Tramadol, a centrally acting synthetic opioid, exerts its effects through weak μ-opioid receptor agonism and inhibition of serotonin and norepinephrine reuptake, which may offer less effective relief in acute postoperative settings, particularly in high-intensity pain scenarios such as sternotomy.(8)

Hemodynamic parameters, particularly pulse rate and diastolic blood pressure, further support the more favorable profile of Ketorolac. At 24 hours postoperatively, patients in the Ketorolac group had significantly lower pulse rates and diastolic blood pressures, which may reflect superior pain control and reduced sympathetic activation compared to the Tramadol group. These physiological effects are important in the postoperative cardiac surgery population, where maintaining stable hemodynamics is critical to recovery and prevention of complications.(15) Additionally, patients in the Ketorolac group experienced shorter durations of ICU and hospital stays compared to those in the Tramadol group, suggesting broader implications for recovery and resource utilization. This finding aligns with reports indicating that optimal postoperative pain control contributes to earlier mobilization, reduced stress response, and fewer cardiopulmonary complications, ultimately leading to improved clinical outcomes and decreased length of hospitalization.(6)

Despite concerns regarding the use of NSAIDs like Ketorolac in postoperative cardiac patients—particularly the risk of bleeding and renal dysfunction—recent evidence suggests that short-term use of Ketorolac at recommended doses is safe and not associated with increased perioperative complications when appropriately monitored.(16-19) In our study, no adverse events necessitated withdrawal or rescue analgesia, affirming the safety of both drugs under controlled conditions. The absence of dropouts and the successful completion of follow-up for all participants further strengthen the reliability of the study's conclusions.

The present study has several limitations. Firstly, the sample size was relatively small, which may limit the statistical power and generalizability of the findings to broader patient populations. Being a single-center study, the results may also reflect institutional practices that are not universally applicable. Additionally, the study evaluated outcomes over a relatively short duration, focusing primarily on pain scores at 12 and 24 hours postoperatively; longer-term outcomes, including pain at later time points, opioid-sparing effects, and complications such as bleeding or renal impairment, were not assessed. Although randomization and blinding were employed, the study did not stratify patients based on comorbid conditions or specific surgical procedures, which could influence pain perception and analgesic response. Moreover, the use of subjective pain assessment tools, while standardized, can be influenced by individual variability and may not fully capture the multidimensional experience of postoperative pain.

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Conclusion

In conclusion, this prospective, double-blinded, randomized controlled study demonstrated that Ketorolac provided significantly better postoperative analgesia compared to Tramadol in patients undergoing cardiac surgery via median sternotomy. Patients in the Ketorolac group experienced lower pain scores at both 12 and 24 hours postoperatively, along with improved hemodynamic stability and shorter durations of ICU and hospital stay. These findings suggest that Ketorolac is a more effective and potentially advantageous alternative to Tramadol for managing acute postoperative pain in this clinical setting.

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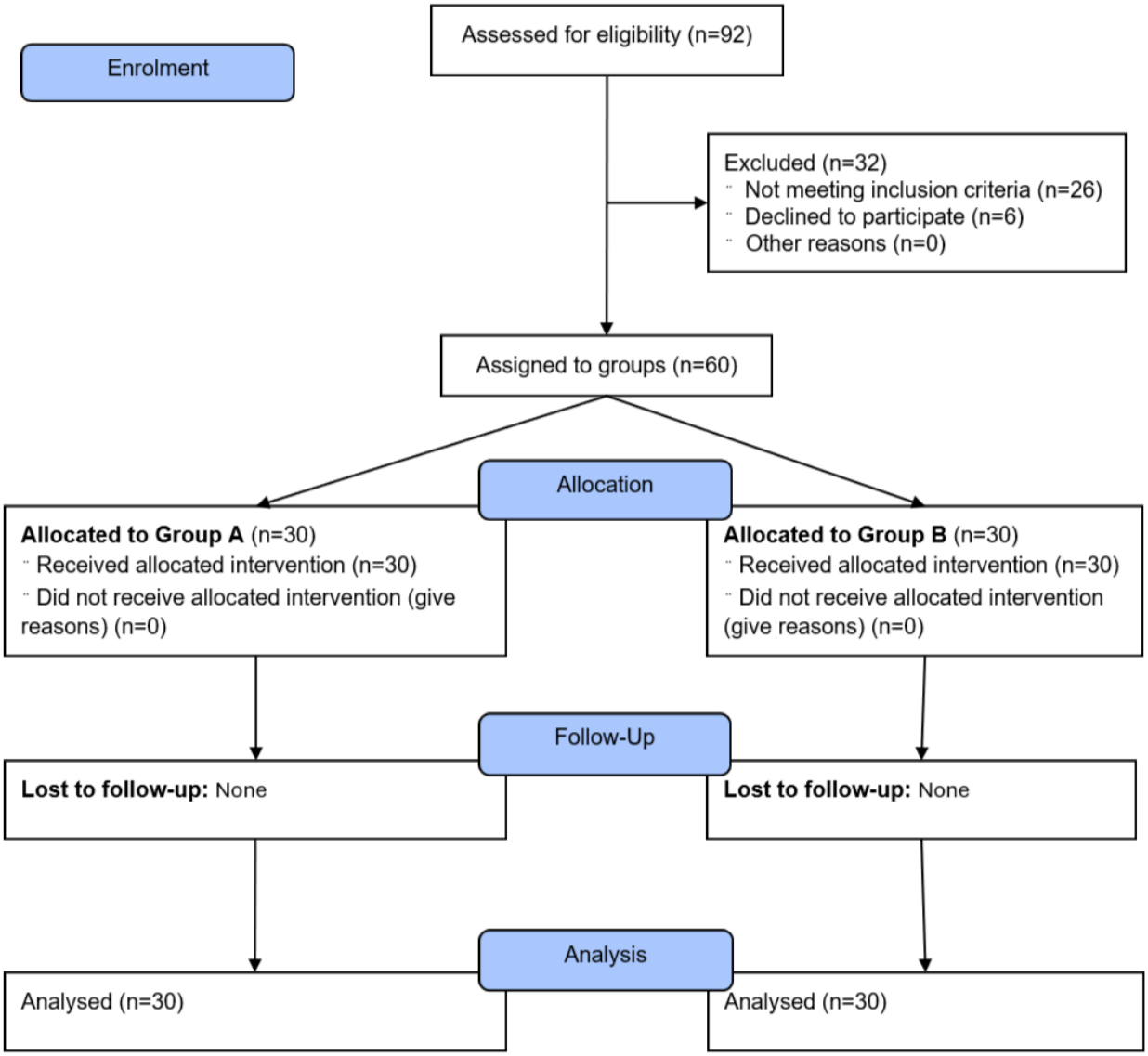

Figure 1: Study flowchart

Table 1. Baseline Demographic and Clinical Characteristics of Study Participants

		Group Ketorolac N = 30	**Group Tramadol N = 30**	**P value**
		n (%)	**n (%)**	
Age (in years), Mean (SD)		56.2 (13.4)	51.7 (11.2)	0.334
Age (in years)	≤40	6 (20.0)	8 (26.7)	0.564
	40 to 60	14 (46.7)	15 (50.0)	
	>60	10 (33.3)	7 (23.3)	
Gender	Male	21 (70.0)	22 (73.3)	0.774
	Female	9 (30.0)	8 (26.7)	
Comorbidities	Present	18 (60.0)	16 (53.3)	0.598

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	Absent	12 (40.0)	14 (46.7)	
Diagnosis	CAD	20 (66.7)	18 (60.0)	0.778
	RHD	6 (20.0)	7 (23.3)	
	ASD	4 (13.3)	5 (16.7)	
Procedure	CABG	22 (73.3)	21 (70.0)	0.893
	MVR	5 (16.7)	6 (20.0)	
	AVR	3 (10.0)	3 (10.0)	
Duration of mechanical ventilation (hours), Mean (SD)		11.5 (5.3)	11.5 (2.3)	1.000
ICU stay (days), Mean (SD)		3.1 (0.3)	3.4 (0.5)	0.002*
Duration of hospital stay (days), Mean (SD)		6.5 (0.5)	7.3 (0.9)	<0.001*
CAD, Coronary Artery Disease; RHD, Rheumatic Heart Disease; ASD, Atrial Septal Defect; CABG, Coronary Artery Bypass Grafting; MVR, Mitral Valve Replacement; AVR, Aortic Valve Replacement; SD, Standard Deviation *Statistically significant at p<0.05				

Table 2. Comparison of Postoperative Vital Parameters and Pain Scores Between Ketorolac and Tramadol Groups

		Group Ketorolac N = 30	**Group Tramadol N = 30**	**P value**
		Mean (SD)	**Mean (SD)**	
Pulse rate	At 12 hours	93.9 (15.2)	98.5 (17.3)	0.990
	At 24 hours	88.3 (17.7)	99.5 (14.6)	0.008*
P value		0.168	0.799	
Systolic BP	At 12 hours	127.8 (11.2)	128.9 (10.9)	0.740
	At 24 hours	114.5 (11.2)	115.7 (8.2)	0.671
P value		0.017*	0.009*	
Diastolic BP	At 12 hours	69.9 (5.7)	68.4 (5.5)	0.343
	At 24 hours	63.5 (8.6)	71.5 (7.5)	0.002*
P value		0.041*	0.220	
Respiratory rate	At 12 hours	20.3 (2.9)	20.4 (2.6)	0.941
	At 24 hours	20.3 (2.0)	20.9 (2.3)	0.373
P value		1.000	0.591	
SPO_2	At 12 hours	99.3 (1.1)	99.0 (1.2)	0.405
	At 24 hours	99.2 (1.0)	98.7 (1.7)	0.263
P value		1.000	0.252	
VAS score	At 12 hours	5.7 (1.1)	6.3 (1.9)	0.009*
	At 24 hours	3.3 (1.2)	4.1 (1.1)	0.004*
P value		<0.001*	<0.001*	
Wong-Baker FACES Pain Rating Scale	At 12 hours	5.2 (1.4)	5.8 (1.7)	0.034*
	At 24 hours	2.6 (1.0)	4.0 (1.3)	<0.001*
P value				
SD, Standard Deviation *Statistically significant at p<0.05				

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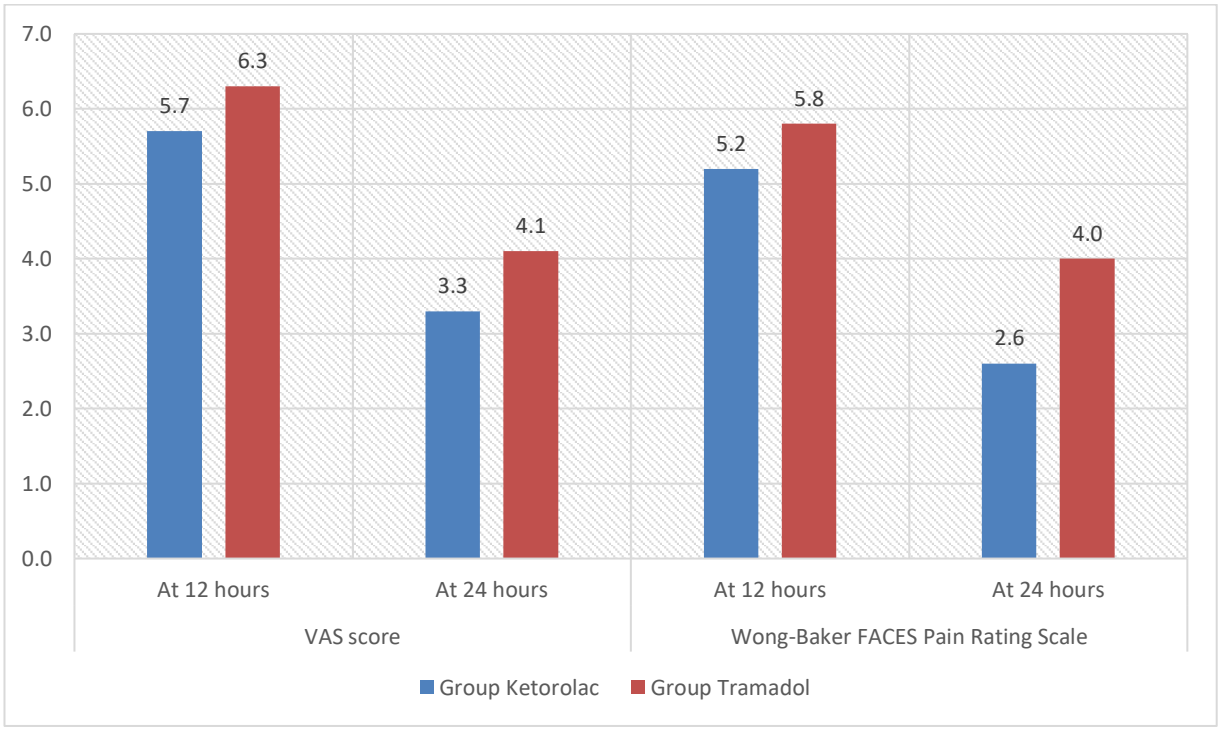

Figure 2: Comparison of Postoperative Pain Scores Between Ketorolac and Tramadol Groups