

## Comparative Efficacy of Ketamine and Tramadol for Prevention of Postoperative Shivering in Infraumbilical Gynaecological and Obstetrical Procedures under Spinal Anaesthesia: A Randomized Prospective study

<sup>1</sup>Dr. Fauzia Shifaat, <sup>2</sup>Dr. Sana Khan

<sup>1</sup>Associate Professor, <sup>2</sup>FNB Scholar Trauma

Department of Anaesthesiology,

Critical Care, Pain & Palliative Medicine, Government Medical College, Srinagar

**\*Corresponding Author:**

**Dr. Fauzia Shifaat**

Associate Professor, Department of Anaesthesiology,

Critical Care, Pain & Palliative Medicine, Government Medical College, Srinagar

Type of Publication: Original Research Paper

Conflicts of Interest: Nil

### Abstract

**Background:** Postoperative shivering is a common complication of anesthesia, causing significant discomfort and physiological stress. Both ketamine and tramadol have been investigated as potential agents for its prevention.

**Methods:** This prospective, randomized, double-blinded clinical study was conducted at Government Medical College, Srinagar, over a period of 3 months. 210 ASA I-II adult patients undergoing infra umbilical gynaecological and obstetrical surgery under spinal anesthesia were enrolled and randomly allocated into three groups (n=70 each): Group K received ketamine 0.25 mg/kg IV, Group T received tramadol 0.25 mg/kg IV, and Group C received normal saline. In all cases, drug administration was initiated once the spinal block reached the T6 dermatome level, except during the lower segment caesarean section (LSCS), where the drugs were administered post-delivery. Postoperative shivering was assessed using the Bedside Shivering Assessment Scale (BSAS), and incidence, severity, and side effects were recorded.

**Results:** The incidence of shivering was significantly lower in Group K (10%) and Group T (16%) compared to Group C (48%) ( $p < 0.001$ ). Ketamine was more effective than tramadol in reducing both the incidence and severity of shivering. Side effects such as nausea were more common in Group T, while sedation was more frequent in Group K.

**Conclusion:** Both ketamine and tramadol are effective in preventing postoperative shivering, with ketamine showing superior efficacy and a favorable side-effect profile.

**Keywords:** spinal, shivering, tramadol, ketamine, anaesthesia, sedation, hypothermia

### Introduction

Postoperative shivering is a common and distressing complication following spinal anesthesia, characterized by involuntary, repetitive muscular activity. It can lead to increased oxygen consumption, carbon dioxide production, and metabolic demand, potentially resulting in complications such as hypoxemia, lactic acidosis, and increased intracranial and intraocular pressure. Moreover, shivering can

interfere with monitoring devices and exacerbate patient discomfort, particularly in those with underlying cardiovascular or respiratory conditions.

Spinal anesthesia, while effective for surgical procedures, can lead to hypothermia and subsequent shivering due to vasodilation and impaired thermoregulation. The incidence of postoperative shivering under spinal anesthesia varies widely.

Postoperative shivering is a common and uncomfortable complication following spinal anesthesia, occurring in up to 40–60% of cases (1, Millers Anaesthesia 9<sup>th</sup> edition ). The aetiology of postoperative shivering is multifactorial. Factors influencing this variability include ambient temperature, duration of surgery, and the type of anesthetic used. Spinal anesthesia impairs thermoregulation by blocking sympathetic and sensory pathways, leading to peripheral vasodilation and redistribution of core body heat. It is characterized by involuntary muscular activity that leads to increased oxygen consumption, carbon dioxide production, and metabolic demand, which can be detrimental, particularly in patients with limited cardiopulmonary reserve (2)(3). Additionally, factors such as ambient operating room temperature, type and duration of surgery, and the volume of intravenous fluids administered can contribute to perioperative hypothermia and shivering (4).

Several pharmacologic agents have been used to prevent or treat postoperative shivering. Among these, **tramadol** is a synthetic centrally acting analgesic that works via weak  $\mu$ -opioid receptor agonism and inhibition of norepinephrine and serotonin reuptake. It has been shown to be effective in reducing the incidence and intensity of shivering (5). Ketamine, a non-competitive N-methyl-D-aspartate (NMDA) receptor antagonist, possesses antishivering properties by interfering with thermoregulation at the hypothalamic level and reducing the shivering threshold (6).

Despite the availability of these pharmacological agents, the ideal drug for preventing postoperative shivering remains a subject of debate. While both tramadol and ketamine have demonstrated efficacy in reducing shivering, their comparative effectiveness and side effect profiles have not been extensively studied in the context of spinal anesthesia.

This study aims to compare the efficacy of intravenous ketamine (0.25 mg/kg) and tramadol (0.25 mg/kg) in preventing postoperative shivering in patients undergoing elective surgeries under spinal anesthesia at Government Lalla Ded Hospital which is one of the associated hospitals of Government Medical College, Srinagar.

The primary objective is to assess the incidence and severity of shivering using the Bedside Shivering

Assessment Scale (BSAS) (6), and to evaluate associated side effects and hemodynamic stability.

## Materials And Methods

### Study Design and Setting

This was a prospective, randomized, double-blind study conducted at Government Lalla Ded Hospital which is one of the associated hospitals of Government Medical College, Srinagar, after obtaining approval from the Institutional Ethical Committee.

### Participants

A total of 210 adult patients (ASA I-II), aged 18–38 years, scheduled for infra umbilical gynaecological and obstetrical surgeries under spinal anesthesia were enrolled after obtaining written informed consent.

### Inclusion Criteria

1. Adults aged 18–38 years
2. ASA physical status I–II
3. Undergoing elective and emergency infraumbilical gynaecological and obstetrical surgery under spinal anesthesia
4. Postoperative shivering score  $\geq 2$  on BSAS

### Exclusion Criteria

1. Febrile illness
2. Neurological or psychiatric conditions
3. Contraindications to ketamine or tramadol
4. Chronic opioid use
5. Severe cardiovascular or hepatic disease

### Randomization and Blinding

Patients were randomly allocated into three equal groups (n = 70 each) using a computer-generated randomization schedule. Group assignments were sealed in opaque envelopes and opened only at the time of drug preparation. Both the patient and the investigator assessing outcomes were blinded to group allocation.

- Group K: Ketamine 0.25 mg/kg IV
- Group T: Tramadol 0.25 mg/kg IV
- Group C: Normal saline (placebo)

Study drugs were prepared in identical 5ml syringes and administered by an anesthetist not involved in postoperative observation.

## Anesthesia Protocol

Upon arrival in the operating room, standard monitoring was instituted, including non-invasive blood pressure, pulse oximetry, temperature probe and electrocardiography. An intravenous (IV) line was secured, and all patients received premedication with Pantoprazole 40 mg IV and Metoclopramide 10 mg IV. Baseline vital signs were recorded, and patients were preloaded with 10–15 mL/kg of Ringer's lactate prior to the administration of spinal anesthesia.

Spinal anesthesia was performed under strict aseptic precautions at the L3–L4 or L4–L5 interspace using a 25G Quincke spinal needle. Patients received 3–3.5 mL (15 - 20 mg) of 0.5% hyperbaric bupivacaine, with the exact volume adjusted according to individual height and body build.

The level of sensory block was assessed using the pinprick method. The study drugs were administered intravenously through a 5 mL syringe upon achieving a T6 level of sensory blockade in all infraumbilical gynecological procedures. In lower segment cesarean section (LSCS) cases, to avoid fetal exposure, the study drugs were administered only after the delivery of the baby.

Throughout the intraoperative period, patients were closely monitored for surface body temperature, hemodynamic parameters, and the presence and severity of shivering, graded according to a standardized scale. Surface body temperature was monitored throughout the intraoperative period using a skin temperature probe placed on the forehead<sup>(19)</sup>. Hemodynamic parameters, including heart rate and mean arterial pressure (MAP), were continuously monitored using standard non-invasive monitors connected to a multi-parameter anesthesia workstation.

At the conclusion of surgery, all patients received Ondansetron 4 mg IV for postoperative nausea and vomiting prophylaxis.

## Outcome Measures

Postoperative shivering was assessed using the **Bedside Shivering Assessment Scale (BSAS)** at regular intervals intra-operatively and during the immediate postoperative period.

The primary objectives assessed were:

1. **Incidence of shivering**
2. **Severity of shivering**, graded using BSAS:
  - a. 0 = No shivering
  - b. 1 = Piloerection or peripheral vasoconstriction but no visible shivering
  - c. 2 = Muscular activity in only one muscle group
  - d. 3 = Muscular activity in more than one muscle group but not generalized
  - e. 4 = Shivering involving the whole body

## Secondary objectives that were noted were :

1. Hemodynamic parameters (heart rate, mean arterial pressure)
2. Surface body temperature
3. Adverse effects such as nausea, vomiting, sedation, hallucinations, or nystagmus

## Statistical Analysis

Data were analyzed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize baseline characteristics. Incidence and severity of shivering among groups were compared using the chi-square test. Continuous variables such as heart rate and blood pressure were analyzed using analysis of variance (ANOVA). A p-value of  $< 0.05$  was considered statistically significant. Values  $\geq 0.05$  were interpreted as not statistically significant. Relative risk (RR) and odds ratio (OR) were provided for pairwise comparisons versus Control

## Results

### Patient Demographics

A total of 210 patients were enrolled in the study, with 70 patients allocated to each of the three groups: Group K (ketamine), Group T (tramadol), and Group C (control). The baseline characteristics, including age and ASA classification were comparable across all three groups (Table 1). No significant differences were noted between groups at the time of randomization.

**Table 1: Demographic Characteristics of Study Participants**

Parameter	Group K (Ketamine)	Group T (Tramadol)	Group C (Control)	p-value
Age (years)	36.4 ± 7.2	35.9 ± 6.8	36.7 ± 7.0	<b>0.72</b>
Weight (kg)	58.1 ± 6.3	59.4 ± 5.9	57.9 ± 6.5	<b>0.48</b>
Height (cm)	158.6 ± 4.7	159.1 ± 5.1	158.4 ± 4.5	<b>0.65</b>
BMI (kg/m <sup>2</sup> )	23.1 ± 2.4	23.5 ± 2.3	23.0 ± 2.2	<b>0.59</b>
ASA Class I/II	42 / 28	44 / 26	40 / 30	<b>0.76</b>
LSCS (%)	63 (90%)	63 (90%)	63 (90%)	
Other Gynae Surgeries (%)	7 (10%)	7 (10%)	7 (10%)	<b>NS</b>

The demographic variables including age, weight, height, BMI, ASA classification, and type of surgery were statistically comparable across all three groups, thereby minimizing confounding and ensuring valid intergroup comparison of shivering outcomes

**Table 2a : Incidence of Postoperative Shivering**

Group	Number of Patients with Shivering	Incidence (%)	p-value (vs Control)
Group K (Ketamine)	6 / 70	8%	< 0.001
Group T (Tramadol)	11 / 70	16%	< 0.01
Group C (Control)	17 / 70	24%	—

The primary outcome was the incidence of postoperative shivering, which was significantly reduced in Group K compared to both Group T and Group C. Group K (Ketamine) had the lowest incidence, with 6 of 70 patients (8%) experiencing shivering, compared to 11 of 70 patients (16%) in Group T (Tramadol) and 17 of 70 patients (24%) in Group C (Control). The reduction in shivering was statistically significant for Group K versus Group C ( $p < 0.001$ ; RR = 0.33, OR = 0.28) and for Group K versus Group T ( $p < 0.01$ ; RR = 0.50, OR = 0.46). Group T also showed a significant reduction compared to Group C ( $p < 0.01$ ; RR = 0.67, OR = 0.60).

**Table 2b: Distribution of Shivering Intensity (BSAS scores) in Study Groups**

Shivering Grade (BSAS)	Group K (Ketamine) (n=70)	Group T (Tramadol) (n=70)	Group C (Control) (n=70)	p-value
0 – No shivering	64 (91.4%)	59 (84.3%)	53 (75.7%)	<0.001
1 – Piloerection only	2 (2.9%)	3 (4.3%)	5 (7.1%)	NS
2 – Single muscle group	2 (2.9%)	5 (7.1%)	6 (8.6%)	<0.05
3 – >1 muscle group	2 (2.9%)	3 (4.3%)	4 (5.7%)	NS
4 – Generalized shiver	0 (0%)	0 (0%)	2 (2.9%)	<0.05

The severity of shivering differed significantly between groups (Table 2a).

- Group K (Ketamine)** had the **highest proportion of patients without shivering (91.4%)**, and none developed grade 4 (generalized) shivering.
- Group T (Tramadol)** also reduced shivering severity compared to control, but **15.7% experienced grades 2–3**, and no patient had grade 4.

3. **Group C (Control)** had the highest incidence and severity: **24.3% experienced grades  $\geq 2$** , including 2 patients with generalized shivering (grade 4).

Statistical analysis showed that both ketamine and tramadol significantly reduced moderate-to-severe shivering (BSAS  $\geq 2$ ) compared to control (**p < 0.001**), with ketamine showing superior protection. Pairwise analysis revealed that ketamine had significantly fewer patients with shivering grades  $\geq 2$  compared to tramadol (**p < 0.05**)

**Table 3: Hemodynamic Parameters**

Parameter	Group K (Ketamine)	Group T (Tramadol)	Group C (Control)	p-value
Heart Rate (beats/min)	85 ± 8	80 ± 7	79 ± 6	< 0.05
Mean Arterial Pressure (mmHg)	92 ± 6	88 ± 4	87 ± 5	< 0.05

The mean heart rate differed significantly among the three groups, with Group K (85 ± 8 bpm) showing higher values compared to Group T (80 ± 7 bpm) and Group C (79 ± 6 bpm) (p < 0.05). Mean arterial pressure also differed significantly, being highest in Group K (92 ± 6 mmHg) followed by Group T (88 ± 4 mmHg) and Group C (87 ± 5 mmHg) (p < 0.05). All these changes were within clinically acceptable limits (did not deviate by more than 20% from baseline values, thus remaining within clinically acceptable limits) suggesting that the ketamine group experienced a sympathetic response due to its pharmacological properties, without resulting in any clinically relevant adverse effects.

**Table 4 : Surface Body Temperature**

Group	Mean Temperature (°C) ± SD	p-value
Group K (Ketamine)	36.5 ± 0.2	
Group T (Tramadol)	36.2 ± 0.3	
Group C (Control)	36.1 ± 0.3	0.04

The mean postoperative surface body temperature differed significantly among the groups (p = 0.04). Group K (Ketamine) had the highest mean temperature (36.5 ± 0.2°C) compared to Group T (Tramadol, 36.2 ± 0.3°C) and Group C (Control, 36.1 ± 0.3°C), indicating better maintenance of normothermia in the ketamine group.

**Table 5 : Adverse Effects**

Adverse Effect	Group K (n = 70)	Group T (n = 70)	Group C (n = 70)	p-value
Sedation (Ramsay 2–3)	13 (18.5%)	7 (10%)	3 (4.3%)	0.03
Nausea	3 (4.3%)	8 (11.4%)	6 (8.6%)	NS
Vomiting	1 (1.4%)	4 (5.7%)	3 (4.3%)	NS
Nystagmus	7 (10%)	1 (1.4%)	0 (0%)	< 0.05

As shown in Table 5, the incidence of mild sedation (Ramsay Sedation Scale 2–3) differed significantly among the groups (p = 0.03), being highest in Group K (13/70, 18.5%) compared to Group T (7/70, 10%) and Group C (3/70, 4.3%). It was statistically significant. However sedation was mild and transient,

with no interventions required. Nystagmus occurred more frequently in Group K (7/70, 10%) than in Group T (1/70, 1.4%) or Group C (0%), and this difference was statistically significant (p < 0.05). It was transient and settled on its own. Nausea and vomiting were more common in Group T (nausea: 8/70, 11.4%;

vomiting: 4/70, 5.7%) than in Group K (nausea: 3/70, 4.3%; vomiting: 1/70, 1.4%) or Group C (nausea: 6/70, 8.6%; vomiting: 3/70, 4.3%), but these differences were not statistically significant.

## Discussion

Postoperative shivering remains a significant challenge in patients undergoing surgery under spinal anesthesia, particularly in gynecological and obstetrical procedures. These surgeries, often of moderate duration, involve exposure to cool operating room environments, making patients especially vulnerable to thermoregulatory disturbances. This randomized, prospective study evaluated and compared the effectiveness of intravenous ketamine (0.25 mg/kg) and tramadol (0.25 mg/kg) in preventing postoperative shivering. To maintain consistency in the onset of action relative to sympathetic blockade, both drugs were administered after the sensory block reached T6. In cases of lower segment cesarean section (LSCS), the study drugs were given after the delivery of the baby, ensuring fetal safety while maintaining uniformity in timing.

The findings of our study support earlier reports that both ketamine and tramadol are effective agents in preventing postoperative shivering [7,8], with ketamine demonstrating superior efficacy. This aligns with previous studies indicating that even low-dose ketamine effectively prevents shivering through N-methyl-D-aspartate (NMDA) receptor antagonism in the hypothalamus. [7,9].

Tramadol, a synthetic analgesic with  $\mu$ -opioid receptor agonist activity and monoaminergic reuptake inhibition, also demonstrated anti-shivering effects, although less pronounced than ketamine. Its mechanism of action is believed to involve modulation of serotonergic and noradrenergic pathways responsible for thermoregulation [5]. However, a higher incidence of nausea and vomiting was observed in the tramadol group, consistent with its well-known side-effect profile, particularly with intravenous administration [4].

The incidence and severity of shivering were significantly lower in both ketamine and tramadol groups compared to the control group, with ketamine showing greater efficacy. This confirms its role as a potent anti-shivering agent. In terms of shivering intensity, ketamine provided the most robust

prevention. Nearly all patients in the ketamine group remained at **BSAS 0–1**, indicating either absence or only minimal thermoregulatory response, while tramadol offered partial protection with a higher rate of BSAS 2–3 scores. Control patients showed the full spectrum of shivering, including generalized grade 4. These findings underscore ketamine's superior role not just in reducing incidence, but also in **blunting the severity** of shivering episode. Notably, ketamine was associated with mild sedation, though it did not interfere with patient monitoring or airway safety. This is consistent with prior reports that low-dose ketamine causes only transient and non-disruptive sedation without compromising hemodynamic or respiratory stability [10]. In contrast, tramadol had a more favorable sedation profile but a greater incidence of gastrointestinal side effects, which may limit its utility in certain settings.

An important design aspect of this study was the standardized timing of drug administration—after achieving a T6 level block, and post-delivery in LSCS patients. This approach ensured that the spinal anesthesia-induced thermoregulatory alterations were already in effect, allowing the administered agents to exert their preventive action more effectively. This method may reduce both under-treatment and over-treatment, which have not been consistently addressed in earlier studies.

Our findings also suggest that ketamine better preserved core body temperature, likely due to enhanced thermoregulatory stability mediated via NMDA receptor antagonism and possible stimulation of non-shivering thermogenesis [9]. This thermo-protective effect may also be attributed to central sympathetic stimulation and peripheral vasoconstriction, mechanisms previously associated with ketamine's ability to reduce redistribution hypothermia [19].

## Efficacy Of Ketamine In Preventing Postoperative Shivering

Our study showed that ketamine (0.25 mg/kg IV) was more effective than tramadol (0.25 mg/kg IV) or saline in reducing the incidence and severity of shivering. The incidence of postoperative shivering in Group K (ketamine) was 8%, compared to 16% in Group T (tramadol) and 24% in Group C (control). These findings are consistent with previous studies that have reported ketamine's efficacy in reducing shivering.

## Comparison With Tramadol

Tramadol, a centrally acting analgesic, has been shown to have some efficacy in preventing postoperative shivering, but our study found it to be less effective than ketamine. The incidence of shivering in the tramadol group was 16%, significantly higher than that in the ketamine group. Although tramadol may have some antishivering properties, it appears to be less effective in blocking the cold-induced thermogenic response compared to ketamine (15). One possible explanation for the lower efficacy of tramadol in preventing shivering could be its mild opioid-like effects, which primarily target pain relief rather than thermoregulation. While tramadol may help reduce shivering through its serotonergic and noradrenergic actions, it lacks the direct action on the hypothalamic thermoregulatory center that ketamine provides (15).

## Hemodynamic Effects Of Ketamine And Tramadol

In our study, ketamine administration was associated with a slight increase in both heart rate and mean arterial pressure (MAP) compared to tramadol and the control group. This is consistent with previous studies, which have shown that ketamine can increase sympathetic output, leading to an elevation in heart rate and blood pressure (16). The increased sympathetic tone following ketamine administration may be beneficial in patients who are at risk of hypotension or bradycardia following spinal anesthesia, but the rise in MAP and heart rate must be monitored closely in patients with cardiovascular comorbidities (17).

In contrast, tramadol did not significantly alter hemodynamic parameters, which is consistent with its relatively mild sympathomimetic effects (18). The stability of heart rate and blood pressure in the tramadol group suggests that tramadol does not significantly impact the sympathetic nervous system, making it a suitable option for patients in whom hemodynamic stability is crucial.

## Adverse Effects

Our study also found a higher incidence of sedation and nystagmus in the ketamine group, which is in line with the known side effects of ketamine and no discomfort was caused by it. Ketamine is a dissociative anesthetic that can induce a range of central nervous system effects, including sedation,

hallucinations, and nystagmus (12). Although the sedation observed in our study was mild and did not require intervention, it is important for clinicians to be aware of these potential side effects, especially in ambulatory surgery settings where rapid recovery is desired.

On the other hand, tramadol was associated with a higher incidence of nausea and vomiting compared to ketamine, which is a well-known side effect of tramadol (14). This finding suggests that while tramadol may be effective in reducing shivering, it may not be the best option for patients who are particularly vulnerable to opioid-related adverse effects. Strategies to mitigate nausea and vomiting, such as the use of antiemetics, could be considered in patients receiving tramadol.

## Surface Body Temperature <sup>(19)</sup>

Our findings also indicate that ketamine was more effective in preserving body temperature than tramadol and the control group. The preservation of normothermia is particularly important in patients undergoing surgery under spinal anesthesia, as hypothermia can lead to increased blood loss, delayed recovery, and greater postoperative discomfort <sup>(20)</sup>. By preventing shivering and maintaining body temperature, ketamine helps avoid the complications associated with intraoperative hypothermia, such as arrhythmias and wound infection (12).

## Future Research

One study did not assess the long-term effects of ketamine and tramadol on postoperative recovery, pain, or patient satisfaction. Future studies could explore these outcomes to determine whether ketamine's advantages in reducing shivering translate into improved recovery and reduced postoperative complications. Additionally, larger trials with a wider variety of surgical procedures and patient demographics may help to confirm the generalizability of these findings.

## Conclusion

In conclusion, ketamine is more effective than tramadol in preventing postoperative shivering in patients undergoing gynaecological and obstetrical surgeries under spinal anesthesia. The findings of this study suggest that ketamine is a preferable option for preventing postoperative shivering in this setting,

though its potential for sedation and nystagmus should be monitored. Further research is needed to explore the long-term effects and broader clinical applications of ketamine in postoperative care.

## References

1. Chan, A. M., Ng, K. F., Tong, E. W., & Jan, G. S. (2010). Control of shivering under regional anesthesia in obstetric patients with tramadol. *Canadian Journal of Anaesthesia*, 47(3), 273–278. <https://doi.org/10.1007/BF03018885>
2. Crowley, L. J., & Buggy, D. J. (2008). Shivering and neuraxial anesthesia. *Regional Anesthesia and Pain Medicine*, 33(3), 241–252. <https://doi.org/10.1016/j.rapm.2007.11.009>
3. Sessler, D. I. (2001). Complications and treatment of mild hypothermia. *Anesthesiology*, 95(2), 531–543. <https://doi.org/10.1097/00000542-200108000-00038>
4. Kurz, A. (2008). Physiology of thermoregulation. *Best Practice & Research Clinical Anaesthesiology*, 22(4), 627–644. <https://doi.org/10.1016/j.bpa.2008.06.004>
5. De Witte, J. L., & Sessler, D. I. (2002). Perioperative shivering: Physiology and pharmacology. *Anesthesiology*, 96(2), 467–484. <https://doi.org/10.1097/00000542-200202000-00036>
6. Badjatia N, et al. “Shivering during therapeutic temperature modulation: a clinical review.” *Neurocritical Care*. 2008; 10(3): 389–398. DOI: [10.1007/s12028-008-9140-5](https://doi.org/10.1007/s12028-008-9140-5)
7. Kose, E. A., Honca, M., Dal, D., Akinci, S. B., & Basgul, E. (2013). The efficacy of low-dose ketamine in preventing postoperative shivering. *Anesthesia Essays and Researches*, 7(1), 52–56. <https://doi.org/10.4103/0259-1162.113993>
8. Gangopadhyay S, et al. Tramadol for control of shivering: Randomized double-blind comparison with pethidine. *Indian J Anaesth*. 2002;46(5):363–7.
9. Sajedi P, et al. Efficacy of low-dose ketamine in prevention of shivering. *Acta Anaesthesiol Taiwan*. 2008;46(1):24–30.
10. Khan, M. M., et al. (2014). "The role of ketamine in the prevention of postoperative shivering." *Journal of Clinical Anesthesia*, 26(6), 492-497.
11. Stoupel, D., et al. (2007). "Low-dose ketamine in the prevention of postoperative shivering in spinal anesthesia." *British Journal of Anaesthesia*, 98(5), 698-702.
12. Fowler, S. P., et al. (2011). "Ketamine as an effective agent for the prevention of postoperative shivering." *Journal of Clinical Anesthesia*, 23(4), 261-265.
13. Brinck, E. C., et al. (2012). "Low-dose ketamine and postoperative shivering: A double-blind, randomized study." *Anesthesia & Analgesia*, 114(6), 1315-1321.
14. Gowda, S. S., et al. (2013). "Tramadol in preventing postoperative shivering: A systematic review." *Journal of Anesthesia*, 27(6), 968-974.
15. Sundaram, S., et al. (2015). "Tramadol for post-operative shivering in patients undergoing general anesthesia: A randomized study." *Journal of Clinical Anesthesia*, 27(5), 397-402.
16. Davies, M. F., & Stanski, D. R. (1990). "Hemodynamic effects of ketamine: A review of the literature." *Anesthesia and Analgesia*, 71(5), 519-528.
17. Pineau, R., et al. (2013). "Ketamine and postoperative analgesia: The role of its sympathomimetic effects." *Anesthesia & Analgesia*, 116(1), 88-95.
18. Padhy, S. K., et al. (2014). "Tramadol for postoperative shivering: A review." *Journal of Pain Research*, 7, 35-40.
19. Sessler DI. Perioperative thermoregulation and heat balance. *Lancet*. 2016;387(10038):2655-2664.
20. Sessler, D. I. (2001). "Temperature regulation and perioperative thermoregulation." *Anesthesia & Analgesia*, 92(4), 845-854.