

Effect of Comprehensive Warming Measures on Reducing Limb Pain During Recovery From Anaesthesia in Patients Undergoing Laparoscopic Cholecystectomy: A Retrospective Study

Ann. Ital. Chir., 2025 96, 10: 1315–1321
<https://doi.org/10.62713/aic.4335>

Bo Zheng^{1,2}, Haijuan He^{1,2}, Haixi Yan^{3,4}, Lili Wu¹

¹Department of Anesthesiology, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, 318000 Taizhou, Zhejiang, China

²Department of Anesthesiology, Enze Hospital, Taizhou Enze Medical Center (Group), 318000 Taizhou, Zhejiang, China

³Department of Clinical Laboratory, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, 318000 Taizhou, Zhejiang, China

⁴Department of Clinical Laboratory, Enze Hospital, Taizhou Enze Medical Center (Group), 318000 Taizhou, Zhejiang, China

AIM: This study aimed to explore the effect of comprehensive warming measures on reducing limb pain in patients undergoing laparoscopic cholecystectomy during recovery from anaesthesia.

METHODS: The medical records of 131 patients who underwent laparoscopic cholecystectomy in our hospital from June 2021 to June 2023 were retrospectively analyzed. According to the perioperative interventions administered, the samples were divided into a warming group ($n = 62$, in which comprehensive warming measures were applied, including preoperative forced-air warming, intraoperative use of warmed fluids and gases, and postoperative continuous warming) and a routine group ($n = 69$, in which routine management measures without active warming were applied, limited to maintenance of ambient room temperature, the use of standard draping and unheated fluids/gases). The Steward recovery score was used to evaluate the quality of anaesthesia recovery, and postoperative limb pain was assessed using the Visual Analogue Scale (VAS). Surgical indicators were also compared between the two groups.

RESULTS: Baseline data, as well as operation time and blood loss, were not significantly different between the two groups (all $p > 0.05$). Infusion volume and length of hospital stay were significantly different between the two groups ($p < 0.001$). In terms of the quality of anaesthesia recovery, level of consciousness, level of airway patency, and limb movement in the warming group were significantly higher than those in the routine group ($p < 0.05$). The postoperative VAS score in the warming group was significantly lower than that in the routine group ($p < 0.001$). Incidence of complications was not significantly different between the two groups ($p = 0.308$).

CONCLUSIONS: Comprehensive warming measures improved limb pain and recovery quality in patients undergoing laparoscopic cholecystectomy, highlighting their clinical value.

Keywords: perioperative warming; cholecystectomy; laparoscopic; anaesthesia recovery period; limb pain; retrospective studies

Introduction

Laparoscopic cholecystectomy (LC) represents one of the most common types of operations in general surgery [1]. It is regarded as the gold standard therapeutic approach for benign gallbladder diseases (such as gallstones and cholecystitis) [2] since it causes less trauma and enables rapid recovery [3]. However, postoperative pain (especially shoulder pain) is a common problem among patients undergoing LC [4] and is often related to CO₂ pneumoperitoneum, low temperature stimulation, inflammatory response and other factors [5]. However, the current study focused on perioperative limb pain, which is distinct from the aforementioned shoulder pain. In the Post-Anaesthesia Care Unit, hypothermia, shivering and restlessness can aggra-

vate pain perception and prolong recovery time [6]. The incidence rates of intraoperative hypothermia [7] (core temperature $<36^{\circ}\text{C}$) in male and female patients were 27.1% and 23.8%, respectively. This condition results in delayed drug metabolism, coagulation dysfunction and increased pain sensitivity. Hypothermia induces shivering, increases muscle contraction and oxygen consumption, and aggravates postoperative limb pain. Traditional analgesics such as opioids may cause side effects, including nausea, vomiting, and respiratory depression. However, the synergistic effects of non-pharmacological interventions such as warming are often overlooked [8]. The use of systemic warming measures, such as warming blankets, liquid warming, and ambient temperature control, can reduce intraoperative heat loss, maintain core body temperature, and reduce shivering and inflammatory responses [9]. Zhang *et al.* [10] found that the use of air warming blankets in combination with conventional warming measures effectively maintained the normal body temperature and reduced the incidence of accidental hypothermia during the perioperative period of elderly patients undergoing laparoscopic radical resection of colorectal cancer.

Submitted: 3 September 2025 Revised: 17 September 2025 Accepted: 19 September 2025 Published: 10 October 2025

Correspondence to: Lili Wu, Department of Anesthesiology, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, 318000 Taizhou, Zhejiang, China (e-mail: wulili@enzemed.com).

Most existing studies focus on the effect of warming on hypothermia or the overall recovery, but few works have specifically investigated its effect on limb pain, such as pneumoperitoneum-related shoulder pain. Perioperative hypothermia is known to trigger shivering, which causes sustained involuntary muscle contractions. These contractions increase oxygen consumption, induce metabolic stress, and can result in diffuse postoperative myalgia, which is often reported by patients as limb pain. Therefore, systemic warming may alleviate limb pain indirectly by preventing shivering and improving peripheral circulation. This study aims to analyze the effects of comprehensive warming measures (which refers to a standardized multimodal protocol including preoperative prewarming, intraoperative forced-air warming, and the use of warmed infusions/CO₂, as well as postoperative continuous warming and airway humidification) on limb pain in patients undergoing LC during recovery from anaesthesia.

Materials and Methods

General Information

In this retrospective study, a total of 131 patients who underwent LC in Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University from June 2021 to June 2023 were selected as the research subjects. The participant screening process is illustrated in Fig. 1. This study was conducted in accordance with the principles of the Declaration of Helsinki [11]. Ethical approval has been obtained from the Ethics Committee of Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University (Approval No. K20250846(EZ)).

Inclusion and Exclusion Criteria

Inclusion Criteria

The inclusion criteria are as follows: (1) complete medical records; (2) American Society of Anesthesiologists (ASA) grades I–II; and (3) 18–65 years old.

Exclusion Criteria

The exclusion criteria are as follows: (1) intraoperative complications, such as rupture of the bile duct and anatomical challenges in the hepatocystic (Calot's) triangle; (2) comorbidity with acute cholecystitis or malignant tumor; and (3) mental confusion or loss of consciousness, or patients with diabetic foot.

Implementation Plan

Participants in this study were categorized based on the type of perioperative management measures received, as documented in the medical records. The multimodal warming protocol was applied to patients in the warming group based on the clinical team's decision in selecting the type of warming measures for patients during the study period, whereas patients in the routine group received the hospital's standard care without active warming measures.

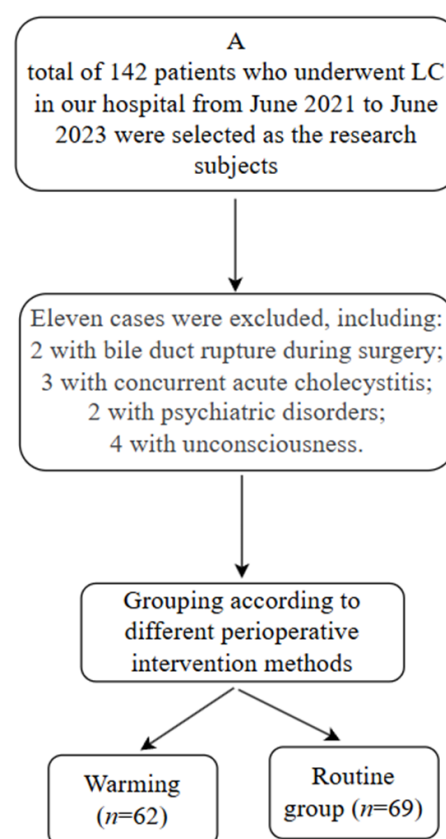


Fig. 1. Screening process of study participants. LC, Laparoscopic cholecystectomy.

Routine Group

Routine measures, which were implemented during the operation, encompass the following: Intraoperative anesthesia, including the use of opioids such as remifentanyl, was routinely administered by the same anesthesiology team. However, detailed individual opioid dosages were not uniformly documented in the medical records and could not be analyzed as covariates. Pneumoperitoneum was established according to the institutional standards, with intra-abdominal pressure maintained between 8 and 12 mmHg. Patients in the routine group received standard perioperative care without the active warming measures, including basic thermal management with ambient room temperature (23–25 °C), standard draping, and the use of unheated fluids/gases, along with routine monitoring of vital signs in patients and standard postoperative wound care.

Warming Group

Comprehensive warming measures were implemented for every patient in the warming group. The warming interventions were carried out in the following order:

- (1) In the preoperative evaluation, core body temperature (such as nasopharyngeal or tympanic membrane temperature) of patients was measured and recorded one hour be-

fore surgery. Nevertheless, continuous temperature trajectories were not uniformly documented across all patients and were therefore not included in this retrospective analysis. If the body temperature is lower than 36 °C, the operation should be delayed, accompanied by the application of active warming measures. Identify high-risk factors based on the 2023 consensus on the prevention and treatment of hypothermia, focusing on high-risk factors such as age (>60 years), low body mass index (BMI), ASA grade $\geq$ II, and preoperative hypothermia [12].

(2) For prewarming, a forced-air warming blanket was used to cover the trunk and limbs of patients 20 minutes before anaesthesia induction, and the temperature was set at 38–40 °C to reduce heat redistribution. The operating room temperature was controlled to minimize patient exposure time and help maintain normothermia. If preoperative fluid infusion is needed, the fluid is heated to 37 °C by using an infusion heater.

(3) Following anaesthesia induction, patients' body temperature was generally monitored every 15–30 minutes according to routine practice; however, due to variability in documentation, continuous trajectories were not uniformly available from all patients. During the operation, a forced-air warming blanket was used continuously, ensuring that it did not come into contact with the surgical field. Pneumoperitoneum was established using heated and humidified CO₂ (37 °C) to reduce heat loss as a result of cold gas exposure to the peritoneum. All intravenous fluids (including blood transfusions) were heated to 37 °C, and the peritoneal irrigation fluid was heated to 38–40 °C to avoid direct exposure of the internal organs. A thermal insulation blanket was used to cover the non-surgical area, and only the necessary parts of the surgical field were exposed. The temperature of the operating table was adjusted to 37–40 °C to prevent heat loss through conduction.

(4) During the recovery period from anaesthesia, patients' body temperature was measured every 15–30 minutes until it stabilized at $\geq$ 36 °C. For patients with hypothermia (<36 °C), a forced-air warming blanket was used until the body temperature returned to normal. Heated and humidified oxygen (37 °C) was also provided through a breathing mask to reduce heat loss from the respiratory tract.

(5) In cases of postoperative shivering, 25 mg of pethidine (Qinghai Pharmaceutical Co., Ltd., Xining, China; Sinopharm approval number: H63020022; specification: 1 mL:50 mg) or 50 mg of tramadol (Jiangsu Jiuxu Pharmaceutical Co., Ltd., Xuzhou, China; Sinopharm approval number: H20023536; specification: 2 mL:50 mg) was intravenously injected to control the shivering. Since hypothermia increases the risk of infection, incisions should be made under close surveillance, and treatment for redness, exudation or fever (>38 °C) should be offered in time as necessary.

Due to the retrospective nature of this study, comprehensive data on continuous temperature monitoring and hypothermia incidence were unavailable for all patients and were therefore not included in the analysis. Continuous monitoring with esophageal or nasopharyngeal probes was applied in selected cases. However, because of data variability in documentation, we could not uniformly stratify monitoring by surgical phase. In this study, forced-air warming blankets were applied with a temperature between 38 °C and 40 °C. The specific value within this range was adjusted by the anesthesiology team according to the patients' intraoperative status and monitoring results. Because of the retrospective study design, temperature settings were not standardized across all patients, which may have introduced some variability.

Observation Indicators

Physiological Indicators

Data on operation time, bleeding volume, infusion volume and length of hospital stay were collected and compared between the two groups.

Quality of Anaesthesia Recovery

The quality of anaesthesia recovery was assessed using the Steward recovery score (range 0–6) [13]. It consists of three primary domains: Consciousness (0 = not responding, 1 = responding to stimuli, 2 = fully awake), Airway (0 = airway obstruction, 1 = requiring airway maintenance, 2 = coughing on command/maintaining airway patency), and Movement (0 = no movement, 1 = non-purposeful movement, 2 = purposeful movement). Each patient's total score and domain-specific scores were recorded.

Degree of Pain During Anaesthesia Recovery

Limb pain was defined as limb discomfort or myalgia reported by patients during the recovery period and assessed using the Visual Analogue Scale (VAS). The VAS was used to evaluate the degree of limb pain in the two groups of patients before and after the operation. A 10 cm VAS ruler was used, marked with 10 intervals from '0' and '10' ends, where '0' indicates no pain and '10' represents the most severe, intolerable pain.

Each patient was instructed to mark the position on the ruler that best represented the intensity of pain experienced.

Postoperative Complications

Incidence of postoperative complications, including abdominal infection, postoperative nausea and vomiting, and intestinal obstruction, was recorded. In this study, "abdominal infection" was identified according to clinical diagnosis, such as the presence of fever, abdominal tenderness, and the initiation of antibiotic treatment, as documented in the medical records. The Centers for Disease Control and Prevention (CDC) criteria for surgical site infection (SSI) were not strictly applied due to the inconsistent availability

Table 1. Comparison of baseline data between the two groups.

Variables	Warming group (n = 62)	Routine group (n = 69)	χ^2/Z	p
Age (years), M (Q ₁ , Q ₃)	40.50 (32.25, 48.00)	39.00 (32.00, 50.00)	0.38	0.707
BMI (kg/m ²), M (Q ₁ , Q ₃)	21.80 (20.80, 22.80)	21.40 (20.50, 22.40)	1.31	0.190
Preoperative basal body temperature (°C), M (Q ₁ , Q ₃)	36.90 (36.62, 37.10)	36.90 (36.70, 37.20)	0.37	0.709
Hemoglobin (g/L), M (Q ₁ , Q ₃)	137.50 (127.25, 147.75)	135.00 (127.00, 144.00)	0.80	0.425
Operating room temperature (°C), M (Q ₁ , Q ₃)	24.00 (23.00, 25.00)	24.00 (23.00, 25.00)	0.48	0.634
Gender, n (%)			2.78	0.095
Male	36 (58.06)	30 (43.48)		
Female	26 (41.94)	39 (56.52)		
ASA classification, n (%)			3.00	0.083
Grade I	36 (58.06)	50 (72.46)		
Grade II	26 (41.94)	19 (27.54)		
Education level, n (%)			0.44	0.932
Junior high school	31 (50.00)	32 (46.38)		
Junior college or above	10 (16.13)	12 (17.39)		
High school	11 (17.74)	15 (21.74)		
Elementary school and below	10 (16.13)	10 (14.49)		
Place of residence, n (%)			0.01	0.904
Cities	29 (46.77)	33 (47.83)		
Rural	33 (53.23)	36 (52.17)		

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index.

of microbiological and imaging data. Shivering episodes were recorded qualitatively in patient charts, but a standardized assessment tool such as the Bedford Shivering Score was not applied.

Statistical Analysis

The SPSS (Statistics version 26.0, IBM Corp., Armonk, NY, USA) software was used to analyze the collected data. The Shapiro–Wilk test was utilized to assess the normal distribution of continuous data. Data that did not conform to normal distribution, expressed as median and interquartile range (P₂₅, P₇₅), were analyzed using the Mann–Whitney *U* test for between-group comparisons, and the Hodges–Lehmann estimator was used to calculate the median difference with its 95% confidence interval. PowerPoint was used to plot Fig. 1 of this paper.

Results

Baseline Data

The comparison of baseline data between the two groups showed no significant differences in age, gender, BMI and other parameters (all *p* > 0.05), supporting the comparability of the groups at baseline (Table 1). As continuous temperature curves and data on the hypothermia incidence cannot be fully extracted from the medical records, these variables were not included in the analysis.

Comparison of Various Surgical Indicators

Operation time and blood loss were not significantly different between the warming and routine groups (*p* > 0.05). Meanwhile, infusion volume and length of hospital stay

were significantly different between the two groups of patients (*p* < 0.001, Table 2).

Comparison of Anaesthesia Recovery Quality Between the Two Groups

The levels of consciousness and airway patency and the score of limb movement in the warming group were significantly higher than those in the routine group (*p* < 0.05, Table 3)

Comparison of Pain Degree at Different Moments

There was no significant difference in the preoperative VAS scores between the warming group and the routine group (median [P₂₅, P₇₅]: 5.00 (3.00, 7.00) vs. 5.00 (3.00, 7.00), *p* = 0.654). Postoperative limb pain experienced by patients in the warming group was significantly lower than that in the routine group (median [P₂₅, P₇₅]: 4.00 (3.00, 5.00) vs. 5.00 (4.00, 5.00), *p* < 0.001).

Comparison of Complication Incidence Between the Two Groups

The incidence of complications was lower in the heat preservation group (6.5%) compared with the routine group (11.59%), although this difference was not statistically significant (*p* = 0.308, Table 4).

Discussion

In this study, we investigated the effect of comprehensive warming measures on limb pain in patients undergoing LC. The warming group had significantly better outcomes compared with the routine group, in terms of anaesthesia recovery quality, postoperative pain control and length of hospi-

Table 2. Comparison of surgical indicators between the two groups.

Variables	Routine group (n = 69)	Warming group (n = 62)	Statistic	p	Difference (95% CI)
Operation time (min), M (Q ₁ , Q ₃)	85.00 (78.00, 93.00)	85.00 (75.00, 94.00)	Z = 0.25	0.803	-3.00~5.00
Amount of bleeding (mL), M (Q ₁ , Q ₃)	37.00 (29.00, 45.00)	38.00 (27.25, 45.75)	Z = 0.39	0.695	-4.00~5.00
Infusion volume (mL), M (Q ₁ , Q ₃)	835.00 (736.00, 1027.00)	734.50 (661.75, 833.50)	Z = 4.15	<0.001	60.00~163.00
Length of hospital stay (day), M (Q ₁ , Q ₃)	5.00 (4.00, 6.00)	4.00 (3.00, 5.00)	Z = 6.30	<0.001	1.00~2.00

CI, confidence interval.

Table 3. Comparison of the quality of anaesthesia recovery between the two groups.

Variables	Warming group (n = 62)	Routine group (n = 69)	Statistic	p	Difference (95% CI)
Consciousness, M (Q ₁ , Q ₃)	1.00 (1.00, 2.00)	1.00 (0.00, 1.00)	Z = 2.04	0.041	-1.00~0.00
Airway patency, M (Q ₁ , Q ₃)	2.00 (1.00, 2.00)	1.00 (0.00, 1.00)	Z = 3.56	<0.001	-1.00~0.00
Limb movement, M (Q ₁ , Q ₃)	1.00 (1.00, 2.00)	1.00 (0.00, 2.00)	Z = 3.24	0.001	-1.00~0.00
Total score, M (Q ₁ , Q ₃)	4.00 (3.00, 5.00)	2.00 (1.50, 4.00)	Z = -4.649	<0.001	-2.00~-1.00

tal stay (all $p < 0.05$). Regarding complications, there was a clear trend towards a lower incidence in the warming group (6.5%) compared with the routine group (11.6%), with a borderline p -value of 0.308. While this did not meet the conventional threshold for statistical significance, the finding suggests a potentially meaningful difference that may have been underpowered to reach significance due to the limited sample size. Future studies with larger patient cohorts are needed to clarify whether comprehensive warming measures reduce complication rates.

Perioperative hypothermia can cause adverse events, such as increased risk of surgical site infection, cardiovascular events (e.g., arrhythmia) and impaired myocardial conduction function [14]. Therefore, warming measures should be implemented during the operation. Comprehensive warming measures collectively refer to a standardized set of intervention strategies to maintain the core body temperature of patients by implementing multiple active and passive methods before, during and after surgery. These measures prevent the occurrence of hypothermia ($<36^{\circ}\text{C}$) and related complications, as well as promote postoperative recovery [15]. In the present study, we implemented comprehensive warming measures for patients undergoing LC. The Steward recovery score of patients in the warming group was significantly higher in all domains. Specifically, consciousness was improved with a modest but significant difference ($p = 0.041$), whereas level of airway patency, limb movement score and the total score showed highly significant differences (all $p < 0.001$) between the warming and routine groups, indicating that a more complete and coordinated anaesthesia recovery could be achieved by utilizing the warming approaches, consistent with the previously reported results [16,17]. Intraoperative warming could improve the quality of recovery by maintaining normal core body temperature, promoting the activity of drug metabolism-related enzymes and accelerating the clearance of anaesthetic drugs. Intraoperative hypothermia may induce shivering and increase airway resistance; however, warming measures can help maintain airway patency indi-

rectly by reducing the risk of shivering. The improved score of limb movement may be related to the improvement of peripheral circulation and the reduction of muscle stiffness through warming.

This study also found that the implementation of comprehensive warming measures can relieve perioperative limb pain to a certain extent, consistent with the report by Çiftci *et al.* [18]. Hypothermia can activate sympathetic nerves, aggravate peripheral vascular contraction and tissue ischemia, promote the release of inflammatory factors, and amplify pain signals. The observed reduction in limb pain is most likely explained by the preventive effect of warming on shivering. Hypothermia-induced shivering involves repetitive muscle contractions, which can lead to widespread myalgia, often perceived by patients as limb pain. By maintaining normothermia, comprehensive warming reduces shivering episodes, improves peripheral circulation, and shortens the residual effect of muscle relaxants, thereby alleviating postoperative discomfort in the extremities.

The implementation of comprehensive warming measures also reduced the amount of fluid administered and shortened the length of hospital stay. Warming reduces the need to increase the infusion volume for maintaining blood pressure, which could be elevated due to hypothermia-induced vasoconstriction. Faster recovery and pain relief can promote early food intake and ambulation, thereby decreasing the length of hospital stay. The shortened length of hospital stay may be attributed to improved postoperative recovery quality, pain relief, and earlier ambulation, which contribute to rapid recovery of eating and movement functions. It is important to note that the routine group received standard perioperative care in the hospital without active warming measures—the real-world routine management at the time of the study.

The present study uncovered several beneficial effects of the warming measures; however, several limitations of this study should be highlighted. First, a formal cost-effectiveness analysis was not performed to compare the

Table 4. Comparison of complication incidence between the two groups.

Groups	Abdominal infections, <i>n</i> (%)	Nausea and vomiting, <i>n</i> (%)	Intestinal obstruction, <i>n</i> (%)	Total incidence rate
Routine group (<i>n</i> = 69)	3 (4.35)	3 (4.35)	2 (2.90)	11.59% (8/69)
Warming group (<i>n</i> = 62)	1 (1.61)	2 (3.23)	1 (1.61)	6.45% (4/62)
χ^2				1.038
<i>p</i>				0.308
Difference (95% CI)				0.828~9.138

additional costs incurred from the utilization of warming equipment with the potential savings from reduced length of hospital stay and complications. Future studies should apply incremental cost-effectiveness ratio (ICER) calculations based on international cost-effectiveness thresholds. Second, pain assessment relied solely on the VAS score, which did not differentiate between incisional and referred pain, and no neurological screening tools were employed in the present study to yield more in-depth mechanistic insights into the pain. Future studies should incorporate pain maps and validated neurological tools for analysis. Regarding recovery, the Steward recovery score was used, rather than the more advanced tools such as the Quality of Recovery-15 (QoR-15). Separately, data on the continuous core temperature monitoring were not available, precluding calculation of the hypothermia area under the receiver operating characteristic curve (AUC). Future studies should incorporate validated recovery scales and data on continuous temperature monitoring.

Furthermore, this study was subject to the inherent risk of bias and unmeasured confounders. In particular, significant differences in fluid volume were observed between the two groups of patients. Since the use of warmed intravenous fluids is considered a core component of the active warming protocol, it is difficult to isolate the effects of fluid temperature and volume from those of other warming measures. Because multivariable adjustment for volume was not performed, the results should be interpreted with caution. Additionally, this study did not attempt to investigate the levels of inflammatory markers (such as interleukin (IL)-6, C-reactive protein (CRP), and tumor necrosis factor α (TNF- α)). Therefore, the potential mechanistic link between warming, inflammation suppression, and pain relief could not be verified. Future studies should dynamically monitor inflammatory markers at different time points during the perioperative period and delineate the biological mechanisms by which warming interventions exert analgesic effects. Besides that, the current study reported temperature monitoring at intervals of every 15–30 minutes but did not standardize frequency and/or phases for conducting and recording anesthesia induction, surgical procedure, and recovery. Furthermore, the temperature setting range for the forced-air warming blanket was wide. Compared to the European guidelines that recommend monitoring every 5 minutes during anesthesia induction, every 15 minutes during surgery, and every 10 minutes during recovery, the protocol of this study, which utilized a fixed warming blan-

ket temperature of 38 °C, lacked standardization. This may affect the consistency of temperature management and the interpretation of results, necessitating further optimization and harmonization in future studies. The temperature setting of the forced-air warming device was operator-adjusted within a 38–40 °C range rather than being standardized to a single value, which may lead to heterogeneous results during the warming interventions. In addition, without taking into consideration hypothermia incidence and comprehensive temperature data, this study failed to prove whether the clinical benefit of the comprehensive warming measures is entirely mediated by ameliorating hypothermia. Future studies should use continuous core temperature monitoring data and standardized hypothermia indicators to further verify the mechanism of action of these warming measures. The frequency of core temperature monitoring and the setting of the warming device also did not fully adhere to international guidelines. Other potential confounders, such as intraoperative opioid dose and pneumoperitoneum pressure, were also not consistently recorded. In the future, it is necessary to conduct multicenter, prospective trials with standardized protocols, larger samples, and longer follow-up to assess chronic pain, coupled with monitoring of biomarkers for an extended follow-up period to offer more insights into the findings obtained. It should be noted that this study specifically focused on limb pain. Although postoperative shoulder pain due to pneumoperitoneum is a more common clinical problem, it was not assessed in this study. Future studies could evaluate both shoulder pain and limb pain, in parallel, to better delineate their respective mechanisms and explore the corresponding management strategies.

Conclusions

Comprehensive warming measures may enhance the perioperative experience and recovery quality in patients undergoing LC by maintaining a stable body temperature, highlighting their clinical potential in this regard. Through this retrospective analysis, we learnt that multimodal warming interventions contribute to improved recovery quality and attenuated limb pain. However, without continuous intraoperative temperature data, we were unable to validate that these benefits were directly mediated by normothermia. It should be noted that the findings from this single-center retrospective study are not broadly generalizable due to the surgical techniques used, anesthetic protocols, and patient

demographics. Therefore, prospective multicenter randomized controlled trials with standardized core temperature monitoring are warranted to validate the broader applicability of the comprehensive warming measures tested.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

BZ and HJH designed the research study. HXY and LLW performed the research. BZ, HXY, HJH and LLW analyzed the data. BZ and LLW participated in drafting the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study obtained approval from the Ethics Committee of Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University (Approval No. K20250846(EZ)), all patients signed a written informed consent. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Acknowledgment

Not applicable.

Funding

This research was funded by the Science and Technology Plan Project of Luqiao District, Taizhou City, Zhejiang Province. Project Number: 2023S1004.

Conflict of Interest

The authors declare no conflict of interest.

References

- [1] Motter SB, de Figueiredo SMP, Marcolin P, Trindade BO, Brandao GR, Moffett JM. Fenestrating vs reconstituting laparoscopic subtotal cholecystectomy: a systematic review and meta-analysis. *Surgical Endoscopy*. 2024; 38: 7475–7485. <https://doi.org/10.1007/s00464-024-11225-8>.
- [2] Alberton A, Peltz ED. Cholecystectomy. *The Surgical Clinics of North America*. 2024; 104: 1203–1215. <https://doi.org/10.1016/j.su.2024.04.011>.
- [3] Timerbulatov MV, Grishina EE, Aitova LR, Aziev MM. Modern principles of safety in laparoscopic cholecystectomy. *Khirurgiia*. 2022; 104–108. <https://doi.org/10.17116/hirurgia2022121104>. (In Russian)
- [4] Shrestha BB, Lakhe G, Ghimire P. Postoperative Pain after Laparoscopic Cholecystectomy in a Tertiary Care Center: A Descriptive Cross-sectional Study. *JNMA; Journal of the Nepal Medical Association*. 2024; 62: 502–506. <https://doi.org/10.31729/jnma.8719>.
- [5] Park SJ. Postoperative Shoulder Pain after Laparoscopic Surgery. *Journal of Minimally Invasive Surgery*. 2020; 23: 3–4. <https://doi.org/10.7602/jmis.2020.23.1.3>.
- [6] Carella M, Beck F, Piette N, Lecoq JP, Bonhomme VL. Effect of pre-operative warming on intraoperative hypothermia and postoperative functional recovery in total hip arthroplasty: a randomized clinical trial. *Minerva Anestesiologica*. 2024; 90: 41–50. <https://doi.org/10.23736/S0375-9393.23.17555-9>.
- [7] Ahmed U, Ullah H, Samad K. Mean Temperature Loss During General Anesthesia for Laparoscopic Cholecystectomy: Comparison of Males and Females. *Cureus*. 2021; 13: e17128. <https://doi.org/10.7759/cureus.17128>.
- [8] McIsaac DI, Ladha KS. Postoperative Opioid Prescribing: Finding the Balance. *Anesthesiology*. 2022; 137: 131–133. <https://doi.org/10.1097/ALN.0000000000004297>.
- [9] Yang G, Zhu Z, Zheng H, He S, Zhang W, Sun Z. Effects of different thermal insulation methods on the nasopharyngeal temperature in patients undergoing laparoscopic hysterectomy: a prospective randomized controlled trial. *BMC Anesthesiology*. 2021; 21: 101. <https://doi.org/10.1186/s12871-021-01324-7>.
- [10] Zhang J, Deng L, Wang X, Song F, Hou H, Qiu Y. Effect of Forced-Air Warming Blanket on Perioperative Hypothermia in Elderly Patients Undergoing Laparoscopic Radical Resection of Colorectal Cancer. *Therapeutic Hypothermia and Temperature Management*. 2022; 12: 68–73. <https://doi.org/10.1089/ther.2021.0010>.
- [11] World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013; 310: 2191–2194. <https://doi.org/10.1001/jama.2013.281053>.
- [12] National Anesthesia Professional Quality Control Center. Expert consensus on prevention and treatment of hypothermia in perioperative patients (2023 Edition). *Journal of Clinical Anesthesiology*. 2023. <https://doi.org/10.12089/jca.2023.07.018>. (In Chinese)
- [13] Steward DJ. A simplified scoring system for the post-operative recovery room. *Canadian Anaesthetists' Society Journal*. 1975; 22: 111–113. <https://doi.org/10.1007/BF03004827>.
- [14] Yi N, Wang Z, Cui R. Warming with a composite warming strategy reduces intraoperative hypothermia in patients undergoing open hepatectomy for liver cancer: A randomized controlled study. *Medicine*. 2025; 104: e41616. <https://doi.org/10.1097/MD.00000000000041616>.
- [15] Zhuang H, Li W, Xue X, Wang H, Li S, Zhong Y. The Impact of Comprehensive Nursing and Warming Measures on Emergence Agitation and Maternal-Neonatal Safety in Women Undergoing General Anesthesia for Cesarean Section. *Alternative Therapies in Health and Medicine*. 2024; 30: 90–95.
- [16] Li W, Hu Z, Liu J, Yuan Y, Li K. The effect of aggressive management of intraoperative body temperature on postoperative APACHE II score and prognosis in high-risk patients undergoing thoracoscopic surgery. *Journal of Thoracic Disease*. 2022; 14: 3429–3437. <https://doi.org/10.21037/jtd-22-873>.
- [17] Yoo JH, Ok SY, Kim SH, Chung JW, Park SY, Kim MG, et al. Efficacy of active forced air warming during induction of anesthesia to prevent inadvertent perioperative hypothermia in intraoperative warming patients: Comparison with passive warming, a randomized controlled trial. *Medicine*. 2021; 100: e25235. <https://doi.org/10.1097/MD.00000000000025235>.
- [18] Çiftçi C, Kara I, Büyükcavlak M, Aslanlar E. Effect of Perioperative Active Warming on Postoperative Pain and Shivering in Preschool Pediatric Patients: A Randomized Controlled Trial. *Indian Pediatrics*. 2024; 61: 829–834.

© 2025 The Author(s).

