Risk Factors for Hypothermia during Laparoscopic or Open Surgery of Colorectal Cancer under General Anesthesia

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Yi-Hui Tu[1], Di Zhang[1]

[1]Operating Room, Zhongnan Hospital of Wuhan University, 430071 Wuhan, Hubei, China

AIM: Colorectal cancer (CRC) is one of the most prevalent malignancies, which is commonly treated with curative surgical resection, often leading to intraoperative hypothermia. Therefore, this study aimed to compare and analyze the risk factors for intraoperative hypothermia associated with laparoscopic and open CRC resections under general anesthesia.

METHODS: This study included 120 CRC patients admitted between January 2023 and January 2024. Data from these patients were analyzed using logistic regression analysis to investigate the risk factors for hypothermia during CRC surgery. Additionally, surgical indicators such as, intraoperative bleeding volume, number of lymph nodes dissected, and operation time, and serum inflammatory markers like Interleukin-6 (IL-6) and Interleukin-8 (IL-8) were assessed and compared between the two surgical groups.

RESULTS: The study group comprised 41 men and 79 women, with a mean age of 52.53 $\pm$ 8.90 years and an average body mass index (BMI) of 23.13 $\pm$ 3.32 kg/m^2. The American Society of Anesthesiologists (ASA) score was measured as 1 for 62 (51.67%) patients and 2 for 58 (48.33%). Among them, 50 patients underwent open surgery, whereas 70 patients were treated with laparoscopic surgery. Gender, laparoscopic surgery, intraoperative fluid infusion volume, prolonged anesthesia, and intraoperative blood transfusion were determined as the independent risk factors for intraoperative hypothermia during CRC surgery under general anesthesia ($p < 0.05$). The intraoperative bleeding volume was significantly reduced ($p < 0.01$), with significantly longer operation time ($p < 0.05$) in patients treated with laparoscopic surgery compared to those with open surgery. However, the two groups had a similar number of lymph nodes dissected. Additionally, the levels of IL-6 and IL-8 in both laparoscopic and open surgery of patients increased significantly after surgery, but the extent of increase in the patients of laparoscopic surgery was significantly lower than that in the patients of open surgery ($p < 0.05$).

CONCLUSIONS: In conclusion, gender, surgical approach, intraoperative fluid infusion volume, prolonged anesthesia, and intraoperative blood transfusion are the potential risk factors for hypothermia during laparoscopic radical CRC surgery under general anesthesia.

Keywords: colorectal cancer; surgical resection; intraoperative hypothermia; risk factors

Introduction

Colorectal cancer (CRC), a gastrointestinal malignancy of the colon or rectum, is characterized by the abnormal proliferation of colonic glandular epithelial cells [1]. Epidemiological data suggest that CRC accounts for approximately 10% of tumor-related mortalities, with projected incidence more than double by 2035 [2,3]. Surgical resection is the curative intervention used in treating CRC; however, it is associated with the potential risk of intraoperative hypothermia [4]. Intraoperative hypothermia, characterized by core body temperature below 36 °C, is a potential impairment associated with surgical interventions; however, it can be prevented [5]. Intraoperative hypothermia leads to significant surgical complications, such as increased perioperative bleeding and transfusion needs, delayed postanesthesia recovery, enhanced risk of surgical site infection, and prolonged hospital stay [6]. Therefore, investigating the risk factors of intraoperative hypothermia is crucial for effective management of surgical interventions. Previous studies have also pointed out that intraoperative hypothermia may be related to factors such as old age (>60 years old), low weight, malnutrition, intraoperative infusion of large amounts of unheated solution, and prolonged anesthesia time (>2 hours) [7,8]. Although laparoscopic CRC surgery is less invasive, it still carries the risk of intraoperative hypothermia that can significantly impact the patient's postoperative recovery [9]. However, due to its minimally invasive surgical procedure, laparoscopic surgery for CRC is widely utilized. It can significantly reduce the risk of perioperative complications, enable more precise anatomical dissection, improve cosmetic outcomes, and offer faster recovery than open radical CRC resection [10,11]. Therefore, this retrospective study was conducted to investigate, interpret, and compare intraoperative hypothermia risk factors associated with these two surgical interventions and provide a comprehensive report.

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Correspondence to: Di Zhang, Operating Room, Zhongnan Hospital of Wuhan University, 430071 Wuhan, Hubei, China (e-mail: Dina0420@126.com).

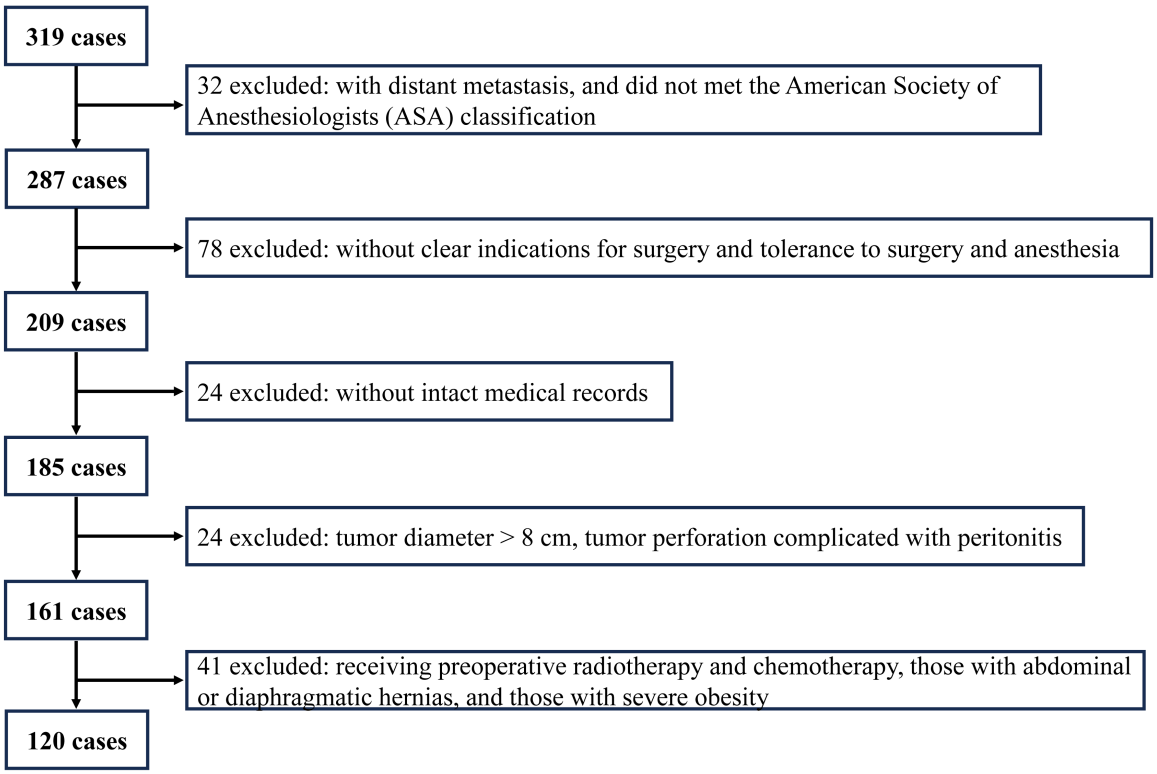

Fig. 1. A flowchart of patients' screening and selection.

Materials and Methods

Patients' Information

This study included 120 CRC patients admitted between January 2023 and January 2024 after careful screening following predetermined inclusion and exclusion criteria. The complete process of screening patients was shown in Fig. 1.

The inclusion criteria for patients were as follows: (1) Patients diagnosed with primary CRC (without distant metastasis) [12] using colonoscopy, biopsy, and postoperative pathology; (2) Patients fulfilling the American Society of Anesthesiologists (ASA) classification requirements [13]; (3) Patients with clear surgical indications; (4) Patients exhibited tolerance to surgery and anesthesia; (5) Patients whose complete medical records were available.

Exclusion criteria included: (1) Patients with distant tumor metastasis; (2) Tumor diameter greater than 8 cm; (3) Tumor perforation complicated by peritonitis; (4) Contraindications for surgery; (5) Presence of chronic inflammation or acute infection; (6) Patients undergoing palliative surgery; (7) Patients receiving preoperative radiotherapy or chemotherapy; (8) Those with abdominal or diaphragmatic hernias; and (9) severe obesity.

The study design adhered to the guidelines in the Declaration of Helsinki and was approved by the Ethics Committee of Zhongnan Hospital of Wuhan University with Approval Number 2023-043. After understanding the purpose of the study, all patients provided written informed consent. The two experimental groups were clinically comparable, with no significant differences in baseline data ($p > 0.05$).

Treatment Methods

All the surgical procedures were performed under general anesthesia. The surgical procedure for individual patients was adapted based on the doctor's advice or the patient's choice. The 4-port method was used, with the observation port placed 10 mm from the umbilicus and the operation ports placed according to the patient's anatomy. An artificial pneumoperitoneum was created. Additionally, an abdominal laparoscopic was performed to assess the presence of adhesions and ascites, evaluate the tumor and its interaction with surrounding tissues, and investigate any metastases. In case of difficult intraoperative positioning of the lesion, a colonoscopy could be used to determine the lesion location.

Furthermore, the mesentery was dissected laparoscopically, carefully managing the blood vessels and removing the lymph nodes. Subsequently, the damaged intestinal segment was removed through a small incision in the abdomen and was excised and anastomosed *in vitro*. En bloc resection principle and no-touch isolation technique were employed to minimize the risk of intraoperative traumas. All patients received standard fluid support postoperatively.

Detection Indicators

Baseline data: The baseline data, such as gender, age range, mean age, body mass index (BMI), and ASA classification grade, were collected from all the study participants for a comparative analysis.

Table 1. The baseline characteristics of patients.

Characteristic	All patients (n = 120)	Hypothermia group (n = 20)	Normal temperature group (n = 100)
Age, years (n, %)			
<55	58 (48.33%)	5 (25.00%)	53 (53.00%)
≥55	62 (51.67%)	15 (75.00%)	47 (47.00%)
Average age, years	52.53 ± 8.90	58.85 ± 8.53	51.27 ± 8.58
Sex (n, %)			
Male	41 (34.17%)	11 (55.00%)	30 (30.00%)
Female	79 (65.83%)	9 (45.00%)	70 (70.00%)
BMI, kg/m^2	23.13 ± 3.32	24.15 ± 3.54	22.93 ± 3.25
ASA score (n, %)			
1	62 (51.67%)	9 (45.00%)	53 (53.00%)
2	58 (48.33%)	11 (55.00%)	47 (47.00%)
Surgical approach, (n, %)			
Open surgery	50 (41.67%)	3 (15.00%)	47 (47.00%)
Laparoscopic surgery	70 (58.33%)	17 (85.00%)	53 (53.00%)
Intraoperative fluid infusion volume, mL, (n, %)			
<1500	81 (67.50%)	6 (30.00%)	75 (70.00%)
≥1500	39 (32.50%)	14 (70.00%)	25 (30.00%)
Intraoperative bleeding volume, mL, (n, %)			
<150	77 (64.17%)	10 (50.00%)	67 (67.00%)
≥150	43 (35.83%)	10 (50.00%)	33 (33.00%)
Intraoperative blood transfusion (n, %)			
With	46 (38.33%)	15 (75.00%)	31 (31.00%)
Without	74 (61.67%)	5 (25.00%)	69 (69.00%)
Anesthesia duration, min, (n, %)			
<150	95 (79.17%)	8 (40.00%)	87 (87.00%)
≥150	25 (20.83%)	12 (60.00%)	13 (13.00%)

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

Perioperative indicators: The intraoperative blood loss, the number of lymph nodes dissected, and operation time (OT) were observed and recorded.

Serum inflammatory markers: Fasting venous blood samples (3 mL) were collected from the elbow of each patient before and after the surgery. Following centrifugation, the resultant serum was analyzed for Interleukin-6 (IL-6) and Interleukin-8 (IL-8) levels using enzyme-linked immunosorbent assay (ELISA).

Statistical Analysis

The quantitative data were expressed as mean ± standard deviation ($\bar{x} \pm s$). The inter-group comparisons were conducted using an independent sample *t*-test, whereas the intra-group comparisons were performed using a paired *t*-test. The discrete quantitative data were expressed as percentages (%) and analyzed using the χ^2 tests. Multivariate logistic regression was used to analyze the factors leading to intraoperative hypothermia during laparoscopic CRC surgery. All the statistical analyses were performed using SPSS 21.0 software (SPSS Statistics Inc., Chicago, IL, USA), with $p < 0.05$ indicating statistically significant differences.

Results

Baseline Data

The study group comprised 41 men and 79 women with a mean age of 52.53 ± 8.90 years. The average body mass index was 23.13 ± 3.32 kg/m^2. The American Society of Anesthesiologists score for 62 (51.67%) patients was 1, and for 58 (48.33%) patients, it was 2. Among them, 50 patients underwent open surgery, and 70 patients received laparoscopic surgery. The characteristics of the study participants are summarized in Table 1.

Univariate and Multivariate Analysis of Hypothermia during Radical CRC Surgery under General Anesthesia

The univariate analysis indicated that factors such as gender, age, surgical approach, intraoperative fluid infusion volume, anesthesia duration, and intraoperative blood transfusion were significantly associated with the incidence of hypothermia during radical CRC surgery under general anesthesia ($p < 0.05$). These factors with significant differences were considered dependent variables in the univariate analysis. In contrast, the incidence of hypothermia during radical CRC surgery under general anesthesia was taken as a dependent variable for multivariate analysis using the Logistic regression model. The results suggested gen-

Table 2. Analysis of risk factors for hypothermia.

Variables	Overall complication			
	Univariate		Multivariate	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Sex				
Male	Ref			
Female	2.852 (1.071–7.593)	0.036	7.177 (1.296–39.760)	0.024
Age (years)				
<55	Ref			
≥55	0.296 (0.100–0.875)	0.028	4.059 (0.861–19.124)	0.077
ASA grade				
I	Ref			
II	0.726 (0.277–1.903)	0.514		
BMI				
<24	Ref			
≥24	0.503 (0.189–1.338)	0.169		
Surgical approach, (n, %)				
Open surgery	Ref		Ref	
Laparoscopic surgery	4.636 (1.227–16.827)	0.020	8.018 (1.162–55.335)	0.035
Intraoperative fluid infusion volume, mL, (n, %)				
<1500	Ref		Ref	
≥1500	7.000 (2.430–20.166)	<0.001	39.686 (5.407–291.305)	<0.001
Intraoperative bleeding volume, mL, (n, %)				
<150	Ref			
≥150	2.030 (0.769–5.359)	0.153		
Intraoperative blood transfusion (n, %)				
With	Ref			
Without	0.150 (0.050–0.449)	0.001	0.077 (0.013–0.444)	0.004
Anesthesia duration, min, (n, %)				
<150	Ref			
≥150	10.038 (3.451–29.198)	<0.001	9.071 (1.827–45.038)	0.007

OR, odds ratio; CI, confidence interval; BMI, body mass index.

der, laparoscopic surgical procedure, intraoperative fluid infusion volume, prolonged anesthesia, and intraoperative blood transfusion as the independent risk factors associated with intraoperative hypothermia under general anesthesia ($p < 0.05$). The univariate and multivariate analyses are shown in Tables 2,3.

Surgical Indicators and Serum Inflammatory Markers for Open and Laparoscopic Surgery

In the previous part of the study, laparoscopic surgery was found to be an independent risk factor, so we compared the surgical indexes and serum inflammatory indexes of laparoscopic and open surgery. Surgical indicators, such as intraoperative blood loss, the number of lymph nodes dissected, and the OT were assessed and compared between the two groups. The results revealed reduced intraoperative bleeding ($p < 0.01$), similar lymph node dissecting ($p > 0.05$), and longer OT in the patients undergoing laparoscopic surgery compared to those treated with open surgery (Fig. 2, $p < 0.05$).

Furthermore, the impacts of these two surgical procedures on inflammatory markers such as IL-6 and IL-8 were analyzed by measuring them using ELISA. The findings revealed a significant increase in blood inflammatory markers after both surgical procedures (laparoscopic surgery: $p < 0.01$; open surgery: $p < 0.05$). However, the postoperative levels of these inflammatory markers were significantly elevated in patients treated with open CRC surgery compared to those with laparoscopic surgery (Fig. 3, $p < 0.05$).

Discussion

Intraoperative hypothermia is the most common complication, with an incidence of approximately 80% in CRC patients undergoing surgical interventions [14]. Exploring the risk factors leading to intraoperative hypothermia and optimizing the management of CRC resections are critical for improving the therapeutic efficacy of CRC radical surgeries and minimizing the incidence of intraoperative hypothermia-induced impairments such as coagulation, transfusion, drug metabolism, and surgical site infection [15,16]. For this reason, the current retrospective analysis was performed to investigate and compare the risk factors for intraoperative hypothermia associated with open and laparoscopic CRC surgeries under usual anesthesia.

Table 3. Values of risk factors for hypothermia analysis.

Analysis	Variable	B	SE	Wald χ^2	OR (95% CI)	*p*-value
Univariate	Female	1.048	0.500	4.399	2.852 (1.071–7.593)	0.036
	Age (years) ≥55	–1.219	0.554	4.841	0.296 (0.100–0.875)	0.028
	ASA grade II	–0.321	0.492	0.425	0.726 (0.277–1.903)	0.514
	BMI ≥24	–0.687	0.499	1.896	0.503 (0.189–1.338)	0.169
	Laparoscopic surgery	1.534	0.658	5.440	4.636 (1.227–16.827)	0.020
	Intraoperative fluid infusion volume (mL)	1.946	0.540	12.993	7.000 (2.430–20.166)	<0.001
	Intraoperative bleeding volume (mL)	0.708	0.495	2.045	2.030 (0.769–5.359)	0.153
	Intraoperative blood transfusion	–1.899	0.560	11.503	0.150 (0.050–0.449)	0.001
	Anesthesia duration (min)	2.306	0.545	17.926	10.038 (3.451–29.198)	<0.001
Multivariate	Female	1.971	0.873	5.091	7.177 (1.296–39.760)	0.024
	Age (years) ≥55	1.401	0.791	3.137	4.059 (0.861–19.124)	0.077
	Laparoscopic surgery	2.082	0.986	4.461	8.018 (1.162–55.335)	0.035
	Intraoperative fluid infusion volume (mL)	3.681	1.017	13.099	39.686 (5.407–291.305)	<0.001
	Intraoperative blood transfusion	–2.558	0.891	8.236	0.077 (0.013–0.444)	0.004
	Anesthesia duration (min)	2.205	0.818	7.273	9.071 (1.827–45.038)	0.007

SE, standard error.

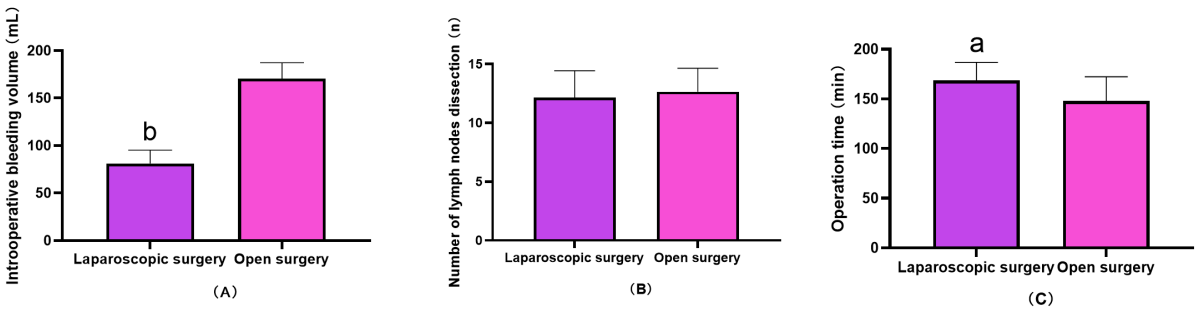

Fig. 2. Comparison of surgical indices associated with laparoscopic and open colorectal cancer (CRC) surgeries. (A) Intraoperative bleeding volume. (B) Number of lymph nodes dissected. (C) Operation time. Note: [a] indicates $p < 0.05$ and [b] denotes $p < 0.01$ compared to the open surgery group.

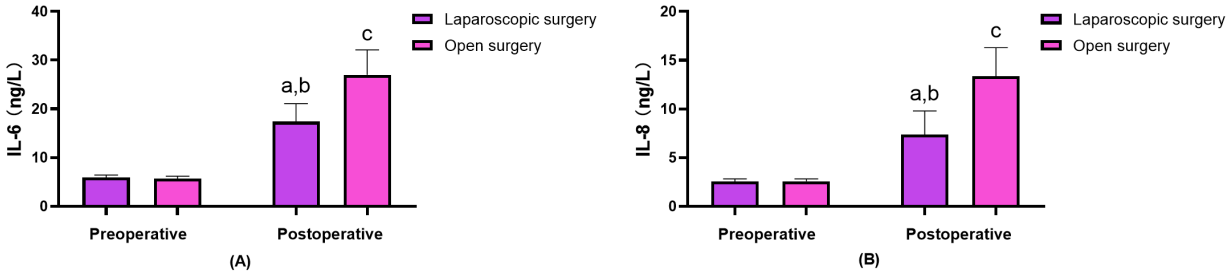

Fig. 3. Comparison of serum inflammatory markers in patients undergoing laparoscopic and open CRC surgery. (A) Comparison of Interleukin-6 (IL-6) pre- and post-operation. (B) Comparison of Interleukin-8 (IL-8) pre- and post-operation. Note: [a]$p < 0.01$, the laparoscopic surgery group postoperatively versus the laparoscopic surgery group preoperatively; [b]$p < 0.05$, the laparoscopic surgery group postoperatively versus the open surgery group postoperatively; [c]$p < 0.05$, the open surgery group postoperatively versus the open surgery group preoperatively.

In the current study, the univariate analysis revealed that gender, age, surgical approach, intraoperative fluid infusion volume, anesthesia duration, and intraoperative blood transfusion are significantly associated with intraoperative hypothermia in radical CRC surgery under general anesthesia. Additionally, the multivariate analysis identified

gender, surgical approach, intraoperative fluid infusion volume, prolonged anesthesia, and intraoperative blood transfusion as the independent risk factors for hypothermia during radical CRC surgery under general anesthesia. These findings highlight the need to standardize the operating room, improve the professional skills of anesthesiologists with regular professional training, shorten the duration of anesthesia, and enhance the cooperation between doctors and nurses during the surgery. Furthermore, managing intraoperative blood transfusion and thermal regulation is imperative, with special care for detecting and promptly managing potential transfusion complications. If required, thermal intervention or hypothermia prophylaxis can be utilized for intraoperative thermal regulation. For example, the liquids to be infused during operation can be properly heated, and the respiratory tract can be warmed if necessary, so as to avoid hypothermia related to slow venous return caused by wrapping the lower limbs with surgical towels and circulating booster pumps during operation. Recently, study has investigated and analyzed the risk factors associated with perioperative hypothermia. In a study involving 1091 newborns or 1-year-old infants who underwent surgery under general anesthesia, younger age, low body weight, longer surgical duration, large amounts of intraoperative fluid infusion, and lack of pre-warming management were identified as risk factors for intraoperative hypothermia in such patients [17]. These findings were similar to those suggested by the current study. Hu Z *et al*. [18] revealed lower BMI, lower baseline core temperature, thoracic and morning surgeries, and prolonged OT as the significant risk factors for intraoperative hypothermia in patients undergoing robotic surgery. Additional study identified that ASA physical status III/IV and preoperative hypothermia are significantly associated with postoperative hypothermia in patients with head, neck, breast, general, urological, and vascular surgeries [19].

The current study found no significant difference in the number of lymph nodes dissected between the two surgical intervention groups. However, laparoscopic CRC surgery was found to reduce intraoperative blood loss and longer OT compared to open CRC surgery. Huang Z *et al*. [20] found that laparoscopic CRC radical surgery is associated with longer OT, reduced intraoperative blood loss, and shorter time to the first postoperative bowel movement, flatulence, and liquid diet initiation compared to open radical resection, which is similar to the findings of our study. These findings suggest that the laparoscopic and open CRC surgeries pose similar clinical impacts regarding the number of lymph nodes dissected with no clinical advantage in operation time. However, laparoscopic CRC resection exhibits a significant clinical advantage in reducing intraoperative blood loss.

According to the data of serum inflammatory indicators, the research group also showed elevated IL-6 and IL-8 after surgery like the control group, but the increase was not great, with lower postoperative IL-6 and IL-8 levels. It indicates that laparoscopic radical CRC surgery is more conducive to inhibiting inflammatory responses that are abnormally activated in CRC patients after operation than open radical CRC surgery, with relatively milder responses of the body to surgery-induced stress. In the study by He LH *et al*. [21], although the levels of L-6 and IL-8 in CRC patients after laparoscopic CRC radical surgery were significantly increased, they were still significantly lower than those who underwent open radical resection. In addition, laparoscopic CRC radical surgery is more conducive to reducing surgical trauma, inflammation, and operation-related pain stress, consistent with our research results. The above results may be attributed to the following clinical advantages of laparoscopic radical CRC surgery: (1) The surgery provides the surgeon with a clearer and more precise surgical field of view, which is beneficial for the operation and accurate judgment and can help reduce the accidental damage of surgery to abdominal organs, intestines, tissues, etc. [22]. (2) The surgical environment is almost enclosed and does not expose the patient's abdominal cavity to the air, minimizing the potential air pollution and stress caused by an open environment [23]. (3) As a minimally invasive procedure, the operation has the advantages of less trauma, less stimulation, and less intraoperative bleeding, which reduces the traumatic stress caused by the operation [24].

This study focused on the risk factors associated with hypothermia during CRC surgeries under general anesthesia, aiding potential knowledge in the field. By comprehensively analyzing various factors, including gender, surgical approach, intraoperative fluid infusion volume, anesthesia duration, and intraoperative blood transfusion, this study thoroughly explored the potential risks associated with the incidence of intraoperative hypothermia. Additionally, by comparing the effects of laparoscopic and open CRC surgeries on patients, this study addressed the complications related to hypothermia and analyzed the differences in intraoperative bleeding, lymph node dissection, and serum inflammatory indicators, providing a more comprehensive report for clinical treatment.

However, this study has certain limitations. This study is a single-center study with a relatively small sample size, which may introduce some bias. Therefore, multi-center studies with larger sample sizes are highly recommended to validate the reliability of these results. In this research, only some common risk factors were considered, and there may be other potential factors that were not included in the analysis. More in-depth studies are required to improve the understanding of the risk factors for hypothermia. Moreover, this study provides general guidelines regarding the prevention and intervention strategies for hypothermia; therefore, clinical studies are needed to explore more specific and effective preventive and treatment interventions.

Conclusions

In conclusion, gender, surgical approach, intraoperative fluid infusion volume, prolonged anesthesia, and intraop-

erative blood transfusion are the potential risk factors for intraoperative hypothermia in treating CRC under general anesthesia. However, laparoscopic radical CRC surgery under general anesthesia has certain clinical advantages for CRC patients, mainly reflected in a smaller intraoperative bleeding volume, lower levels of IL-6 and IL-8, and milder surgical trauma-related stimulation. Therefore, close attention should be paid to such factors during the perioperative period and targeted preventive measures should be taken to minimize or prevent the risk of hypothermia and related adverse events.

Availability of Data and Materials

The data supporting the findings in this study are included in the article and can be obtained from the corresponding author upon reasonable request during the present study.

Author Contributions

YT conducted the experiments and wrote the manuscript. DZ analyzed the data. DZ was responsible for the study design. Both authors have been involved in revising it critically for important intellectual content. Both authors gave final approval of the version to be published. Both authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study design adhered to the guidelines in the Declaration of Helsinki and was approved by the Ethics Committee of Zhongnan Hospital of Wuhan University with Approval Number 2023-043. After understanding the purpose of the study, all patients provided written informed consent.

Acknowledgment

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Conflict of Interest

The authors declare no conflict of interest.

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