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RESEARCH

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A prospective randomized study of the efficacy of continuous active warming in patients undergoing laparoscopic gastrectomy

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Abstract

Background The RCT study on the efficacy of continuous active warming (CAW) in patients undergoing laparoscopic gastrectomy is scarce. The purpose of this research was to determine if a significant difference between continuous active warming (CAW) and active warming when body temperature is below 36 °C (BAW) in terms of incidence of intraoperative hypothermia and clinical rehabilitation in patients undergoing laparoscopic gastrectomy surgery.

Methods A prospective, randomized and controlled trial with a sample of 62 patients who underwent elective total laparoscopic radical gastrectomy was conducted. Patients assigned to CAW group were warmed immediately since the surgical incision procedure, the others were warmed while the body bladder temperature dropped to 36 °C. The bladder temperature of the patient was recorded every 30 min during the operation. One-way ANOVA and ANOVA with repeated measures were used for comparisons between multiple groups, independent samples *t*-test for pair-wise comparisons.

Results This study included a total of 62 patients, with 31 in each group. Among them, there were 52 males and 10 females, with an age range of 39 to 83 years. The mean age in the CAW group was (62.52 ± 8.15) years, and in the BAW group, it was (62.74 ± 9.20) years. The overall incidence of hypothermia was 16.13% in 62 patients who underwent elective total laparoscopic radical gastrectomy. The incidence of shivering and agitation after operation was both 3.23% in CAW group, and it was 32.26% and 29.03% in BAW group. Time from end of surgery to tracheal extubation in CAW group was significantly lower than BAW group. In addition, continuous active warming could shorten time to first postoperative flatus of patients and relieve postoperative pain.

Conclusion Our study showed that continuous active warming in patients undergoing laparoscopic gastrectomy decreased the incidence of intraoperative hypothermia and contributed to postoperative rehabilitation.

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Trial Registration It was permitted by the Ethics Committee of Xijing Hospital, Air Force Military Medical University, China. No. KY20212024-C-1 25/01/2021 and was registered with the Chinese Clinical Trial Registration Center (11/02/2025) (www.chictr.org.cn; registration number: ChiCTR2500097060).

Keywords Intraoperative hypothermia, Laparoscopic gastrectomy, Active warming, Core temperature

Background

Gastric cancer is the fifth most common cancer worldwide and the third most common cause of cancer death [1]. At present, China as the biggest developping country, gastric cancer has the third highest incidence and mortality of all cancer types, accounting for 44.0% of new cases and 48.6% of gastric cancer-related deaths worldwide, respectively [2]. Nowadays, laparoscopic gastrectomy (LG) has shown a series of advantages over open gastrectomy (OG) in treatment of gastric cancer in view of the implemented gradually of Enhanced Recovery after Surgery (ERAS) protocols [3]. The studies report that laparoscopic gastrectomy can reduce the loss of blood, decrease the analgesic dosage, shorten the first defecation time and et al. [4–6], in the meantime, there is no significant difference in overall survival rate, death related to gastric cancer and death due to other causes [7]. However, dry and cold carbon dioxide (CO_2) insufflation in laparoscopic gastrectomy results in increasing the incidence of intraoperative hypothermia [8].

Normally, the body core temperature is jointly regulated by the hypothalamic thermoregulatory center and the neurohumour, in order to maintain a dynamic balance between the heat production and dissipation [9]. However, autonomic thermoregulation has been upsetted and the threshold for vasoconstriction or tremors have been descreased by the application of anesthetic drugs under general anesthesia(GA) [10]. In addition, the risk factors including the duration of surgery, a significant portion of patient's surface area is exposure to the cold ambient environment of operation rooms (ORs), the volume of intravenous fluid or irrigation and the patient's nutritional status are by far the most common reasons of the core temperature disturbance. Thus, intraoperative hypothermia is the most widespread complication undergoing long-duration surgeries, especially the abdominal surgery. Intraoperative hypothermia, defined as the core temperature below 36 °C during the surgery, the incidence up to 25%~70% [11, 12]. According to the degree of decrease, it can be classified as mild (35.5 ~ 35.9 °C), moderate (35.0 ~ 35.4 °C) and severe (< 35.0 °C) [13].

Evidence has shown that the core temperature below 36 °C under surgery would lead to cardiovascular adverse events, prolonged recovery time of general anethesia, increased infection rate of incisions, and a sequence of other complications [14]. These complications can be catastrophic for patients undergoing laparoscopic gastrectomy [15]. Active warming measures are often taken by the OR staff in order to reduce the incidence of the intraoperative hypothermia, with preventing the redistribution of heat from core to periphery. However, the Randomized Controlled Trial (RCT) studies on the effectiveness of continuous active warming during laparoscopic gastrectomy is scarce. Therefore, we hypothesized that continuous active warming (CAW) will be superior than active warming when body temperature is below 36 °C (BAW) in terms of decreasing the incidence of intraoperative hypothermia. As secondary objectives included presence of shivering and agitation after operation, the time from end of surgery to tracheal extubation, postoperative pain score, the time to first postoperative flatus, postoperative complications, and the inflammatory markers.

Methods

Design

This trial was a prospective randomized controlled study designed to explore the best strategy for the prevention measure of intraoperative hypothermia, and it was permitted by the Ethics Committee of Xijing Hospital, Air Force Military Medical University, China (reference NO. KY20202116-C-1). Meanwhile, it was rigistered at the Chinese Clinical Trial Registration Center (11/02/2025) (registration number: ChiCTR2500097060). This study strictly abided by all legal requirements, regulations and general principles formulated by international agencies concerning ethical conduct in human biomedical research and by the Declaration of Helsinki and the International Ethical Guidelines for Biomedical Research Involving Human Beings. The original protocol was complied strictly by the trial and it could be obtained from the authors upon request.

Subjects

The patients with aged 18 to 85 years, ASA physical classification score I to III grades (ASA score was assessed by the American Society of Anesthesiologists Physical Status Classification Scale [16]), preoperative temperature > 36 °C were included. We excluded patients with preoperative temperature > 37.5 °C, duration of surgery below 1 h, emergency surgery, suffer from hyperthyroidism or hypothyroidism. In addition, the exclusion of criteria included that the treatment changed to open radical gastrectomy and the patients were transfered to intensive care unit (ICU). A sample size was based on the data from our retrospective and observational study, the incidence of the intraoperative hypothermia in which non-continuous active warming patients was 40%, and we assumed that the incidence of continuous active warming patients was 5%.

Sample Size Calculation Formula for Randomized Controlled Trials: $n = \frac{2\bar{p}\bar{q}(Z_\alpha + Z_\beta)^2}{(p1-p2)^2}$. Where n is the required sample size, $\bar{p}$=0.025, $\bar{q}$=0.775, Z_α=1.96, Z_β=1.28, p1=0.4, p2=0.05, and substituting these values into the formula calculates that the minimum sample size for each group should be 30 cases. A total of 62 patients undergoing laparoscopic radical gastrectomy for gastric cancer were included in this study. (Fig. 1).

Intervention

A computer-generated randomized number approach was used to allocate patients into two groups, continuous active warming group (CAW) and active warming when body temperature was below 36 °C group (BAW). The generated random results were sealed in sequentially numbered opaque envelopes and kept by a research assistant. After participants entered the operating room, the randomized envelopes were opened according to the recruitment sequence by a nurse, who then provided warmth to the patients accordingly. The research assistant was not involved in intraoperative care and postoperative follow-up. The patients, surgeons, nurses, and the investigator performing follow-up assessments were blinded to the allocation.

The operating room temperature was adjusted to 22 ~ 25 °C, and the humidity was 40%~60% in advance. An effective and safe venous channel was established for patients and intravenous infusion of sodium lactate ringer injection was given at 37 ~ 41 °C once in the operation rooms. The patient was covered with a large surgical sheet and cotton quilt, and the shoulder pad was placed. The abdominal irrigation fluid was heated to 37 ~ 41 °C during the operation.

Some studies have shown that bladder urine temperature is well consistent with the gold standard of core body temperature monitoring (pulmonary artery floating catheter) [17]. Its advantages lie in the fact that the vast majority of patients undergoing general anesthesia require preoperative catheterization to ensure patient safety during surgery. Temperature measurement can be completed by inserting a urinary catheter with a temperature probe into the urethra, which results in minimal trauma, simple application, good tolerance, easy fixation, and reliable data. Urine volume is an important factor affecting its accuracy, meaning that the higher the urine flow rate, the higher the accuracy of the monitoring [18]. After anesthesia induction, a disposable catheterization kit and a No. 14 temperature-measuring catheter were used for catheterization. The catheter was lubricated with paraffin oil, and the temperature connector at the end of the catheter was connected to the temperature monitoring line, with the data displayed on the monitor and simultaneously included in the patient's electronic medical record.

Inflatable thermal blankets, due to their adjustable temperature, can create a warm environment around the patient, preventing heat transfer from the core to the body surface, and are currently commonly used in clinical practice for active warming. A forced air warming device (Smiths Medical, Level 1, EQ-5000) heats the surrounding room temperature air to 44 °C and then blows the heated air through a hose to the warming blanket and the patient. Before the surgery began, the hose of the warming blanket was placed between the warming blankets at the patient's neck (since the special surgical position required for laparoscopic radical gastrectomy for gastric cancer, the warming blanket cannot completely cover the patient's body surface), with the air outlet positioned at the neck's major blood vessels, directing the warm air towards the opposite side of the incision to avoid increasing the risk of incision infection. Significantly, patients assigned to CAW group were warmed immediately since the surgical incision procedure, the others were warmed while the body bladder temperature dropped to 36 °C. The temperature was set at 44 °C, and the heating machine was stopped when the body temperature rose to 37.5 °C. The bladder temperature of the patient was recorded every 30 min during the operation, in the meantime, abnormal conditions such as sweating were observed and appropriate treatment was taken at any time.

Anesthetic induction and temperature monitoring

Due to the guidance of enhanced recovery after surgery (ERAS), all patients who underwent laparoscopic radical gastrectomy quit smoking for two weeks before surgery, and gastric tube or enema treatment were no longer taken before surgery. Patients were required preoperative fasting for 8 h, and water abstinence for 4 h before surgery to minimise the risk of pulmonary aspiration of gastric contents. During the anaesthesia procedure, left upper extremity venous puncture and invasive arterial puncture were performed for the sake of monitoring vital signs. All patients were administered by intravenous anesthesia, dexamethasone 0.15 ~ 0.2 mg/kg, sufentanil 0.4 ~ 0.6 μg/kg, etomidate 0.2 ~ 0.3 mg/kg, rocuronium bromide 0.9 mg/kg were conducted during induction phase of anesthesia. Tracheal intubation was performed with the a visual laryngoscope, and a 7.5 tracheal catheter was routinely used for men and a 7 tracheal catheter for women. Target-controlled infusion of propofol was used for 2 ~ 3 μg/ml, and remifentanil was used for constant

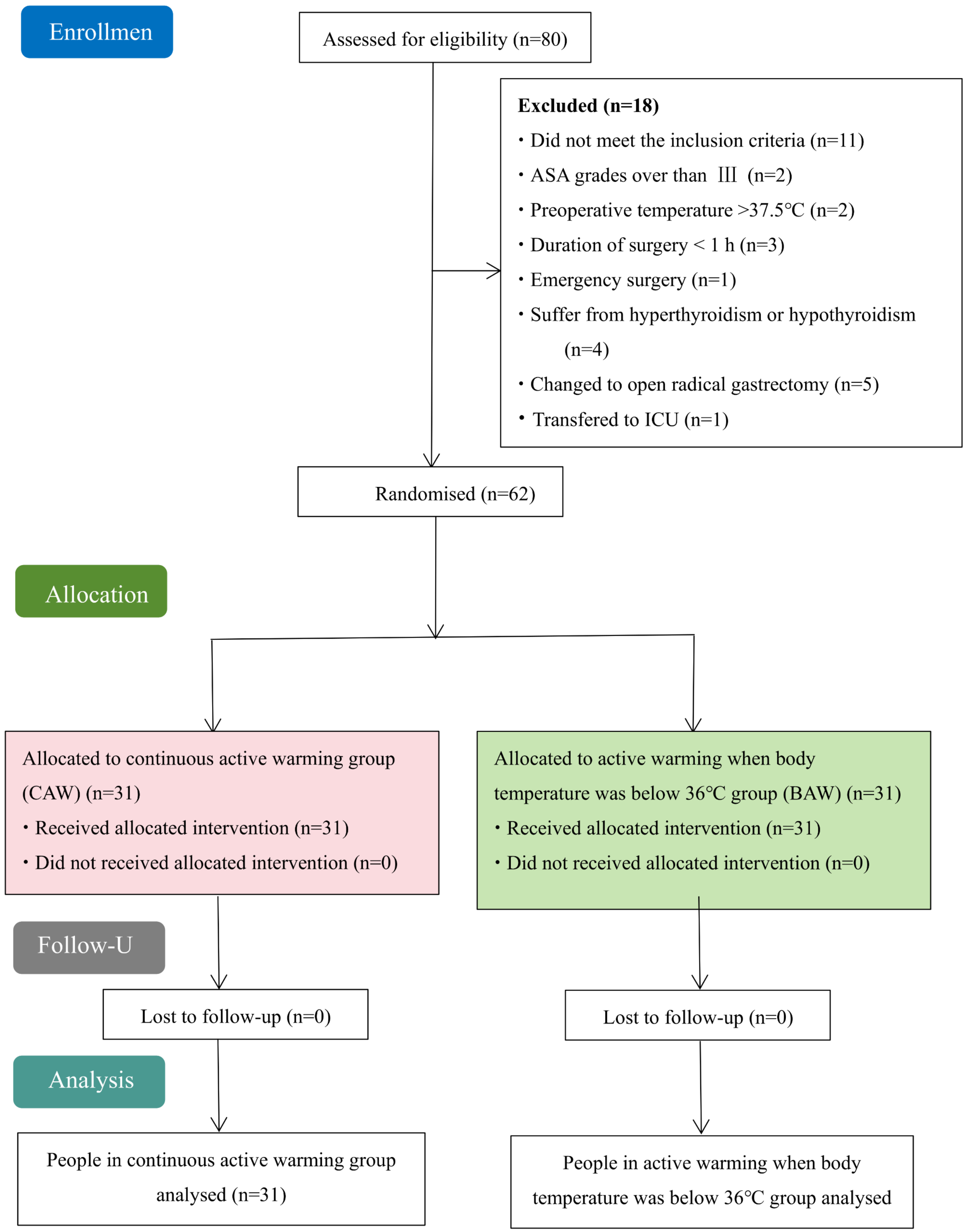

Fig. 1 Consort flowchart diagram

rate infusion of 0.1 ~ 0.2 μg/kg/min during maintenance phase of anesthesia. Timely and accurate treatment while the patient's vital signs fluctuated during the whole procedure.

The first body bladder temperature (T0) as the baseline temperature was recorded while the patient's urinary tube was inserted at the induction stage of anethesia. Then, temperature at the start of surgery was considered as T1. Next, temperature was recorded every 30 min until 3 h after surgery (T2 ~ T8), as well as patients were transferred to PACU after surgery (T9).

To ensure the continuity and accuracy of core body temperature monitoring in patients and to promptly and effectively implement rewarming measures for those with lower core temperatures, the Post-Anesthesia Care Unit (PACU) used the same bladder temperature connection lines as the operating room. The temperature connector at the end of the catheter was connected to the temperature monitoring line, with the data displayed on the monitor and simultaneously included in the patient's electronic medical record.

During their stay in the PACU, patients were assessed by the anesthesia nurses using the "Anesthesia Recovery Period Shivering Grading Scale" and the "Anesthesia Recovery Period Agitation Assessment Scale." Patients with higher grades received continuous comprehensive warming measures, including covering them with blankets and quilts, heating intravenous fluids, blood, and blood products, as well as the continuous use of warming blankets. Continuous, proactive, and effective warming measures have improved the quality of patient recovery from anesthesia and reduced adverse reactions.

2.5 Variables and statistics. SPSS Statistics Software 27.0 (IBM, New York) was used to analyse the data. Count data were represented by example (n) or percentage (%), and measurement data were represented by mean ± standard deviation ($\bar{x} \pm s$). General data were analyzed by *t*-test, chi-square test according to the data type or *Fisher's* exact test when the frequency was < 5. One-way ANOVA and ANOVA with repeated measures were used for comparisons between multiple groups, independent samples *t*-test for pair-wise comparisons, and non-parametric tests was used when homogeneity of variance was not met. $P < 0.05$ indicated a statistical significance.

In this study, the independent variable was the various heating methods (CAW, BAW), the dependent variable was the patients' core temperature. Age (years), body mass index (kg/m^2), ambient temperature (°C), duration of surgery (mins), flushing fluid (ml), volume of crystalloid administered (ml), volume of colloidal administered (ml), hemoglobin (g/L), albumin(g/L) were all continuous variables, the categorical variables were gender (male/female) and the grade of ASA (I, II, III).

Table 1 Patient characteristics ($n = 62$)

Characteristic	groups		χ^2 / t	*P*
	CAW($n = 31$)	BAW($n = 31$)		
Gender			0.000	1.000
male	26	26		
female	5	5		
Grade of ASA			1.217	0.544
I	0	1		
II	28	26		
III	3	4		
Age (years)	62.52 ± 8.15	62.74 ± 9.20	-0.102	0.919
BMI (kg/m^2)	23.60 ± 2.65	25.66 ± 5.70	-1.824	0.073
Ambient temperature (°C)	24.00 ± 0.82	23.97 ± 0.85	0.154	0.878
Duration of surgery (mins)	356.74 ± 551.05	250.48 ± 61.49	1.067	0.290
Flushing fluid (ml)	948.39 ± 699.46	848.39 ± 717.34	0.556	0.580
Volume of crystalloid administered (ml)	2054.84 ± 608.19	2022.58 ± 492.42	0.230	0.819
Volume of colloidal administered (ml)	698.71 ± 322.78	635.48 ± 256.32	0.854	0.396
Hemoglobin (g/L)	135.00 ± 22.88	143.55 ± 23.44	-1.453	0.151
Albumin (g/L)	44.54 ± 3.85	44.56 ± 3.18	-0.029	0.977

Results

Comparison of patient's characteristics between the two groups

62 participants were enrolled in the clinial study who underwent elective total laparoscopic radical gastrectomy from November 2021 to March 2022 in the Department of Gastrointestinal Surgery in our hospital. These patients aged 39 to 83 years, with a median age of 63 years, included 52 males and 10 female. 62 patients were randomised, as demonstrated in Fig. 1. The patient's characteristics including age, body mass index (BMI), ambient temperature, duration of surgery, flushing fluid, volume of crystalloid administered, volume of colloidal administered, hemoglobin, albumin, gender and the grade of ASA were comparable between the two groups. (Table 1).

Comparison of core temperature at different time points between the two groups

Initially, there was no significant difference between the CAW group and the BAW group at the T0, T1, T2 ($P > 0.05$). One hour after the surgery, the core temperature of the CAW group showed a continuous rising trend until patients were transfered to ward. Besides, the core temperature at each time point was higher than the baseline of the patient. However, a downward trend was

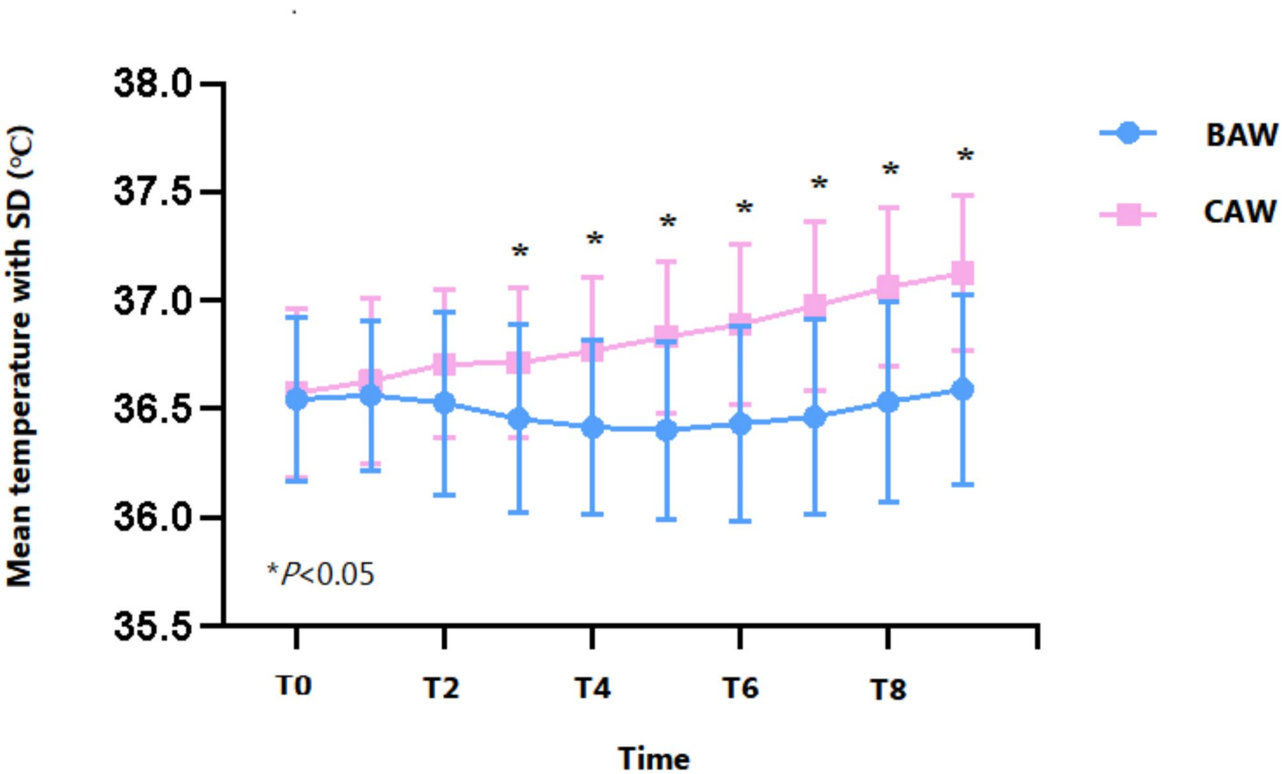

Fig. 2 Mean temperature between the CAW group and BAW group

Table 2 Core temperature at different time points in two groups from repeated measures model ($n = 62$)

Time	CAW group (M ± SD)	BAW group (M ± SD)	Repeated measures F test		
			F	P	ɧ2
T0	36.50 ± 0.40	36.55 ± 0.37			
T1	36.63 ± 0.38	36.56 ± 0.35			
T2	36.71 ± 0.34	36.53 ± 0.42			
T3	36.71 ± 0.34	36.46 ± 0.43			
T4	36.77 ± 0.34	36.42 ± 0.40			
T5	36.83 ± 0.35	36.40 ± 0.41			
T6	36.90 ± 0.37	36.43 ± 0.45			
T7	36.97 ± 0.39	36.47 ± 0.45			
T8	37.06 ± 0.36	36.52 ± 0.46			
T9	37.13 ± 0.35	36.59 ± 0.44			
Group main effect			16.52	< 0.001	0.22
Time main effect			10.85	< 0.001	0.15
Group*Time			10.84	< 0.001	0.15

showed at one hour after the surgery in the BAW group, and the minimum was reached at 3 h of surgery, although it rose slightly at end of the operation. There was a significant difference between the two groups when we comparing the core temperature in the 1 h after the operation ($P < 0.05$). (Fig. 2).

Furthermore, according to the analysis of repeated measures ANOVA, the sphericity test results showed Machly W < 0.001, $P < 0.001$, did not fit the spherical test. Therefore, the corrected results in the "Greenhouse-Geisser" are more reliable in the study. Table 2 shows that from the beginning of the operation to 60 min (T0 ~ T2) after the operation, there was no significant difference in the two groups ($P > 0.05$). However, since 90 min (T3) after the operation, the core temperature of the CAW group was significantly higher than BAW group ($P < 0.05$).

Comparison of the incidence of hypothermia versus time between the two groups

The overall incidence of hypothermia was 16.13% in our study. Among them, the incidence of hypothermia in the BAW group was 32.26%, and none of the patient developed hypothermia in the CAW group. Table 3 shows that the incidence was increasing from the beginning of the operation (T1), until up to 22.58%.

Comparison of the recovery quality after surgery between the two groups

Recovery quality encompasses two aspects: post-anesthetic recovery quality and disease recovery quality. The quality of patient recovery from postoperative anesthesia is typically assessed using indicators such as postoperative shivering, restlessness, time to tracheal extubation, and postoperative pain [19]. For patients undergoing laparoscopic gastric cancer surgery, the incidence of postoperative flatus and complications is also an important

Table 3 Incidence of hypothermia versus time between the two groups (*n* = 62)

Time	CAW group (H/*N*)	BAW group (H/*N*)	*P*
T0	0/31	0/31	—
T1	0/31	1/30	1.000*
T2	0/31	5/26	0.053*
T3	0/31	5/26	0.053*
T4	0/31	5/26	0.053*
T5	0/31	7/24	0.011*
T6	0/31	6/25	0.024*
T7	0/31	7/24	0.011*
T8	0/31	5/26	0.053*
T9	0/31	4/27	0.113*

Table annotation: H, Number of patients of hypothermia; N, Number of patients of normal temperature; * *Fisher's* test。

Table 4 The recovery quality after surgery between the two groups

	CAW group	BAW group	χ^2 / t	P
Grade of shivering			—	0.006*
0	30	21		
1	1	3		
2	0	3		
3	0	4		
Grade of agitation			—	0.012*
0	30	22		
1	0	5		
2	1	3		
3	0	1		
Postoperative complications			—	0.053*
Anastomotic leakage	0	3		
Gastroparesis	0	1		
Intestinal intussusception	0	1		
Time to extubation(min)	11.81 ± 8.07	22.68 ± 8.44	5.185	< 0.001
Immediate postoperative pain score	4.45 ± 1.21	5.52 ± 1.48	3.103	0.003
Time to first postoperative flatus (d)	3.23 ± 0.81	5.55 ± 2.87	4.334	< 0.001

Table annotation: * *Fisher's* test。

evaluation indicator of anesthesia management [20]. In our study, the incidence of shivering and agitation after operation was both 3.23% in CAW group, accordingly, it was 32.26% and 29.03% in BAW group, respectively. Time from end of surgery to tracheal extubation in CAW group was significantly lower than BAW group. In addition, continuous active warming could shorten time to first postoperative flatus of patients and relieve postoperative pain, but had no effect on decreasing the incidence of postoperative complications. These results of the recovery quality after surgery are shown in Table 4.

Table 5 Preoperative inflammatory markers

	CAW group	BAW group	t	P
IL-6(pg/ml)	5.45 ± 3.12	9.25 ± 15.45	1.343	0.184
SAA(mg/L)	5.66 ± 5.12	5.31 ± 3.59	-0.316	0.753
hs-CRP(mg/L)	1.97 ± 1.44	1.87 ± 1.87	-0.252	0.802
PCT(ng/ml)	0.04 ± 0.01	0.04 ± 0.03	0.564	0.575

Table 6 Inflammatory markers on 1 day after surgery

	CAW group	BAW group	t	P
IL-6(pg/ml)	55.76 ± 38.32	75.56 ± 32.67	2.189	0.032
SAA(mg/L)	232.99 ± 223.10	384.06 ± 232.21	2.612	0.011
hs-CRP(mg/L)	42.71 ± 36.50	69.71 ± 25.77	3.365	0.001
PCT(ng/ml)	0.31 ± 0.29	0.54 ± 0.31	2.886	0.005

Table 7 Inflammatory markers on 3 days after surgery

	CAW group	BAW group	t	P
IL-6(pg/ml)	35.55 ± 33.85	60.70 ± 38.04	2.750	0.008
SAA(mg/L)	276.75 ± 135.88	392.92 ± 212.56	2.564	0.013
hs-CRP(mg/L)	52.60 ± 35.23	72.82 ± 37.23	2.197	0.032
PCT(ng/ml)	0.21 ± 0.24	0.40 ± 0.43	2.187	0.033

Table 8 Preoperative coagulation risk

	CAW group	BAW group	t	P
PT(s)	11.92 ± 1.13	12.53 ± 1.38	1.850	0.068
APTT(s)	28.49 ± 7.19	31.45 ± 5.94	1.769	0.082

Table 9 Coagulation risk on 1 day after surgery

	CAW group	BAW group	t	P
PT(s)	12.66 ± 0.56	14.40 ± 1.02	8.317	< 0.001
APTT(s)	35.36 ± 2.40	37.65 ± 3.93	2.768	0.007

Table 10 Coagulation risk on 3 days after surgery

	CAW group	BAW group	t	P
PT(s)	12.25 ± 0.56	13.65 ± 0.87	7.539	< 0.001
APTT(s)	34.09 ± 5.62	36.40 ± 3.08	2.010	0.049

Comparison of the inflammatory markers of perioperative period

Inflammatory markers including IL-6, SAA, hs-CRP, and PCT in the study. Table 5 shows that levels of the inflammatory markers in preoperative period were comparable. Tables 6 and 7 show that the parameters displayed a significant surge on the postoperative day, followed by a marginal decline on the 3 day after surgery, yet they remained elevated above baseline levels.

Comparison of the risk of coagulopathy in the perioperative period

Coagulation risk including PT and APTT in the study. Table 8 indicates that the baseline levels of coagulation risk in the two groups of patients were essentially consistent preoperatively, with no significant difference. Tables 9 and 10 show that the coagulation risk significantly increased in both groups on postoperative days 1 and 3.

Discussion

The high incidence of intraoperative hypothermia is an important cause of morbidity in various types of cancer surgeries, and an independent risk preditor for the overall survival of cancer patients [21]. Actually, the incidence of intraoperative hypothermia of radical tumor resection is still high, the possible reason is considered that operators spend more time in lymph node dissection, complying with the principle of no-touch and block resection in order to avoid tumor dissemination. In addition, in recent years, open abdominal surgery has gradually transformed into laparoscopic procedure within an enhanced recovery after surgery (ERAS) programme, and carbon dioxide (CO_2) insufflation subsequently become into an important factor affecting the decrease of core temperature. However, there are few studies on the effectiveness of continuous active warming during laparoscopic gastrectomy and the association with postoperative rehabilitation. This is the first research to compare continuous active warming and active warming when body temperature was below 36 °C and associate intraoperative hypothemia with recovery after laparoscopic gastrectomy surgery.

The results of this study showed that the overall incidence of hypothermia was 16.13% in 62 patients. Reduction of body temperature were divided into three stages according to the characteristics of the change in the perioperative core temperature: ① Redistribution period, it occurs within 1 h after the induction of anesthesia. The peripheral blood vessels expansion under the taking effect of anesthetic drugs leads to the heat transfers from the center to the periphery, and the core body temperature can be reduced by 1.0 to 1.5 °C; ② Linear reduction period, it occurs within 2 to 3 h after general anesthesia. Due to anesthetic drugs, surgical factors and ambient temperature et al., the heat production and heat dissipation unbalanced under anesthesia; ③ Plateau period, it occurs 3 to 4 h after anesthesia, the core temperature no longer decreases continuously, but gradually stabilizes [22]. (Fig. 3). This is because in the first stage, when vasodilation leads to warm blood reaching the periphery and cold blood from the periphery entering the core circulation, redistribution causes the first rapid decrease in temperature. Vasodilation is caused by the direct action of anesthetics and the indirect consequence of a reduced threshold for vasoconstriction. In the second stage, heat loss exceeds the heat produced by metabolism. Metabolic rate decreases by 15–40% during general anesthesia. The reduction in heat production combined with the increased heat loss during anesthesia leads to a negative heat balance, resulting in hypothermia. Heat loss mainly includes radiation (40%), convection (30%), evaporation (25%), and conduction (5%). In the third stage, which is the plateau period, the core temperature no longer decreases primarily due to maximum vasoconstriction, where any sustained heat loss is balanced by the heat produced by metabolism [23]. The forced-air warming blanket can form a thermal environment arround the patient's body, prevent the transfer of heat from the core to the peripheral and effectively elevate core body temperature after anesthesia induction [24]. Therefore, although the forced-air warming blanket was applied to the patients in the BAW group, it is difficult to elevate the core body temperature above 36 °C because the core body temperature has decreased within the first hour after the induction of anesthesia. Dan et al. [25] showed that the incidence of intraoperative hypothemia in patient undergoing elective open abdominal surgery was at least 34.1%. However, their study included patients undergoing all abdominal surgery and did not focus on patients with gastric cancer. Thus, the incidence of hypothermia was higher than that in our study. Ninht et al. [26] Showed that the prevalence of perioperative hypothermia was up to 41%, the possible explaination was the different temperature measurements, esophageal temperature probe was placed to monitor core temperature after induction of anesthesia and abdominal temperature was placed intraabdominally next to one of the trocars in their study, and bladder temperature cather was used in our research. In addition, the subjects of their study underwent open abdominal surgery which with prolonged exposure of large surfaces of skin.

In present study, intraoperative hypothermia was associated with more presence of postoperative shivering and agitation, more time from end of surgery to tracheal extubation and time to first postoperative flatus, as well as higher immediate postoperative pain score. The results of this study were consistent with those of previous studies, Madrid et al. [28] indicated that the risk of postoperative shivering in surgical patients undergoing active warming was about one-third of patients who did not be supplied of the forced air warming. Most narcotic drugs impair thermoregulation mechanisms in a dose-dependent manner, the patient's sensitivity to hypothermia was reduced by lowering the shivering threshold and impairing the body's ability to regulate temperature. The results showed that the incidence of postoperative shivering in patients under general anesthesia was up to 65%, and shivering can increase the risk of complications by increasing the body's demand for oxygen [29, 30]. Agitation after anesthesia and prolonged postoperative extubation time were common complications in the previous study [29, 31], the result of the present study suggested that the difference in the incidence of agitation and time to extubation between the two groups,

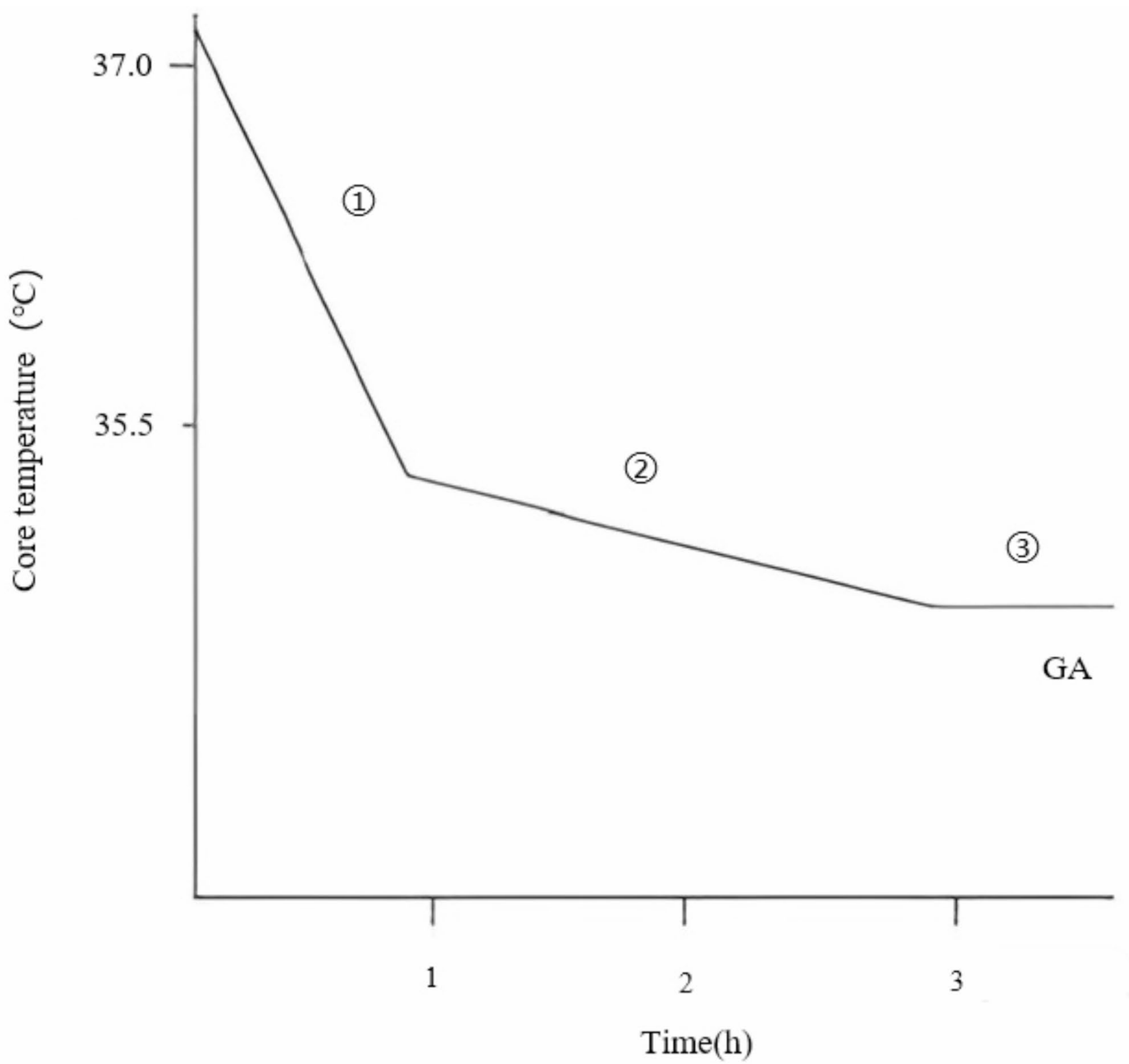

Fig. 3 Characteristic triphasic patterns of hypothermia under general anaesthesia [27]

which is consistent with the findings of Huniler H C et al. [32]. Most cellular functions and enzyme activity are temperature-dependent. Therefore, it is unsurprising that even mild hypothermia prolongs the actions of various drugs. By affecting drug metabolism, perioperative hypothermia is associated with delayed emergence from anesthesia [33]. The results of Luke Reynolds et al. suggested that only 1.9 °C core hypothermia triples the incidence of surgical wound infection following colon resection and increases the duration of hospitalization by 20% [34], which was contrast with the present study. The reason for this might be that this study, in compliance with ethical requirements, considered a patient's body temperature dropping to 36 °C as intraoperative hypothermia, rather than below 36 °C, and all patients received active warming measures. Therefore, the incidence of adverse reactions in patients was reduced. Whether a core body temperature below 36 °C increases the risk of adverse reactions remains to be further studied in future research with ethical approval. Rongjuan et al. [35] showed that introperative normothermia coule enhance the return of intestinal motility and forced-air warmer set to 38 °C during insufflations in laporascopic colorectal patients could significantly reduce the day to first flatus, which was consist with our study. Yeh et al. [36] showed that the passage of flatus was more delayed on the use of heated and humidified CO_2 in patients undergoing laparoscopic colorectal surgery. However, the day to first flatus was relatedy to much more risk factors, such as enema, perioperative care in accordance with the enhanced recovery after surgery (ERAS) guidelines, et al. Furthermore, the study was limited to the colorectal surgery. In our study, intraoperative hypothermia resulted in higher immediate postoperative pain score that was clinically significant. Persson et al. [37] studied the relationship between hypothermia and the disposition of opioids in patients undergoing subtotal hysterectomy. However, the conclusion of the study was that the requirements of opioid did not seem to be influenced by intraoperative hypothermia in a clinical setting which was contrast with us. The reason for this might be that the patients included in this study all underwent laparoscopic surgery. Research has shown that the introduction of dry and cold CO_2 gas into the abdominal cavity can cause the peritoneum to dry out, damage the peritoneal surface, induce inflammatory reactions, and subsequently release various algogenic substances such as kinins and prostaglandins, increasing the patient's pain perception [35]. Additionally, postoperative pain is influenced by many factors, including the standard of pain management, preoperative pain education, and non-pharmacological management strategies [38]. David et al. [39] showed that humidified and heated laparoscopy significantly decreased immediate postoperative pain scores compared to standard laparoscopy. Whereas, whether intraoperative hypothermia lower the immediate postoperative pain score still need to be confirmed.

We observed that hypothermia prolonged the proinflammatory response whereas normothermia enhanced the anti-inflammatory response were consistent with those of previous studies [40, 41]. It has been shown that the expression of proinflammatory cytokines such as TNF-α and IL-6 is significantly increased when the body is stimulated by hypothermia [42]. Intraoperative hypothermia, as an acute stressor, could cause obvious neuroendocrine changes in the body, and the immune system cells release a large number of immune factors into the body, which could participate in the regulation of immune and inflammatory responses of the body. Intraoperative hypothermia suppresses the initial phase of thrombin production, thereby reducing the coagulant activity and inhibiting the coagulation reaction. Studies have confirmed that there is a slight delay in thrombin production at mild hypothermia, and a significant delay at 32 ~ 34 °C. This was consistent with the results of our study. We found that patients with intraoperative hypothermia lost more blood during surgery, although there was no significant difference.

Limitations

We acknowledge that the study has several limitations. First of all, this study was only conducted for patients undergoing laparoscopic gastric cancer surgery, and its applicability to other populations needs to be further verified. Then, bladder temperature seems to have a good reliability and not to be inferior to the other assessment site currently used [43]. However, the gold standard for measuring core temperature remains the pulmonary artery catheter [44], therefore, the quality need to be verified by more temperature measurement methods in the future. Additionally, we must acknowledge that the age range of the patient population included in this study (18–85 years) is quite broad. Since body temperature regulation is a part of homeostatic control and varies significantly among different age groups, further subdivision is required in future research. Importantly, it is notable that the patients with same surgical procedure, the same surgeon, and the same treatment plan were included in the study.

Conclusions

In conclusion, continuous active warming can effectively prevent intraoperative hypothermia in patients with gastric cancer, and improve the quality of postoperative rehabilitation. Operating room nurses and anesthesiologists should pay more attention to perioperative core body temperature changes and take targeted preventive measures.

Supplementary Information

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Supplementary Material 1

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Author contributions

Conception of the study: Mengjia Luo, Hongjuan Lang, Yanran Dai; Literature review and design of trial: Mengjia Luo, Hongjuan Lang, Xiangying Feng; Data analysis and Statistics: Yujie Wang, Xin Guo; Manuscript editing and review: Mengjia Luo, Hongjuan Lang, Juan Du, Gang Ji; The final version of the manuscript has been approved by all authors.

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Data availability

Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate
The present study complied with the term of the Declaration of Helsinki and was permitted by the Ethics Committee of Xijing Hospital, Air Force Military Medical University, China. Informed consent for the study was obtained from all subjects and/or their legal guardians by signing an informed consent form.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Smyth EC, Nilsson M, Grabsch HI, et al. Gastric cancer[J] Lancet. 2020;396(10251):635–48.
2. Yang WJ, Zhao HP, Yu Y, et al. Updates on global epidemiology, risk and prognostic factors of gastric cancer[J]. World J Gastroenterol. 2023;29(16):2452–68.
3. Guerrini GP, Esposito G, Magistri P, et al. Robotic versus laparoscopic gastrectomy for gastric cancer: the largest meta-analysis[J]. Int J Surg. 2020;82:210–28.
4. Wu X, Wang X, Wang Y, et al. Comparison of clinical efficacy between laparotomy and laparoscopic radical surgery for gastric cancer and their effects on CRP, CEA and insulin resistance[J]. J BUON. 2020;25(1):255–61.
5. Zeng F, Chen L, Liao M, et al. Laparoscopic versus open gastrectomy for gastric cancer[J]. World J Surg Oncol. 2020;18(1):20.
6. Long D, Feng Q, Li ZS, et al. Laparoscopic versus open gastrectomy for serosa-invasive gastric cancer: A single-center retrospective cohort study[J]. Surgery. 2021;169(6):1486–92.
7. Huang C, Liu H, Hu Y, et al. Laparoscopic vs open distal gastrectomy for locally advanced gastric cancer: Five-Year outcomes from the CLASS-01 randomized clinical Trial[J]. JAMA Surg. 2022;157(1):9–17.
8. Yu T, Cheng Y, Wang X, et al. Gases for Establishing Pneumoperitoneum during laparoscopic abdominal surgery[J]. Cochrane Database Syst Rev. 2017;6(6):CD9569.
9. Osilla EV, Marsidi JL, Shumway KR et al. Physiology, Temperature Regulation[J]. 2023.
10. Sessler DI. Perioperative thermoregulation and heat balance[J]. Lancet. 2016;387(10038):2655–64.
11. Torossian A, Brauer A, Hocker J, et al. Preventing inadvertent perioperative hypothermia[J]. Dtsch Arztebl Int. 2015;112(10):166–72.
12. Li T, Xu G, Yi J, et al. Intraoperative hypothermia induces vascular dysfunction in the CA1 region of rat Hippocampus[J]. Brain Sci. 2022;12(6):692.
13. Tsuchida T, Takesue Y, Ichiki K, et al. Influence of Peri-Operative hypothermia on surgical site infection in prolonged gastroenterological Surgery[J]. Surg Infect (Larchmt). 2016;17(5):570–6.
14. Campbell G, Alderson P, Smith AF, et al. Warming of intravenous and irrigation fluids for preventing inadvertent perioperative hypothermia[J]. Cochrane Database Syst Rev. 2015;2015(4):CD9891.
15. Kanda M. Preoperative predictors of postoperative complications after gastric cancer resection[J]. Surg Today. 2020;50(1):3–11.
16. Aronson WL, McAuliffe MS, Miller K. Variability in the American society of anesthesiologists physical status classification Scale[J]. AANA J. 2003;71(4):265–74.
17. Uminska JM, Buszko K, Ratajczak J, et al. Comparison of temperature measurements in esophagus and urinary bladder in comatose patients after cardiac arrest undergoing mild therapeutic hypothermia[J]. Cardiol J. 2020;27(6):735–41.
18. Fallis WM. Monitoring bladder temperatures in the OR[J]. AORN J. 2002;76(3):467–76. 481–486.
19. Abdelaziz T, Mohammed EH, Kamal ED, et al. The effect of intramuscular Dexmedetomidine versus oral Gabapentin premedication on the emergence agitation after rhinoplasty. A prospective, randomized, double-blind controlled trial[J]. BMC Anesthesiol. 2025;25(1):50.
20. Yu J, Zheng T, Yuan A, et al. The role of Patient-Controlled epidural analgesia in the Short-Term outcomes of Laparoscopic-Assisted gastrectomy in elderly gastric Cancer Patients[J]. J Surg Res. 2025;306:257–65.
21. Morozumi K, Mitsuzuka K, Takai Y, et al. Intraoperative hypothermia is a significant prognostic predictor of radical cystectomy especially for stage II muscle-invasive bladder cancer[J]. Med (Baltim). 2019;98(2):e13962.
22. Sessler DI. How three linked clinical observations led to an Understanding of perioperative heat balance: A personal reflection on the scientific process[J]. J Clin Anesth. 2024;96:111496.
23. Riley C, Andrzejowski J. Inadvertent perioperative hypothermia[J]. BJA Educ. 2018;18(8):227–33.
24. Chen YC, Cherng YG, Romadlon DS, et al. Comparative effects of warming systems applied to different parts of the body on hypothermia in adults undergoing abdominal surgery: A systematic review and network meta-analysis of randomized controlled trials[J]. J Clin Anesth. 2023;89:111190.
25. Jiang D, Li Q, Wang H, et al. Effect of a Forced-Air warming blanket on different parts of the body on core temperature of patients undergoing elective open abdominal surgery: A randomized controlled Single-Blind Trial[J]. J Perianesth Nurs. 2024;39(6):1042–8.
26. Nguyen NT, Fleming NW, Singh A, et al. Evaluation of core temperature during laparoscopic and open gastric bypass[J]. Obes Surg. 2001;11(5):570–5.
27. Carvalho I, Carvalho M, Abelha F, et al. Effectiveness of a new thermal insulation blanket in the control of inadvertent perioperative hypothermia and comfort: a randomized controlled trial[J]. BMC Anesthesiol. 2024;24(1):455.
28. Madrid E, Urrutia G, Roque IFM, et al. Active body surface warming systems for preventing complications caused by inadvertent perioperative hypothermia in adults[J]. Cochrane Database Syst Rev. 2016;4(4):CD9016.
29. Ji J, Gu X, Xiao C. Comparison of perioperative active or routine temperature management on postoperative quality of recovery in PACU in patients undergoing thoracoscopic lobectomy: A randomized controlled Study[J]. Int J Gen Med. 2022;15:429–36.
30. Akbarpour RM, Jafarpoor H, Shamsalinia A, et al. Effects of a forced-air warming system and warmed intravenous fluids on hemodynamic parameters, shivering, and time to awakening in elderly patients undergoing open cardiac surgery[J]. Ann Card Anaesth. 2023;26(4):386–92.
31. Zhao J, Le Z, Chu L, et al. Risk factors and outcomes of intraoperative hypothermia in neonatal and infant patients undergoing general anesthesia and surgery[J]. Front Pediatr. 2023;11:1113627.
32. Huniler HC, Deniz MN, Gunisen I, et al. Effects of perioperative hypothermia on extubation, recovery time, and postoperative shivering in breast Surgery[J]. Ther Hypothermia Temp Manag. 2024;14(2):110–7.
33. Ruetzler K, Kurz A. Consequences of perioperative hypothermia[J]. Handb Clin Neurol. 2018;157:687–97.
34. Reynolds L, Beckmann J, Kurz A. Perioperative complications of hypothermia[J]. Best Pract Res Clin Anaesthesiol. 2008;22(4):645–57.
35. Jiang R, Sun Y, Wang H, et al. Effect of different carbon dioxide (CO2) insufflation for laparoscopic colorectal surgery in elderly patients: A randomized controlled trial[J]. Med (Baltim). 2019;98(41):e17520.
36. Yeh CH, Kwok SY, Chan MK, et al. Prospective, case-matched study of heated and humidified carbon dioxide insufflation in laparoscopic colorectal surgery[J]. Colorectal Dis. 2007;9(8):695–700.
37. Persson K, Lundberg J. Perioperative hypothermia and postoperative opioid requirements[J]. Eur J Anaesthesiol. 2001;18(10):679–86.
38. Balki I, Khan JS, Staibano P, et al. Effect of perioperative active body surface warming systems on analgesic and clinical outcomes: A systematic review and Meta-analysis of randomized controlled Trials[J]. Anesth Analg. 2020;131(5):1430–43.
39. Balayssac D, Pereira B, Bazin JE, et al. Warmed and humidified carbon dioxide for abdominal laparoscopic surgery: meta-analysis of the current literature[J]. Surg Endosc. 2017;31(1):1–12.
40. Billeter AT, Rice J, Druen D, et al. Warming to 39 degrees C but not to 37 degrees C ameliorates the effects on the monocyte response by Hypothermia[J]. Ann Surg. 2016;263(3):601–7.
41. Eskla KL, Porosk R, Reimets R, et al. Hypothermia augments stress response in mammalian cells[J]. Free Radic Biol Med. 2018;121:157–68.

42. Sun M, Chu F, Zhang L, et al. Effect of medium with moderate temperature on patient's body temperature during percutaneous endoscopic lumbar discectomy[J]. J Orthop Surg Res. 2022;17(1):336.
43. Buccione E, Chiavaroli V, Scarponcini FD, et al. Bladder temperature during neonatal targeted temperature management: A case Report[J]. Adv Neonatal Care. 2023;23(5):418–24.
44. Verheyden C, Neyrinck A, Laenen A, et al. Clinical evaluation of a cutaneous zero-heat-flux thermometer during cardiac surgery[J]. J Clin Monit Comput. 2022;36(5):1279–87.

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