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ORIGINAL RESEARCH

Comparison of Perioperative Active or Routine Temperature Management on Postoperative Quality of Recovery in PACU in Patients Undergoing Thoracoscopic Lobectomy: A Randomized Controlled Study

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Background: Whether intraoperative temperature management can help patients recover quickly in the postanesthesia care unit (PACU) still remains to be investigated. This study aimed to investigate the effect of intraoperative temperature management on the quality of postoperative recovery of patients who underwent pulmonary lobectomy in the PACU.

Methods: Totally, 98 patients aged 45–60 years with a body mass index of 20–25 kg/m^2 who underwent elective thoracoscopic lobectomy were enrolled. Patients were categorized into two groups using a random number table: the conventional group received routine intervention to maintain normothermia (Group C, n = 49) and the aggressive group received integrated interventions (Group A, n = 49). In Group C, normothermic fluid was infused intravenously, the heating blanket was turned on when the intraoperative temperature was <35.0 °C, and the warming was stopped when the temperature reached 36.5 °C. In Group A, the fluid heated to 37 °C was infused intravenously, and the heating blanket was used intraoperatively. When the body temperature was >37 °C, the heating blanket was turned off, and when the body temperature was <36.5 °C, the heating blanket was turned on to continue heating.

Results: Steward awakening scores at 1 min and 5 min after extubation and PaO_2 levels at 15 min after extubation were higher in Group A than in Group C ($P < 0.05$); incidence of chills, nausea, and vomiting in the PACU was lower in Group A than in Group C ($P < 0.05$); and length of stay in the PACU was shorter in Group A than in Group C ($P < 0.05$).

Conclusion: Aggressive intraoperative temperature management of patients undergoing thoracoscopic lobectomy can improve the quality of postoperative recovery in the PACU through a safe and smooth transition compared with routine insulation measures.

Keywords: hypothermia, recovery room, thoracoscopy, thoracic surgery

Introduction

Intraoperative hypothermia is a common side effect in patients receiving general anesthesia as well as in patients under regional anesthesia, the diagnostic criteria for which is a core temperature of <36°C.[1] The incidence of intraoperative hypothermia in patients undergoing surgery ranges from 4% to 72%, and it has been reported to be as high as 90% in some studies.[2–6] Factors that contribute to the occurrence of hypothermia during the perioperative period include cold room

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temperature,[7–9] long operation time,[2] fluid loss,[7] effects of anesthesia,[9,10] skin exposure and temperature of intravenous fluids.[2,7] It is important to identify these risk factors and effectively maintain normal body temperature during the perioperative period, which is related to the perioperative life safety of patients.

Intraoperative hypothermia can increase the risk of clinical complications, including postoperative infection of the surgical incision,[11] inhibition of coagulation and increased surgical bleeding,[12] impact on drug metabolism, extended duration of action of muscle relaxants, and prolonged postoperative awakening time.[13] In severe cases, cardiovascular complications such as ventricular fibrillation and cardiac arrest can occur,[14] which ultimately delays the patient's postoperative recovery. Therefore, intraoperative temperature management is vital for the postoperative recovery of patients with general anesthesia. Patients who are anesthetized for more than 30 min are recommended to be provided measures for temperature management. The fluid used for infusion should be warmed to 37°C, and the core temperature should be monitored and recorded every 30 min.[15]

The large surface and prolonged exposure of the thoracic surgical wound to external factors increases the incidence of intraoperative hypothermia in thoracic patients. Thoracic patients should be monitored postoperatively in the PACU. The PACU is an important hub that connects the postoperative resuscitation period with patients' safe return to the ward. The rapid recovery of patients in the PACU is essential for the turnover of PACU beds and for reducing the cost of patient care. Thus, whether intraoperative temperature management can help patients recover quickly in the PACU should be investigated further.

In this study, we compared the effects of aggressive measures for intraoperative temperature management versus conventional measures on the quality of postoperative recovery of patients undergoing pulmonary lobectomy.

Patients and Methods

General Information

A total of 100 patients admitted to our hospital for elective thoracoscopic surgery were enrolled. The patients were categorized into a conventional group (Group C, n = 50 patients) and an aggressive group (Group A, n = 50 patients) using a random number table The inclusion criteria were (1) American Society of Anesthesiologists (ASA) classification, I–III; (2) age, 45–60 years; (3) body mass index (BMI), 20–25 kg/m^2; and (4) absence of preoperative fever (temperature > 37.3°C). The exclusion criteria were (1) coagulation disorder, (2) severe cardiovascular system disease, (3) infectious disease that caused elevated body temperature, (4) hepatic and renal dysfunction, (5) endocrine system diseases such as hypothyroidism or hyperthyroidism, and (6) diabetes mellitus. The elimination criteria were (1) patients requiring intraoperative blood transfusion and (2) intraoperative temperature of <35°C for 30 min. This study was approved by the ethics committee of the First Affiliated Hospital of Soochow University in 2017 (no. ISRCTN57998533). We obtained signed written informed consent from all patients after informing them and their families of the related risks. This study was conducted in accordance with the Declaration of Helsinki.

Anesthesia Methods

After the patient entered the operating room, two peripheral venous accesses were established. We monitored the electrocardiogram, blood pressure, pulse oximetry, and bispectral index (BIS) (multifunctional vital signs monitor, Philips, The Netherlands). The left radial artery was punctured under local anesthesia to monitor invasive arterial blood pressure and for blood gas analysis.

Anesthesia was induced with the following regimen: intravenous etomidate 0.3 mg kg^{-1}, sufentanil 0.3 μg kg^{-1}, and rocuronium bromide 0.6 mg kg^{-1}. Depending on the patient's physical condition, mechanical ventilation was performed after inserting an appropriate left or right double-lumen endotracheal tube (Henan Xinxiang Camelman Medical Devices Co., Xinxiang, China) as well as positioning the fibrilloscope (Pantex, Japan). The ventilation parameter settings were as follows: volume control mode, inhalation oxygen concentration of 80%, tidal volume of 6–8 mL kg^{-1}, positive end-expiratory pressure of 4 cm H_2O, and inspiratory-to-expiratory ratio of 1:2. The respiratory rate was adjusted to maintain the partial pressure of end-tidal carbon dioxide at 35–45 mmHg.

Anesthesia was maintained with propofol 4–9 mg·kg^{-1}·h^{-1}, remifentanil 0.1–1 μg·kg^{-1}·min^{-1}, and intermittent intravenous infusion of rocuronium bromide. BIS values were maintained at 40–60. Lactated Ringer's solution was continuously infused intravenously at a rate of 3–5 mL kg^{-1} h^{-1}. Fluctuations of mean arterial pressure were no more than 20% of the basal value.

Body Temperature Monitoring and Management

After anesthesia induction, a nasopharyngeal temperature probe (Philips) was lubricated and inserted into the nasal cavity to continuously monitor the core temperature. According to relevant studies[16,17] and our experience in clinical practice, the depth of the nasopharyngeal temperature probe was 10–15 cm.

The operating room temperature was set and maintained around 22°C with 40–60% humidity. The same anesthesiologist and team of surgeons treated all patients. Patients in both groups were not preheated outside the operating room, and were covered with blankets of the same thickness after admission. An inflatable heating blanket (3M, USA) was placed below the umbilicus, and intraoperative peritoneal flushing fluid was heated for 37–38°C before use.

In Group C, normothermic fluid was infused intravenously, with the temperature of 21–22°C. The heating blanket was turned on when the intraoperative temperature was < 35.0°C, and the warming was stopped when the temperature reached 36.5°C. In Group A, an infusion heater was used to heat the intravenous fluid to 37°C, and the heating blanket was turned on for heating 10 min after induction. The heating blanket was turned off when the body temperature was > 37°C, and the heating blanket was turned on to continue heating when the body temperature was < 36.5°C.

Postoperatively, patients with a tracheal catheter were transferred to the PACU. All patients were covered with cotton blankets, and 6 L/min oxygen was provided using a nasal catheter after extubation.

Postoperative Analgesia Strategy

Sufentanil 0.1 μg/kg was given 30 min before the end of surgery as postoperative analgesia, tolisetron mesylate 5 mg was given to prevent postoperative nausea and vomiting, and an intravenous analgesia pump was connected before suture. Patients in both groups were given intravenous self-controlled analgesia pump until 48 h after surgery, sufentanil 2 mg/mL, background dose of 0.05 $\mu g \cdot kg^{-1} \cdot h^{-1}$, single dose of 0.05 μg/kg, locking time 20 min.

Remedial analgesia: Patients with VAS score ≥ 4 were given flurbiprofen axetil 50 mg intravenously, with the maximum daily dose not exceeding 200 mg.

Measurement of Outcomes

The room temperature was set around 22°C before the patient entered the operating room, and the ambient temperature of the operating room was recorded every 5 min from the patient entered the operating room until the patient left the room to calculate the average room temperature. Patients' temperature was recorded at 10 min after induction (T1), 45 min after the start of surgery (T2), 60 min after induction (T3), at the end of surgery (T4), at admission to the PACU (T5), 15 min after admission to the PACU (T6), and at discharge from the PACU (T7). The quality of recovery was assessed by measuring indicators such as the time to extubation (from the end of the surgery to extubation); Steward awakening scores at 1 and 5 min after extubation; partial pressure of oxygen (PaO_2) levels at 15 min after extubation; incidence of ventricular arrhythmias (no abnormalities on the patient's preoperative ECG and observation of premature ventricular ejection, ventricular tachycardia, ventricular flutter, and ventricular fibrillation on ECG after admission to the PACU); incidence of nausea, vomiting, and chills; and the length of stay in the PACU. The criteria for discharge from the PACU included hemodynamic stability, clear consciousness, adequate ventilation of the lungs, airway patency without additional support, and SpO_2 maintained at preoperative levels.

Steward awakening score: (1) consciousness: 2 scores for awake, 1 score for responding to stimuli, 0 score for no responding; (2) airway: 2 scores for coughing on command, 1 score for maintaining good airway, 0 score for airway requiring maintenance; (3) movement: 2 scores for moving limbs purposefully, 1 score for non-purposeful movements, 0 score for not moving.

The degree of shivering in patients in the PACU was assessed using the Wrench rating[15] with the following criteria: grade 0, no shivering; grade 1, constriction of hair erector muscle or peripheral blood vessels or bruising of peripheral skin, without myofibrillation; grade 2, myofibrillation in only one group of muscles; grade 3, myofibrillation in more than one group of muscles; and grade 4, general myofibrillation. A Wrench rating of ≥3 indicated the occurrence of chills. If the chill reaction lasted more than 3 min, the patient was treated with tramadol or a warming remedy.

Statistical Analysis

Data were analyzed using SPSS version 22.0. Continuous data were presented as the mean ± standard deviations for normal distribution, or as median (lower and upper quartiles) for skewness distribution. The differences between the 2 groups were analyzed by the independent samples *t*-test for continuous data and the Mann–Whitney *U*-test was used for

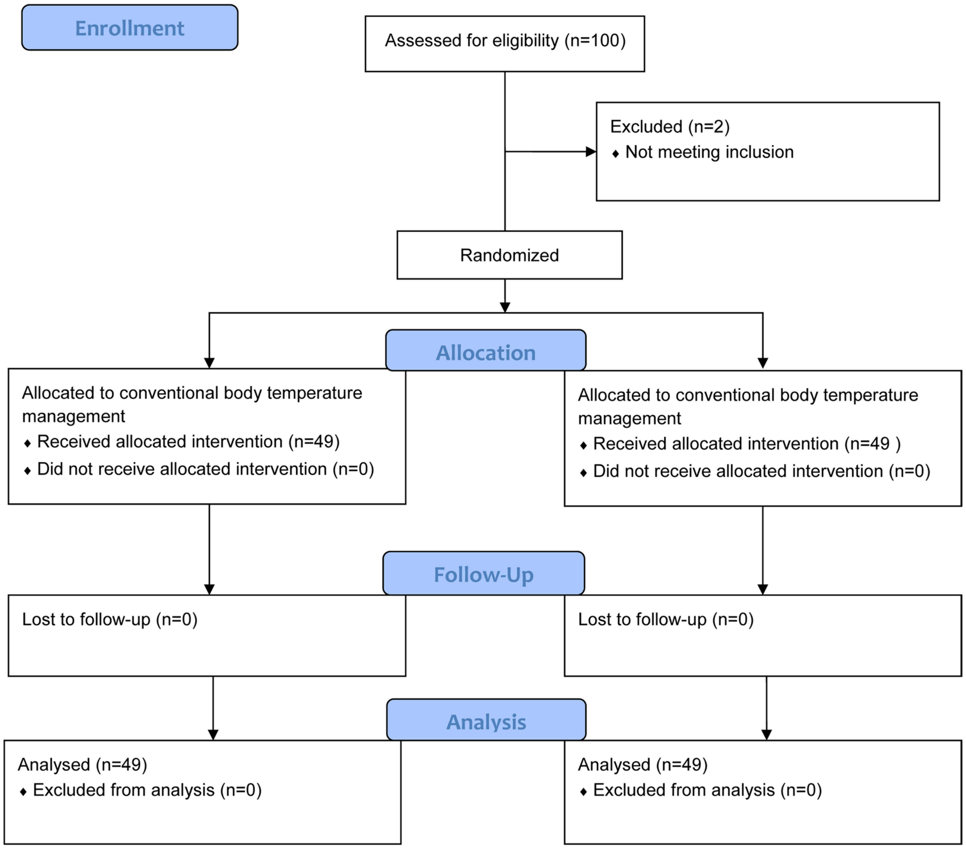

Figure 1 Flow diagram of the study.

dichotomous data and skewed distributed data. The preoperative and postoperative PaO2 levels were analyzed by paired *t*-test. P<0.05 was considered to be statistically significant.

Results

Baseline Data

One hundred patients were initially included in the study. Two patients did not meet the inclusion criteria, and 98 patients eventually completed the study (Figure 1). There were no significant differences in age, sex, BMI, hypertension, surgery time, anesthesia time, intraoperative infusion of fluid, intraoperative bleeding, ASA class, and sufentanil consumption between the two groups (P > 0.05) (Table 1).

Comparison of Body Temperature at Various Time Points

At T1, the temperature of the two groups was not significantly different (P = 0.873). At T2-T7, Group A patients had higher temperatures than Group C patients (P = 0.021, 0.017, 0.042, 0.013, 0.011, 0.034) (Table 2).

Comparison of Extubation Time After Admission to the PACU, Steward Awakening Score, and PaO_2 Levels During Stay in the PACU

The extubation time of Group A patients was shorter than that of Group C (20.0 ± 5.1 vs 16.9 ± 3.6 min, P = 0.006). At 15 min after extubation, Group A patients had higher PaO_2 levels than Group C patients (90.3 ± 10.8 vs 95.1 ± 9.8 mmHg, *P* = 0.001); at 1 and 5 min after extubation, Steward awakening scores were higher in Group A patients than in Group C patients (P < 0.05); Group A patients had a shorter PACU stay than Group C patients (40.1 ± 3.7 vs 37.1 ± 4.3 min, P = 0.014).

Comparison of Complications Associated with Recovery from Anesthesia Between the Two Groups

The difference in the incidence of ventricular arrhythmias between the two groups was not significant (P = 0.204). The incidence of postoperative chills, nausea, and

Table 1 Comparison of Pre- and Intraoperative Data Between the Two Groups

Data	Group C	Group A	*P* value
Age (y)	51.9 ± 4.2	51.5 ± 4.1	0.372
Sex (male/female)	27/22	24/25	0.544
Body mass index (kg/cm^2)	23.0 ± 1.2	23.5 ± 1.1	0.189
Hypertension	15 (30.6)	12 (24.5)	0.498
Operative time (min)	106.1 ± 9.5	107.6 ± 12.2	0.473
Anesthesia time (min)	149.6 ± 10.5	149.3 ± 15.9	0.106
Intravenous infusion (mL)	1034.9 ± 83.9	1019.4 ± 95.1	0.581
Blood loss (mL)	128.0 ± 16.8	125.7 ± 16.9	0.642
Total sufentanil (μg)	40.8 ± 5.7	41.2 ± 6.3	0.715
Operating room temperature (°C)	22.6 ± 2.2	22.4 ± 2.5	0.301
ASA physical status			
I	2 (4.1)	3 (6.1)	
II	45 (91.8)	44 (89.8)	
III	2 (4.1)	2 (4.1)	

Notes: Values are expressed as n, n (%), or mean ± standard deviation.
Abbreviations: Group C, conventional body temperature management group; Group A, aggressive body temperature management group; ASA, American Society of Anesthesiologists.

Table 2 Comparison of Body Temperature (°C) at Each Time Point Between the Two Groups

Time Point	Group C	Group A	*P* value
T_1	36.21 ± 0.24	36.14 ± 0.22	0.873
T_2	36.13 ± 0.15	36.36 ± 0.19*	0.021
T_3	36.22 ± 0.16	36.41 ± 0.18*	0.017
T_4	36.20 ± 0.14	36.49 ± 0.20*	0.042
T_5	36.27 ± 0.18	36.61 ± 0.18*	0.013
T_6	36.20 ± 0.18	36.54 ± 0.11*	0.011
T_7	36.19 ± 0.26	36.57 ± 0.17*	0.034

Notes: Values are expressed as mean ± standard deviation. Group C, conventional body temperature management group; Group A, aggressive body temperature management group; T_1, 10 minutes after induction of anesthesia; T_2, beginning of surgery at 45 minutes; T_3, beginning of surgery at 60 minutes; T_4, end of surgery; T_5, admission to the postanesthesia care unit; T_6, 15 min after admission to the postanesthesia care unit; T_7, discharge from the postanesthesia care unit. Compared with Group C, *P < 0.05.

vomiting and the rate of medication remedy for chills were lower in Group A than in Group C (P = 0.037, 0.025, 0.037) (Table 3).

Discussion

In this study, the core body temperature of the patients in Group A was higher than that of those in Group C at all time points during surgery. All patients were extubated in the PACU, and the extubation times of both groups were observed to evaluate the effect of aggressive temperature management measures on the metabolism of the anesthetic agent. The results showed that the extubation time of Group A was significantly shortened. This result may be attributed to the aggressive insulation measures that avoided a delay in metabolism of the anesthetic agent induced by hypothermia. Additionally, aggressive management of intraoperative body temperature could have promoted the recovery of muscle strength and awakening and facilitated the recovery of respiratory function, which ultimately shortened the length of PACU stay.

We showed that PaO_2 levels were higher in Group A than in Group C, which is undoubtedly favorable for patients undergoing lobectomy. The lower PaO_2 levels in Group C may be because hypothermia causes a shift to the left of the oxygen dissociation curve. Particularly during the recovery from postoperative anesthesia, when oxygen consumption is significantly greater than that at resting, it makes patients more susceptible to hypoxemia and acidosis. Persistent hypoxemia and acidosis are strongly associated with postoperative cardiovascular complications in patients undergoing pulmonary surgery.

Typically, a decrease in the core temperature causes a shivering response in the body, which increases metabolic activity to increase the core temperature.[18] However, most anesthetic drugs impair autonomic thermoregulatory mechanisms in a dose-dependent manner, lowering the shivering threshold and weakening the body's ability to regulate temperature, thereby reducing the patient's sensitivity to hypothermia. In contrast, anesthetic drugs cause peripheral vasodilatation, leading to heat redistribution along the core–peripheral temperature gradient, thereby increasing heat loss.[19–22] Moreover, external factors such

Table 3 Comparison of the Quality of Recovery Between the Two Groups in the Postanesthesia Care Unit

Parameters	Group C	Group A	*P* value
Extubation time (min)	21.9 ± 5.4	18.3 ± 4.8*	0.015
PaO_2 (mmHg)	90.3 ± 10.8	95.1 ± 9.8*	0.001
Nausea and vomiting	9 (18.4)	2 (4.1)*	0.025
Ventricular arrhythmia	5 (10.2)	1 (2.0)	0.204
Steward score			
1 minute after extubation	3.5 ± 0.6	4.3 ± 0.8*	0.015
5 minutes after extubation	4.4 ± 0.8	5.5 ± 0.6*	0.003
Shivering classification			
0	32	42	
I	2	2	
II	5	2	
III	8	2	
IV	2	1	
The overall incidence of shivering	10 (20.4)	3 (6.1)*	0.037
The rescue rate of shivering	8 (16.3)	1 (2.0)*	0.031
Length of stay in postanesthesia care unit (min)	40.1 ± 3.7	37.1 ± 4.3*	0.014

Notes: Values are expressed as n, n (%), or mean ± standard deviation. Compared with Group C, *P < 0.05.
Abbreviation: PaO_2, partial pressure of arterial oxygen.

as improper temperature settings in the operating room, body cavity exposure, and unheated irrigation or infused fluids may lead to unnecessary heat loss in patients.[23] Studies have shown that the core temperature can be reduced by 0.5°C–1.5°C within 1 h after anesthesia induction, and it is more likely to be caused by redistribution of body heat rather than dissipation of body heat, thereby highlighting the importance of body temperature management within 1 h after anesthesia induction.[24,25] Inadvertent perioperative hypothermia increases the incidence of perioperative complications, affecting patients' prognosis. In the present study, the body temperature of the patients who received aggressive temperature management was >36°C at all time points in the PACU, both during and after surgery, and was higher than that of the patients who were kept warm by conventional measures. This indicates that active temperature management reduces the occurrence of hypothermia induced by anesthesia and that its effects persist in the postoperative period.

Hypothermia delays the metabolism of anesthetic drugs, and the residue of muscle relaxants leads to difficulties in respiratory function recovery, thereby affecting extubation. Abnormal metabolism of anesthetic drugs leads to delayed awakening. It has been reported that 15 and 30 minutes of active pre-warming prevent postoperative shivering in the PACU,[26] suggesting the importance of maintaining normothermia to avoid postoperative shivering. Studies have shown that decreased intraoperative temperature is associated with prolonged extubation time and PACU stay.[26,27]

Hypothermia increases the incidence of cardiac arrhythmias and hypoxemia in patients; however, the underlying mechanism remains unclear. Studies have shown that norepinephrine levels increase fourfold for every body temperature decrease by 0.7°C and increase sevenfold for every body temperature decrease by 1.3°C; this leads to vasoconstriction, increased blood pressure and heart rate, and increased incidence of myocardial injury and arrhythmias.[28] Chills are a way of producing heat through muscle and blood vessel contractions to compensate for decreased body temperature. However, the shivering response increases the body's metabolism and oxygen consumption and allows accumulation of lactic acids, which in turn increases the risk of cardiovascular system complications. The incidence rate of postoperative shivering in patients under general anesthesia is up to 65%.[29]

Prevention of perioperative hypothermia reduces postoperative complications.[30] Intraoperative temperature management has been shown to reduce myocardial injury and the incidence of arrhythmias.[31] However, the incidence of ventricular arrhythmias in the PACU did not differ between the two groups. The reason for this may be that the sample size was insufficient in this study, or it may be that the body temperature of the two groups of patients was maintained within the normal range.

Aggressive intraoperative temperature management reduces the risk of postoperative hypoxemia and metabolic acidosis.[31] The incidence of hypoxemia was significantly higher in patients with hypothermia than in patients with normal body temperature.[32] The results of both of these studies corroborate our findings.

However, some limitations were noted. First, we only explored the age group of 45–60 years, so whether our results are generalizable to older patients with a higher risk of hypothermia needs to be further investigated. We only conducted a preliminary study on the postoperative recovery of patients in the PACU. It remains to be determined whether aggressive intraoperative temperature management measures impact the recovery of patients in the pulmonary surgery ward and whether the quality of recovery in the PACU has an impact on the long-term prognosis of patients.

Conclusions

Our results indicate that the effectiveness of aggressive temperature management measures (warming blanket + lavage solution + active warming) can improve the quality of recovery in the PACU after surgery, promote the recovery of respiratory function, shorten the time to extubation, and reduce the incidence of complications such as nausea, vomiting, and chills. This improvement will shorten the length of patients' postoperative stay in the PACU. This study preliminarily confirms the significance of aggressive intraoperative temperature management after induction of general anesthesia, which actively compensates for the dissipation of body temperature due to various reasons, and is of clinical significance for the rapid recovery of patients in the PACU after surgery as well as the reduction of complications during the awakening period.

In conclusion, aggressive intraoperative temperature management facilitates recovery from surgery in the PACU for patients undergoing thoracoscopic lobectomy.

Disclosure

Junhui Ji and Xiafang Gu are co-first authors for this study. The authors declare that there is no conflict of interest.

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