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# Meta-analysis of Temperature Protection's Effect on Anesthesia Recovery Quality in Patients by General Anesthesia Surgery

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**Abstract:** *Objective*: To evaluate the effect of temperature protection on anesthesia recovery quality in patients undergoing general anesthesia surgery. *Methods:* A systematic search was conducted in databases for RCTs on the effect of temperature protection on recovery quality in general anesthesia, and literature was included for meta-analysis. Differences between the study group and the control group in awakening time, extubation time, stay in recovery room, agitation, and shivering were analyzed. *Results:* 13 studies were included. The awakening time in study group was lower than that in the control group (MD = -8.08 min, 95% CI: -8.57 to -7.60), extubation time in study group was lower than that in control group (MD = -11.99 min, 95% CI: -12.89 to -11.09), stay in recovery room of study group was shorter than that of control group (MD = -7.13 min, 95% CI: -8.13 to -6.13). Incidence of agitation in study group was lower than that in control group (OR = 0.36, 95% CI: 0.22 to 0.61), incidence of shivering in study group was lower than that in control group (OR = 0.29, 95% CI: 0.18 to 0.45). *Conclusion:* Temperature protection has a good effect on improving recovery quality in general anesthesia surgery and provides a guarantee for safety.

**Keywords:** Temperature protection; Anesthesia recovery; Meta-analysis

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## 1. Introduction

General anesthesia involves the infusion of anesthetic drugs into the body through respiratory tract, intravenous, or other routes, aiming to achieve muscle relaxation, sedation, analgesia, and suppression of intraoperative stress, thereby ensuring the successful completion of surgical procedures [1]. Due to factors such as intraoperative bleeding, exposure, environment, and irrigation, patients under general anesthesia are prone to developing hypothermia [2–4]. Hypothermia not only affects the patient's internal environment, increases the risk of intraoperative infection and the need for blood transfusion, but also impairs the normal breakdown of anesthetic drugs, leading to delayed emergence or agitation, and reducing the quality of anesthetic recovery [5,6]. Poor quality of anesthetic recovery may exacerbate cardiovascular burden, triggering aspiration and hypoxemia [7]. Temperature protection is a nursing method that maintains normal core body temperature through thermal insulation measures during the perioperative period, thereby preventing hypothermia in patients. Temperature protection can regulate patients' perioperative body temperature and prevent the adverse effects of hypothermia[8].

Currently, temperature protection is used in general anesthesia surgery, but its impact on the quality of anesthetic recovery is controversial. Some researchers support that temperature protection can improve the quality of anesthetic recovery in patients undergoing general anesthesia surgery [9]. However, other researchers believe that temperature protection methods such as air insulation have limited effects on the quality of anesthetic recovery and do not produce significant results [10]. Therefore, this study conducts a meta-analysis on the impact of temperature protection on the quality of anesthetic recovery in patients undergoing general anesthesia surgery, aiming to provide evidence-based support for the application of temperature protection.

# 2. Materials and methods

## 2.1. Literature search

This study adhered to the PRISMA 2020 statement. By searching RCTs on the impact of body temperature protection on the quality of anesthesia recovery in patients undergoing general anesthesia surgery in Chinese and English databases such as CNKI, VIP, Wanfang, Cochrane Library, PubMed, Wiley, and Embase, with a search timeframe from the establishment of the databases to February 2026. The search terms included “body temperature protection,” “warming,” “general anesthesia,” “anesthesia recovery,” “Body temperature protection,” “Warming,” “General anesthesia,” and “Anesthesia recovery.” The search was conducted using a combination of subject headings and free-text terms. The CNKI search formula was (subject = “body temperature protection” + “heat preservation” + “intraoperative heat preservation” + “active heat preservation” + “air warming” + “warming blanket” + “body temperature management”) AND subject = “general anesthesia” + “general anesthesia” AND text = “anesthesia recovery” + “recovery quality” + “recovery period” OR text = “extubation time” OR text = “PACU” + “anesthesia monitoring unit,” with the document type set to “research paper”; PubMed search formula ((“anesthesia, general”[MeSH] OR “general anesthesia”[All Fields]) AND (“Regulation, Body Temperature”[MeSH Terms] OR “Active Warming”[All Fields] OR “temperature protection” [All Fields] OR “Intraoperative Warming”[ All Fields] OR “Temperature Management”[All Fields] OR “Inflatable Warming Blankets”[All Fields] OR “forced-Air Warming”[All Fields]) AND (“Delayed Emergence from Anesthesia”[MeSH Terms] OR “awakening”[All Fields] OR “emergence”[All Fields] OR “recovery”[ All Fields] OR “Anesthesia recovery” [All Fields]) OR (“Airway Extubation”[MeSH Terms] OR “extubation”[All Fields] OR “extubation time”[All Fields]) OR (“Length of stay”[MeSH Terms] AND “PACU”[All Fields] OR “PACU stay”[All Fields]) OR (“emergence delirium”[MeSH Terms] OR “agitation”[All Fields] OR “restlessness”[All Fields]) OR “shivering”[MeSH Terms]) AND (“randomized controlled trial”[Publication Type] OR “randomized controlled trials as topic”[MeSH Terms] OR “randomized controlled trial”[All Fields] OR “randomised controlled trial”[All Fields] OR ((“random allocation”[MeSH Terms] OR (“random”[All Fields] AND “allocation”[All Fields]) OR “randomized”[All Fields] OR “random allocation”[All Fields] OR “random”[All Fields] OR “randomisation”[All Fields] OR “randomize”[All Fields] OR “randomizations”[All Fields] OR “randomizing”[All Fields] OR “randomizes”[All Fields]) AND “controlled”[All Fields] AND (“studies”[All Fields] OR “study”[All Fields] OR “studys”[All Fields])) OR “RCTs”[All Fields] OR “prospectively”[All Fields] OR (“prospective”[All Fields])).

## 2.2. Methods

### 2.2.1. Inclusion criteria and exclusion criteria

Inclusion criteria: (1) All were RCTs; (2) The study subjects were patients undergoing general anesthesia surgery, not local anesthesia or regional anesthesia, aged > 18 years, with a surgery duration of ≤ 6 hours [11]; (3) Intervention strategies: The control group received conventional interventions, including passive cotton blankets, surgical bed blankets, and other conventional insulation measures, without receiving any active insulation measures; the study group adopted temperature protection, with temperature protection measures being active warming, using warming devices such as warming blankets and air warming devices, with a core body temperature of ≥ 36℃, and the lowest temperature monitoring time point was upon entering the resuscitation room, where core body temperature was monitored; (4) Outcome indicators: Time to

recovery, time to extubation, duration of stay in the resuscitation room, agitation, and shivering.

Exclusion criteria: (1) Literature for which the full text cannot be obtained; (2) Duplicate literature; (3) Literature with incomplete data or data that cannot be converted; (4) Other types of research, such as animal experiments, systematic reviews, mechanistic studies, conferences, etc.

### 2.2.2. Literature screening and data extraction

Two individuals independently handle the literature screening task and verify the screening results. For controversial literature, a third individual collaboratively evaluates it. After eliminating duplicate literature, the initial screening is conducted by reviewing the titles and abstracts, followed by a full-text reading to determine which literature to include. Data is independently extracted by two individuals and stored in Excel. In case of any questionable data, it is resolved through consultation with the third individual. The extracted information mainly includes the first author, year, sample size (study group/control group), research subjects, and intervention methods (divided into control group intervention and study group intervention, i.e., the insulation methods and equipment used).

### 2.2.3. Quality evaluation

The quality of the included literature was assessed using the Cochrane Bias Tool (RoB) version 1.0, encompassing 7 items across 6 domains: randomization method, allocation concealment, incomplete data, blinding, selective reporting, and other biases. The assessment results were categorized into three types: high risk, unclear, and low risk. In the randomization method item, if a specific random allocation method such as random number table was used, it was considered low risk; if the randomization method was not specifically described, it was considered unclear; otherwise, it was considered high risk. In allocation concealment, if methods such as sealed envelopes or central randomization were used, it was considered low risk; if researchers could predict patient allocation, it was considered high risk. In incomplete data, if the overall dropout rate was < 5% or withdrawal due to outcome-related factors, it was considered low risk; if the overall dropout rate was > 20% or there was an imbalance between groups, it was considered high risk. In blinding of patients and caregivers, if blinding was successfully implemented, it was considered low risk; if blinding was not implemented and the outcome was subjective, it was considered high risk; otherwise, it was considered unclear. In the blinding of outcome assessment, if the assessment personnel were blinded to the allocation and the outcome was objective, it was considered low risk; if blinding was not implemented and the outcome was subjective, and the assessment personnel participated in the nursing intervention, it was considered high risk; otherwise, it was considered unclear. The selective reporting item assessed the completeness of reporting of the primary outcome, while other biases mainly assessed whether the study had other biases such as baseline imbalance. If there was a baseline imbalance, it was considered high risk; if baseline characteristics were similar, it was considered low risk.

### 2.2.4. Statistical methods

All data were analyzed using RevMan 5.3. Dichotomous variables were combined using logarithmic forms, with OR as the effect measure, and continuous variables were analyzed using MD as the effect measure, listing the estimates and 95% CIs. Heterogeneity analysis was conducted using the Cochrane Q test. $P < 0.10$ and $I^2 \geq 50\%$ indicated significant heterogeneity. If there was no significant heterogeneity, a fixed-effects model could be used; otherwise, a random-effects model could be applied for analysis. Subgroup analysis was conducted to explore possible factors. Sensitivity analysis was performed using the one-by-one exclusion method, where each original study was sequentially excluded and meta-analysis was redone to observe changes in OR values and 95% CIs. If the direction of effect and significance remained unchanged after excluding any study, the results were considered robust. Funnel plots and Egger's test were used to analyze publication bias in the studies. The quality of evidence was assessed using the GRADE evidence level. If no data were available, authors were contacted via email for information. If no response was received, the study was excluded.

# 3. Results

## 3.1. Literature screening process and results

A total of 394 articles were initially retrieved, and 13 articles were included after screening, as shown in **Figure 1**.

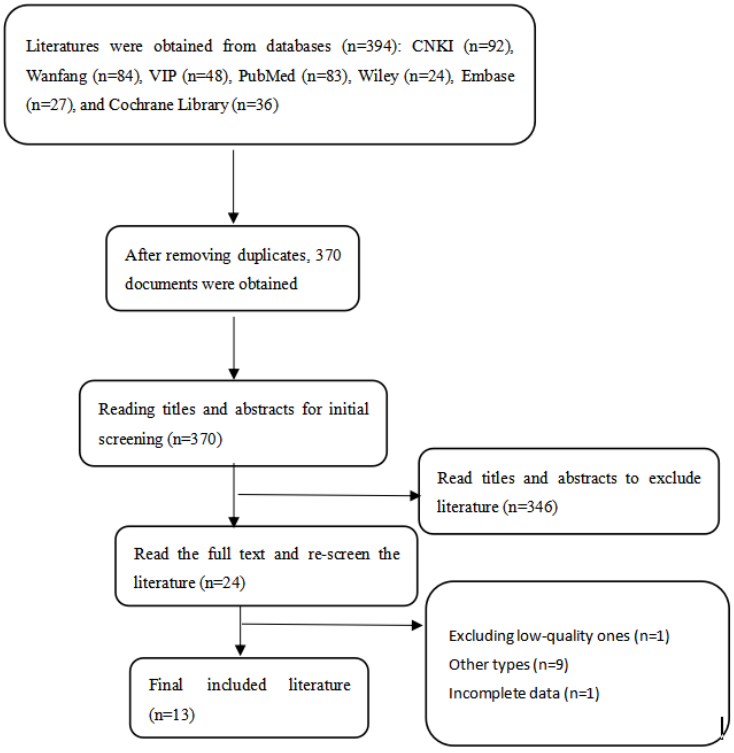


**Figure 1.** Literature screening process

## 3.2. Literature characteristics and quality evaluation

The overall quality of the 13 articles is good, all of which are medium to high-quality. The risk of bias in the articles is shown in **Figures 2** and **3**, and the basic characteristics are presented in **Table 1**.

**Table 1.** Basic characteristics of literature

| First author | Year | Sample size | Research subject | Research group intervention | Control group intervention | Outcome measure |
|---|---|---|---|---|---|---|
| Cho J [12] | 2024 | 24/25 | transurethral surgery | Multi-mode body temperature protection | routine care | ③、④ |
| Chen Lanping [13] | 2024 | 76/76 | Patients undergoing complex trauma surgery under general anesthesia | Inflatable warming blanket for body temperature protection | routine care | ③ |
| Xu Peng [14] | 2020 | 200/200 | general anesthesia patient | Multi-mode enhanced insulation | routine care | ①、②、④、⑤ |
| Zhang Zhengtang [15] | 2023 | 60/60 | general anesthesia patient | Multi-mode enhanced body temperature protection | routine care | ①、② |
| Michele C[16] | 2024 | 20/20 | Total hip arthroplasty | Preoperative forced air heating + whole-body blanket | routine care | ③ |
| Pan Y[17] | 2025 | 40/40 | Patients undergoing resection for endometrial cancer | temperature blanket insulation | routine care | ①、③、④、⑤ |

| First author | Year | Sample size | Research subject | Research group intervention | Control group intervention | Outcome measure |
|---|---|---|---|---|---|---|
| Luo MJ[18] | 2025 | 31/31 | Patients undergoing laparoscopic gastrectomy | Multi-mode continuous active warming | routine care | ②、④、⑤ |
| Han Xinping [19] | 2022 | 43/43 | laparoscopic surgery | air heating | routine care | ①、③、④、⑤ |
| Huang Weibo [20] | 2022 | 41/40 | General anesthesia abdominal surgery | inflatable thermal blanket | routine care | ①、②、④ |
| Jae H [21] | 2021 | 61/59 | General anesthesia elective surgery | Forced air heater for warming during the induction period | routine care | ③、④ |
| Lee S[22] | 2020 | 25/26 | Gynecological laparoscopic surgery | Air heating device | routine care | ④ |
| Chen R[23] | 2026 | 59/59 | thoracoscopic surgery | Closed-loop heating device | traditional management | ③ |
| Shim J [24] | 2024 | 32/34 | Percutaneous nephrolithotomy | Forced air heater | routine care | ③、④ |

Note: ① Time to regain consciousness; ② Time to extubate; ③ Duration of stay in resuscitation room; ④ Shivering events; ⑤ Agitation events

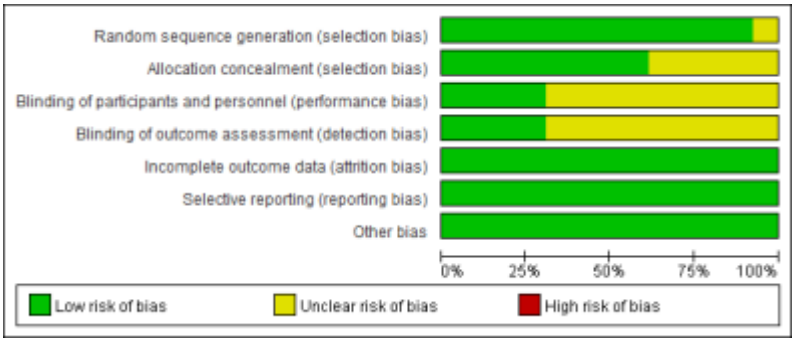


**Figure 2.** Percentage of risk of bias in included studies

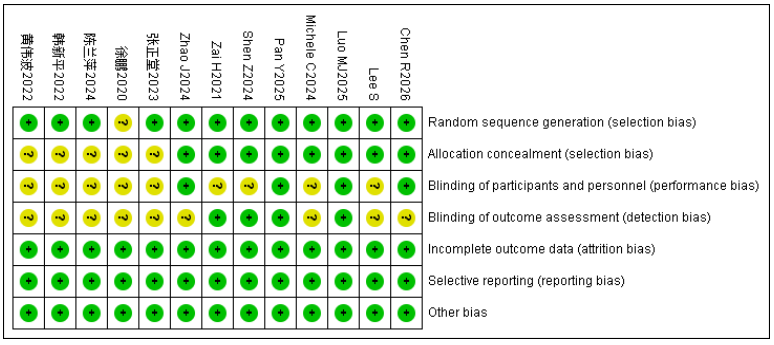


**Figure 3.** Bias risk assessment diagram of included literature

## 3.3. Outcome indicators meta-analysis

### 3.3.1. Time to regain consciousness, extubation time, and duration of stay in the resuscitation room

Four studies reported on the time to recovery (344 cases in total), with the study group exhibiting a shorter time to recovery compared to the control group, and the difference being statistically significant (MD = -8.08 min, 95% CI: -8.57 to -7.60), with no significant heterogeneity ($I^2$ = 4%), as shown in **Figure 4A**. Four studies reported on the time to extubation (332 cases in total), with the study group exhibiting a shorter time to extubation compared to the control group, and the difference being statistically significant (MD = -11.99 min, 95% CI: -12.89 to -11.09), with no significant heterogeneity ($I^2$ = 0%), as shown in **Figure 4B**. Eight studies reported on the duration of stay in the resuscitation room (355 cases in total), with the study

group exhibiting a shorter duration of stay in the resuscitation room compared to the control group, and the difference being statistically significant (MD = -7.13 min, 95% CI: -8.13 to -6.13), with significant heterogeneity ($I^2$ = 93%), as shown in **Figure 4C**.

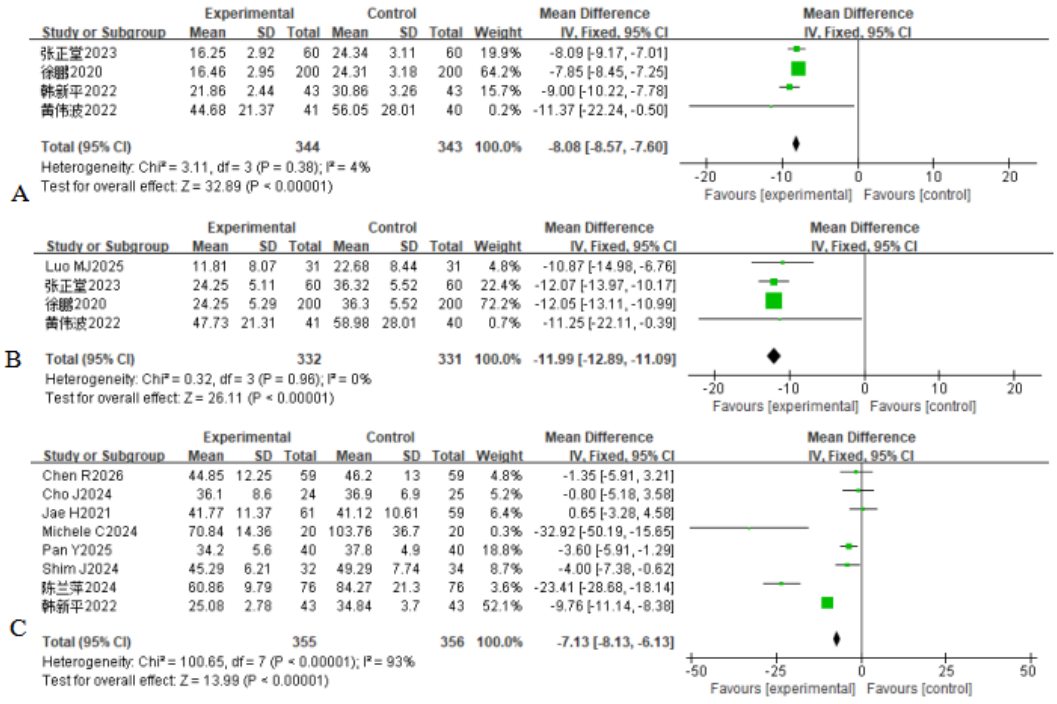


**Figure 4.** Forest plots of wake-up time, extubation time, and recovery room stay time for two groups

### 3.3.2. Restlessness and shivering during the anesthesia recovery period

Four studies reported the incidence of agitation events, and eight studies reported the incidence of shivering events. The incidence of agitation and shivering in the study group was lower than that in the control group, with statistically significant differences (OR = 0.36, 0.29, 95% CI: 0.22–0.61, 0.18–0.45). There was no significant heterogeneity ($I^2$ = 7%), as shown in **Figure 5**.

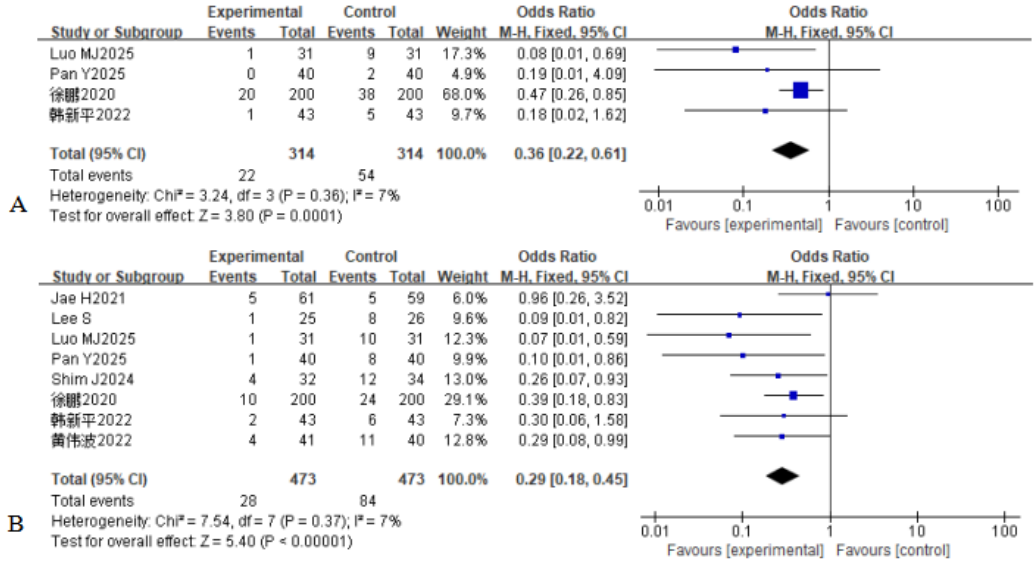


**Figure 5.** Forest plots of agitation and shivering events (A: agitation; B: shivering)

### 3.3.3. Subgroup analysis

Due to heterogeneity, subgroup analysis was conducted on the duration of stay in the recovery room based on surgical type and type of temperature protection measures. Subgroups were divided based on surgical type into laparoscopic surgery, trauma, and orthopedic surgery, and based on temperature protection measures into air warming group, inflatable thermal blanket group, and multi-modal thermal management group. In the laparoscopic surgery subgroup (5 studies), the $I^2$ for the duration of stay in the recovery room was 0%; in the trauma and orthopedic surgery subgroup (2 studies), the $I^2$ was 6%, with all $I^2$ values < 50%. Surgical type can be considered as the source of heterogeneity for the duration of stay in the recovery room; whereas in the air warming group (3 studies), inflatable thermal blanket group (2 studies), and multi-modal thermal management group (2 studies), the $I^2$ values were 93%, 98%, and 92%, respectively, with all $I^2$ values > 50%. Temperature protection measures do not contribute to the heterogeneity in the duration of stay in the recovery room, as shown in **Figure 6**.

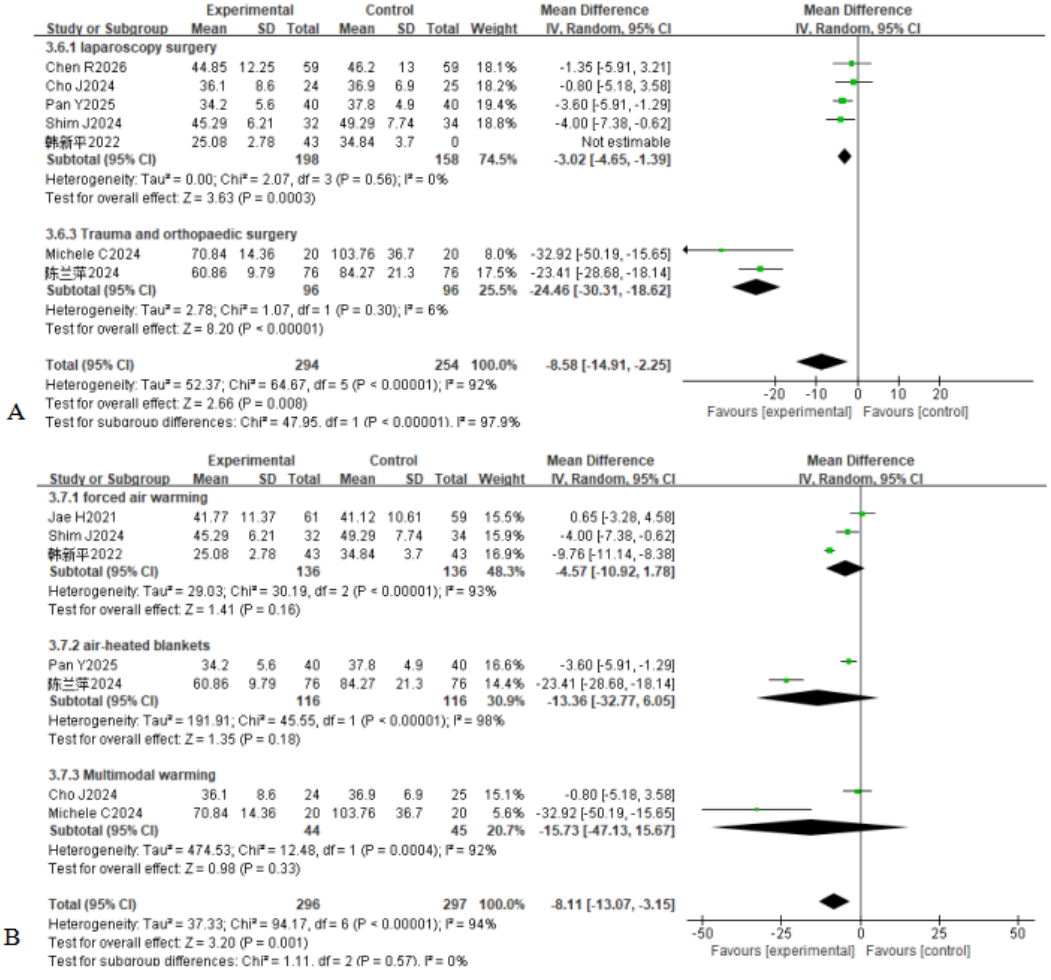


**Figure 6.** Subgroup analysis (A: subgroup analysis by surgical type, B: subgroup analysis by warming method)

## 3.4. Sensitivity analysis

The sensitivity analysis results indicated that the meta-analysis outcomes exhibited good robustness. The effect size values for time to wakefulness, extubation time, duration of stay in the resuscitation room, shivering, and agitation did not significantly differ when analyzed using both random-effects and fixed-effects models, suggesting that the pooled results of the studies were generally reliable. After eliminating any study one by one, the direction and significance of the

pooled effect sizes for each outcome indicator remained unchanged. The pooled effect size ranges for time to wakefulness, extubation time, duration of stay in the resuscitation room, agitation, and shivering were -7.91 to -8.28, -11.84 to -12.05, -4.59 to -8.39, 0.12 to 0.46, and 0.30 to 0.37, respectively, indicating good robustness (all $P < 0.05$).

## 3.5. Publication bias

Regarding the analysis of biases for the outcome indicators, including time to consciousness (Figure 7A), extubation time (**Figure 7B**), duration of stay in the resuscitation room (**Figure 7C**), shivering (**Figure 7D**), and agitation (**Figure 7E**), although some funnel plot points deviate from the median, there was no publication bias as determined by the Egger test ($P > 0.05$). See **Figure 7** and **Table 2**.

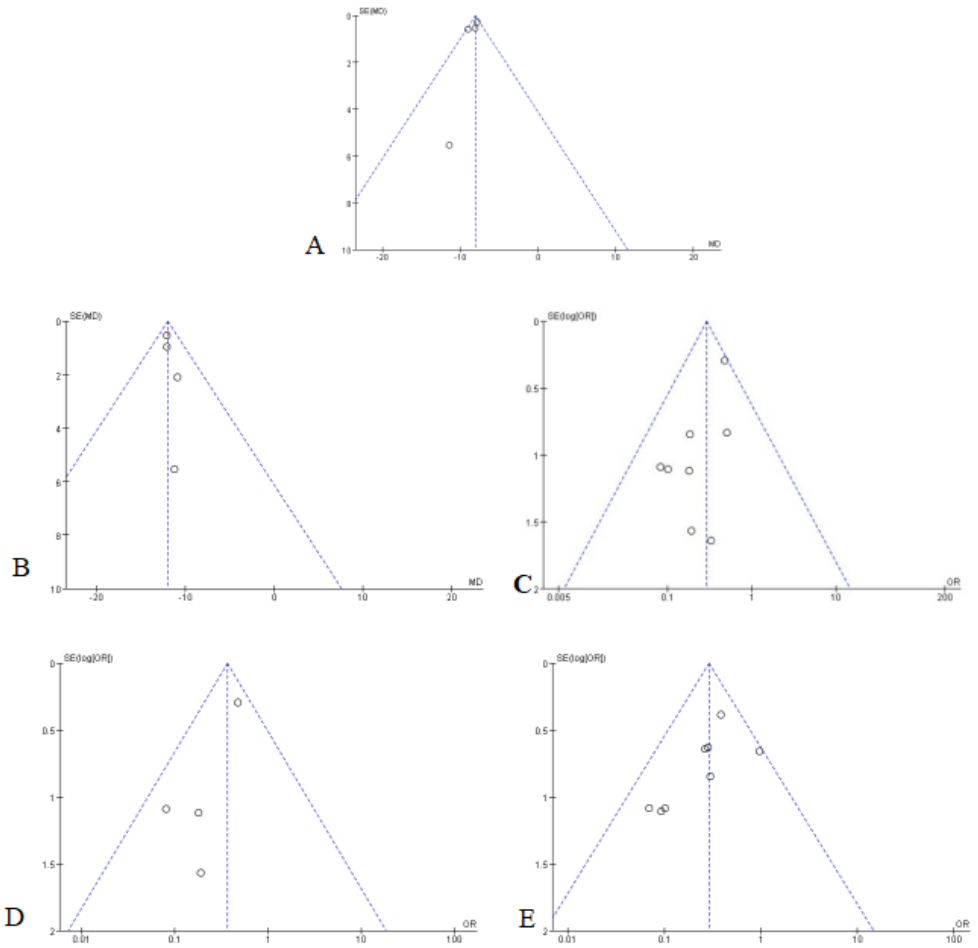


**Figure 7.** Funnel plot

**Table 2.** Egger test results

| Factor | Egger test |
|---|---|
| Wake-up time | 0.308 |
| Extubation time | 0.271 |
| Duration of stay in the recovery room | 0.839 |
| Shivering | 0.082 |
| Agitation | 0.091 |

### 3.6. GRADE evidence level results

According to the GRADE evidence level assessment, among the five outcome indicators, the quality of evidence for recovery time and agitation is moderate, mainly due to the lack of blinding, while the other three indicators have high-quality evidence.

## 4. Discussion

This study, through meta-analysis, reveals that the study group exhibited shorter recovery time, extubation time, and duration of stay in the resuscitation room, as well as lower incidences of shivering and agitation compared to the control group. This indicates that temperature protection is effective in enhancing the quality of anesthesia recovery in patients undergoing general anesthesia surgery. The analysis in this study confirms the hypothesis that, compared to conventional passive interventions, active temperature protection can prevent shivering and cerebral vasospasm caused by hypothermia, reduce the risk of cerebral hypoxia in patients, protect the nervous and cardiovascular systems during the perioperative period, alleviate damage to brain functional areas, and shorten extubation time [25]. Additionally, temperature protection can maintain the normal metabolic rate of general anesthetic drugs in the body, avoiding increased recovery time due to residual anesthetic drugs [26]. The data from this study support clinicians in incorporating active temperature protection measures during general anesthesia surgery to ensure the quality of anesthesia recovery for patients.

However, there is heterogeneity in the analysis of duration of stay in the recovery room in this study, which may be due to differences in the types of surgeries, warming methods, duration of surgery, and types of anesthetic drugs among different studies. The warming methods included in this study are air warming, inflatable warming blankets, and multi-mode warming, and different warming methods may also contribute to heterogeneity. In terms of surgical types, Chen *et al.* [13] studied patients undergoing complex trauma surgery, Pan *et al.* [17] included patients undergoing endometrial cancer resection, while Michele [16] conducted a trial on total hip replacement surgery. The difficulty, operational process, and duration of different surgeries vary, which may be the cause of heterogeneity. Patient comorbidities and types of anesthetic drugs may also be potential factors contributing to heterogeneity. However, due to the wide variety of general anesthetic drugs and the fact that patients in different studies may have various comorbidities, subgroup analysis was not conducted. Taking into account the influence of these factors, this study conducted a subgroup analysis on indicators with heterogeneity and found that surgical type may be the source of heterogeneity. This study has certain limitations. On the one hand, although all included literature are of medium to high quality, there are only 13 articles, and some studies did not provide means and standard deviations. Some data were estimated through indirect methods, which may affect the precision of the effect size. On the other hand, although the Egger test showed no publication bias, due to the small sample size and the exclusion of results from gray literature such as conference abstracts, there may still be potential bias.

## 5. Conclusion

In summary, body temperature protection can enhance the quality of anesthesia recovery in patients undergoing general anesthesia surgery. It is recommended to adopt multiple modes of insulation measures, such as air warming and inflatable warming blankets, for body temperature protection. However, the surgical procedures and intervention strategies included in the literature reviewed in this study vary. More high-quality studies can be conducted in the future to better analyze the advantages of body temperature protection and the differences in its effects across different surgeries.

## Disclosure statement

The authors declare no conflict of interest.

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