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Risk factors for postoperative hypothermia in non-cardiac surgery patients: a systematic review and meta-analysis

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Abstract

Background Postoperative hypothermia seems to be a common problem in surgical patients but is easily ignored. This study aimed to identify risk factors for postoperative hypothermia in non-cardiac surgery patients.

Methods We searched databases including PubMed, Embase, Web of Science, Cochrane Library, CINAHL, VIP, Wan Fang, CNKI, and CBM from inception to April 2025. The studies were selected using inclusion and exclusion criteria. Two reviewers screened studies, extracted data, and independently evaluated the risk of bias. The quality of the study was assessed with the Newcastle-Ottawa Scale, and a meta-analysis was carried out with Revman 5.4 software.

Results A total of 17 studies were included. Age ≥ 60 (odds ratio [OR] = 1.80), BMI < 18.5 kg/m^2 (*OR* = 1.83), ASA III-IV (*OR* = 1.87), endoscopic surgery (*OR* = 1.93), intraoperative blood loss ≥ 100ml (*OR* = 2.35), intravenous fluid ≥ 1000ml (*OR* = 1.87), blood transfusion (*OR* = 1.80), duration of anesthesia > 1 h (*OR* = 1.99) and duration of surgery > 1 h (*OR* = 2.34) were significant risk factors that contributed to postoperative hypothermia in non-cardiac surgery patients.

Conclusion There are many risk factors for postoperative hypothermia in patients undergoing non-cardiac surgery. The results of this research may improve clinician awareness, risk stratification, and prevention of postoperative hypothermia in non-cardiac surgery patients.

Keywords Non-cardiac surgery, Postoperative hypothermia, Risk factors, Meta-analysis

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Introduction

Perioperative hypothermia is a clinical phenomenon in which a patient's core body temperature drops below 36 °C during the perioperative period, resulting from both unplanned and medical purposes, with an incidence rate ranging from 17.0 to 88.6%. This condition can lead to adverse outcomes such as decreased coagulation, cardiovascular events, and even death [1–3]. Currently, most studies on perioperative hypothermia have focused on intraoperative hypothermia [4–6], but less attention has been paid to postoperative hypothermia. Postoperative hypothermia is defined as a core body temperature below 36 °C during the recovery phase after surgery, including in the post-anesthesia care unit (PACU) and in the ward. It can cause infection of the surgical incision, prolong the length of hospital stay, and increase the all-cause mortality rate within the first 30 days post-surgery [7–9]. Given that cardiac surgery often requires patients to be maintained in a state of sustained hypothermia to reduce myocardial oxygen consumption and intraoperative bleeding [10], identifying the risk factors for postoperative hypothermia is essential to ensure the safety of patients undergoing non-cardiac surgery.

Although some studies have reported the risk factors for postoperative hypothermia, the results of each study are not consistent. This systematic review and meta-analysis aims to summarize the current evidence regarding the overall risk factors associated with postoperative hypothermia. The results of this research may help improve clinical understanding of the various risk factors that may cause postoperative hypothermia in non-cardiac surgery patients.

Methods

Standard reporting

Meta-analysis was conducted in adherence to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines [11]. This research has been registered with PROSPERO, and the registration number is CRD-42023488411.

Literature search

A comprehensive search was performed across multiple databases to identify studies published up to April 2025, focusing on risk factors for postoperative hypothermia in non-cardiac surgery patients. The databases searched included China National Knowledge Infrastructure (CNKI), China Science and Technology Journal Database (VIP), WangFang Data, Chinese Biomedical Literature Database (CBM), PubMed, Web of Science, Embase, CINAHL, and the Cochrane Library. The search terms used were "Hypothermia OR Inadvertent hypothermia OR Accidental hypothermia OR Unintended hypothermia OR Unplanned hypothermia" AND "Postoperative OR Perioperative" AND "Risk factors OR factor, risk OR risk factor OR etiology OR predictor OR influencing factor OR impact factor OR relevant factor OR associate factor." Table 1 shows the search strategy in the PubMed database. Search strategies and the number of results from other major databases are shown in Supplementary Appendix 1.

Table 1 Search strategy in pubmed database

Number	Search terms	Results
#1	((((hypothermia[MeSH Terms]) OR (inadvertent hypothermia[Title/Abstract])) OR (accidental hypothermia[Title/Abstract])) OR (unintended hypothermia[Title/Abstract])) OR (unplanned hypothermia[Title/Abstract])	15,644
#2	(postoperative[Title/Abstract]) OR (perioperative[Title/Abstract])	804,723
#3	((((((((risk factors[MeSH Terms]) OR (factor, risk[Title/Abstract])) OR (risk factor[Title/Abstract])) OR (etiology[Title/Abstract])) OR (predictor[Title/Abstract])) OR (influencing factor[Title/Abstract])) OR (impact factor[Title/Abstract])) OR (relevant factor[Title/Abstract])) OR (associate factor[Title/Abstract])	1,706,185
#4	#1 AND #2 AND #3	186

Inclusion and exclusion criteria

The inclusion criteria were as follows:

Participating population: Non-cardiac surgery patients with postoperative hypothermia, aged ≥ 18.

Exposures: Any investigated risk factors/predictors for postoperative hypothermia.

Comparison/control: Not applicable.

Outcome: Postoperative hypothermia.

Type of study: Cohort or case-control studies; temperature measurement sites include but are not limited to scalp, nasopharynx, esophagus, tympanic membrane, etc.

The following types of records were excluded: replicated study data, incomplete data, non-original studies (conference abstracts, editorials, letters, reviews, meta-analyses, commentaries, or case reports), and low-quality studies (grade of Newcastle-Ottawa Scale < 4) [12].

Data extraction

Two researchers independently screened the literature and extracted data according to the inclusion and exclusion criteria. In cases of disagreement, the two parties discussed and resolved them, or consulted experts. Data extraction contents included author, year, study type, number of cases and control groups, risk factors, etc.

Quality assessment

Based on cohort studies and case–control studies, an adapted Newcastle-Ottawa Scale (NOS) was used to evaluate the quality of case-control studies and cohort studies. The NOS consists of eight items, divided into three dimensions: selection, comparability, and outcome. The NOS scale ranges from 0 to 9. Only studies with scores greater than 7 were considered high quality [13]. The quality assessment of included studies based on NOS is shown in Supplementary Table 1.

Strength of evidence

To determine the quality of evidence for each risk factors associated with postoperative hypothermia, the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) framework was used [14]. The GRADE evaluation encompasses five key domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. The overall quality of evidence for each outcome was categorized into four levels: high, moderate, low, or very low [15].

Statistical analysis

Review Manager version 5.4 was used to pool odds ratio (OR) and confidence intervals (CI) for each risk factors. Given the different populations, geographic regions, and methodologies used in the included studies, we used random-effects models for this study, which allow for true effects to differ across different studies when compared with fixed effects models [16–18]. Heterogeneity across studies was evaluated using the Cochrane-Q test, and I^2 was used to reflect the extent of variation across studies, which was described as low, moderate or high with I^2 values of 25, 50 and 75%, respectively [19]. If $I^2 > 50\%$ or $P < .1$, sensitivity analysis was performed by excluding studies one by one to explore sources of heterogeneity. The possible publication bias was evaluated by Egger's test using Stata SE 16.0 [20].

Results

Study selection

The search flow is shown in Fig. 1. A total of 3,006 relevant studies were searched. Most studies were excluded because they were duplicate studies or not relevant to our meta-analysis. Subsequently, 49 articles were reviewed in full-text articles. Ultimately, 17 studies involving 21,004 recipients were included in this meta-analysis [21–37].

Characteristics of the studies and quality assessment

The 17 included publications consisted of 12 cohort studies and 5 case-control studies. The included studies were published between 2016 and 2024. Among these, one study was conducted in France, two in South Korea, one in Brazil, eleven in China, one in America, and one in Thailand. The sample sizes of the included studies ranged from 78 to 7,059. Based on the NOS scores, 11 studies were rated as high-quality and 6 as moderate-quality, with an overall average score of 6.94. The overall quality of the study was good. The study and participant characteristics are shown in Table 2.

Publication bias

The Egger's test was conducted for the statistical investigation to evaluate potential publication bias (Table 3). A publication bias was considered to exist if $P < .05$. The Egger's test showed that seven risk factors had no publication bias ($P > .05$).

Postoperative hypothermia risk factors

Table 3 presents the meta-analysis of risk factors of postoperative hypothermia in non-cardiac surgery patients.

The I^2 statistic was used to measure statistical heterogeneity. Significant risk factors for postoperative hypothermia included age ≥ 60 (OR = 1.80; 95% CI, 1.47–2.21), BMI < 18.5 kg/m^2 (OR = 1.83, 95% CI, 1.35–2.49), ASA III-IV (OR = 1.87; 95% CI, 1.32–2.65), endoscopic surgery (OR = 1.93; 95% CI, 1.32–2.84), blood loss ≥ 100 ml (OR = 2.35; 95% CI, 1.32–4.20), intravenous fluid ≥ 1000 ml (OR = 1.87; 95% CI, 1.61–2.17), blood transfusion (OR = 1.80; 95% CI, 1.07–3.04), anaesthesia time > 60 min (OR = 1.99; 95% CI, 1.56–2.52), surgery time > 60 min (OR = 2.34; 95% CI, 1.81–3.03). A forest plot describing the association between risk factors for postoperative hypothermia in non-cardiac surgery patients is presented in Figs. 2, 3, 4, 5, 6, 7, 8, 9 and 10.

Sensitivity analysis

In the analysis of age (≥ 60), we conducted a sensitivity analysis by excluding each study to explore whether a study significantly impacts the results or contributes considerably to heterogeneity. After excluding the study by Zhang M et al. [31], the heterogeneity decreased significantly, indicating that the study was the primary source of heterogeneity. For the other results, we performed sensitivity analyses by excluding each study individually to explore whether a study had a significant effect on the results or contributed significantly to heterogeneity. Overall, the studies did not influence the results, and our meta-analysis was relatively robust.

Subgroup analysis

For endoscopic surgery, a meta-regression was conducted to analyze the sources of heterogeneity firstly, then we performed a subgroup analysis based on surgery type and publication year, but did not find a source of heterogeneity in surgery type. The outcomes of meta-regression and subgroup analysis are shown in Supplementary Fig. 1.

Strength of evidence

Ratings of the quality of the evidence across the GRADE criteria for each risk factor are displayed in Supplementary Table 2. Due to the nature of observational study, 7 risk factors received a low recommendation based on GRADE score and the rest were very lowly recommended.

Discussion

To better identify patients at risk for postoperative hypothermia, we performed a meta-analysis that included data from 17 studies to systematically analyze risk factors for postoperative hypothermia in non-cardiac surgery patients. After systematic analysis of 17 observational studies, we identified 9 potential risk factors that may be associated with postoperative hypothermia: age ≥ 60 years, BMI < 18.5 kg/m², ASA III-IV classification, endoscopic surgery, blood loss ≥ 100 ml, intravenous fluid ≥ 1000 ml, blood transfusion, anesthesia

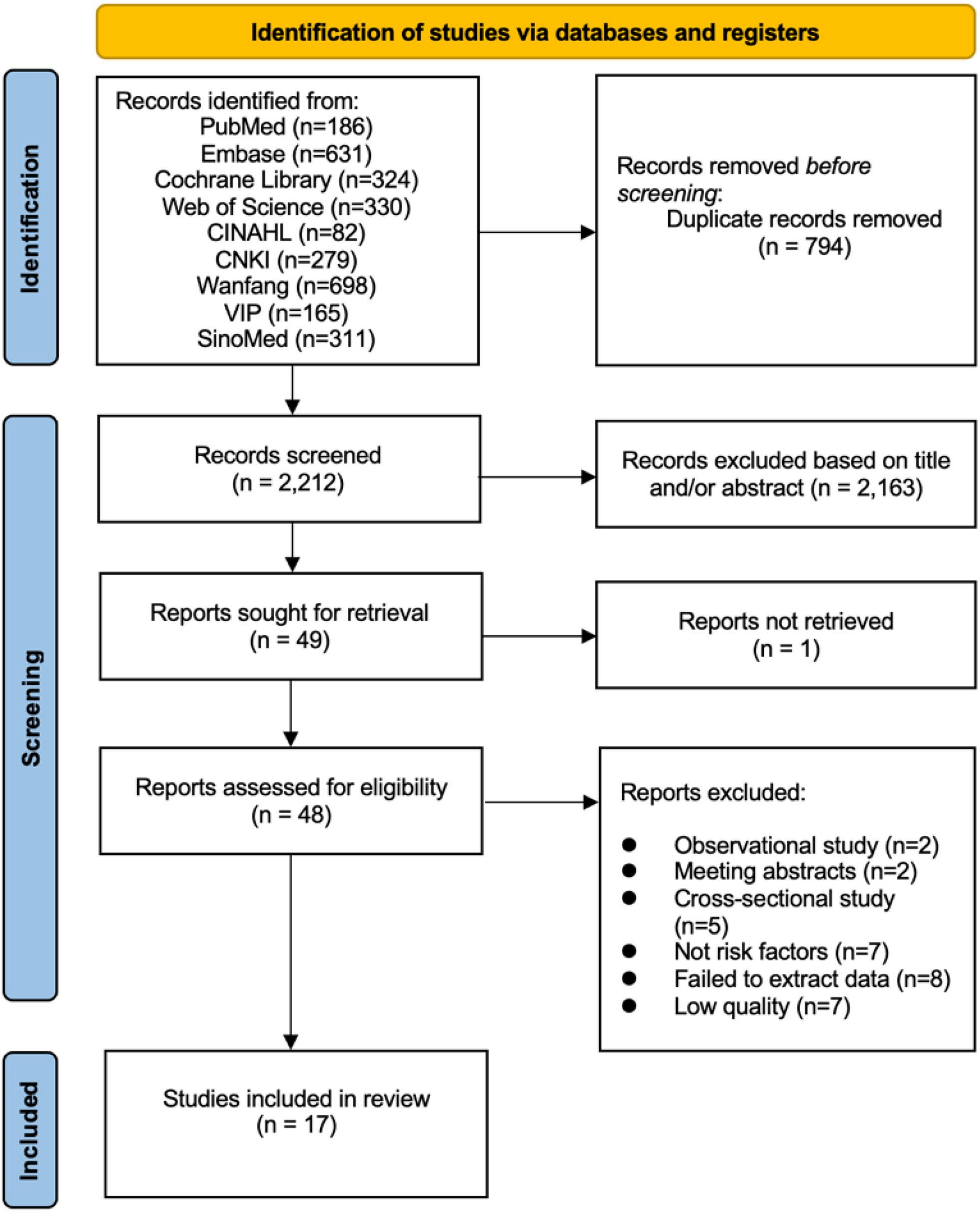

Fig. 1 Flow diagram of the selection process

Table 2 Study and participants characteristics

Study	Year	Country	Type of study	Temperature measurement	Hypothermia/Total	Quality assessment	Risk factors
Alfonsi(21)	2019	France	Cohort study	scalp	478/893	8	2,10,25,27
Cho CK(22)	2021	South Korea	Cohort study	tympanic	268/660	6	7,11,13,14,17,24
Cho SA(23)	2022	South Korea	Cohort study	esophagus	145/516	7	4,6,13,24,26
Kleimeyer(24)	2018	America	Cohort study	esophagus	321/3,822	7	1,2,4,13,14,15,21
Li CX(25)	2021	China	Cohort study	tympanic	113/1,788	8	9,12
Li LL(26)	2022	China	Cohort study	tympanic	173/404	8	2,4,5,21,25
Mendonça(27)	2019	Brazil	Cohort study	tympanic	54/78	6	11,12
Wongyingsinn(28)	2023	Thailand	Cohort study	tympanic	88/742	8	9,13
Xu RR(29)	2023	China	Case-control study	tympanic	52/202	7	2,3,4,13,14,17,22
Zhang H(30)	2022	China	Cohort study	tympanic	1,505/7,059	8	2,4,8,13,14,15,16 18,23,24,26
Zhang M(31)	2021	China	Case-control study	tympanic	15/110	6	2,9,17,23
Xu Y(32)	2016	China	Cohort study	tympanic	243/1,105	6	1,2,4,14,17,19,22 23,24
Li XX(33)	2022	China	Case-control study	NR	50/648	6	2,4,10,14,17,19,24
Wang F(34)	2022	China	Case-control study	rectum	83/1,193	6	2,12
Chen G(35)	2022	China	Case-control study	nasopharynx	93/222	7	2,4,10,12,13,20
Wang YH(36)	2024	China	Cohort study	tympanic	678/1316	7	1,5,7,14
Niu T(37)	2024	China	Cohort study	tympanic	117/246	7	4,17,24,28,29,30,31

NR = not report, 1 = gender, 2 = age, 3 = weight, 4 = body mass index, 5 = PLT, 6 = heart rate, 7 = alcohol abuse, 8 = fasting time, 9 = ASA, 10 = anaesthesia time, 11 = anaesthesia drugs, 12 = type of anesthesia, 13 = baseline temperature, 14 = type of surgery, 15 = operation site, 16 = surgical position, 17 = surgery time, 18 = season of the year, 19 = OR ambient temperature, 20 = preparation time, 21 = intraoperative temperature, 22 = blood loss, 23 = blood transfusion, 24 = intravenous fluid, 25 = intraoperative thermal insulation measures, 26 = intraoperative drugs, 27 = decrease in temperature of > 0.5°C between anesthesia induction and surgical incision, 28 = fluid infusion rate, 29 = type of nerve block, 30 = da Vinci robot-assisted surgery, 31 = artificial pneumoperitoneum time.

Table 3 Publication bias and evidence quality of risk factors of postoperative hypothermia in non-cardiac surgery patients

Risk factors	Combination studies	Sample size	OR (95% CI)	Heterogeneity of study design			Egger's test	Certainty
				χ^2	*P*	I^2		
Age ≥ 60	6	10,129	1.80(1.47 ~ 2.21)	10.66	0.10	44%	0.044	Very low
BMI < 18.5 kg/m^2	2	1,753	1.83(1.35 ~ 2.49)	0.43	0.51	0	NA	Low
ASA III-IV	2	852	1.87(1.32 ~ 2.65)	0.08	0.78	0	NA	Low
Endoscopic surgery	4	9,026	1.93(1.32 ~ 2.84)	28.01	< 0.0001	86%	0.044	Very low
Blood loss ≥ 100 ml	2	1.307	2.35(1.32 ~ 4.20)	1.50	0.22	33%	NA	Low
Intravenous fluid ≥ 1000 ml	4	8,922	1.87(1.61 ~ 2.17)	0.85	0.93	0	0.189	Low
Blood transfusion	2	8,164	1.80(1.07 ~ 3.04)	1.59	0.21	37%	NA	Low
Anaesthesia time > 60 min	3	1,763	1.99(1.56 ~ 2.52)	1.70	0.43	0	0.428	Low
Surgery time > 60 min	4	2,065	2.34(1.81 ~ 3.03)	7.51	0.19	33%	0.137	Low

CI = confidence interval, OR = odds ratio, NA = not applicable.

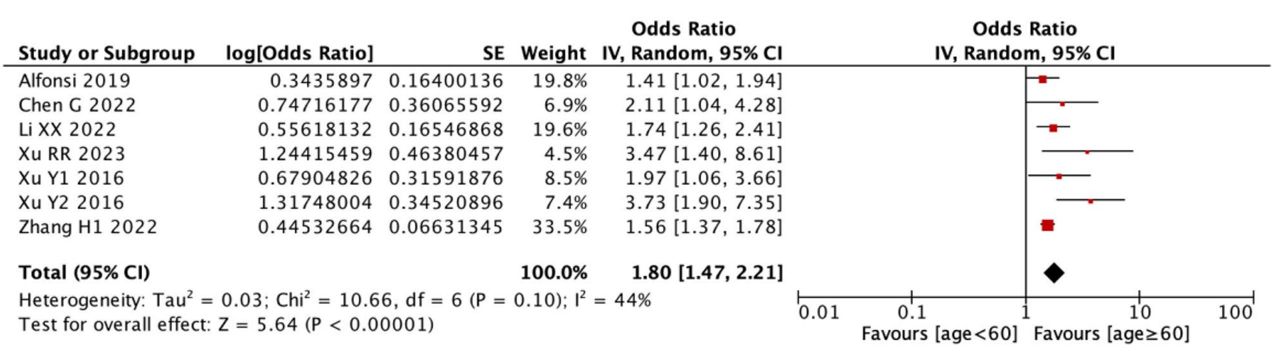

Fig. 2 Forest plot analysis of age ≥ 60

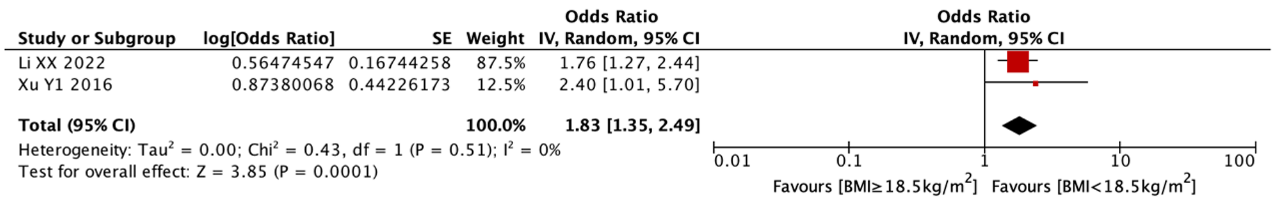

Fig. 3 Forest plot analysis of BMI < 18.5 kg/m^2

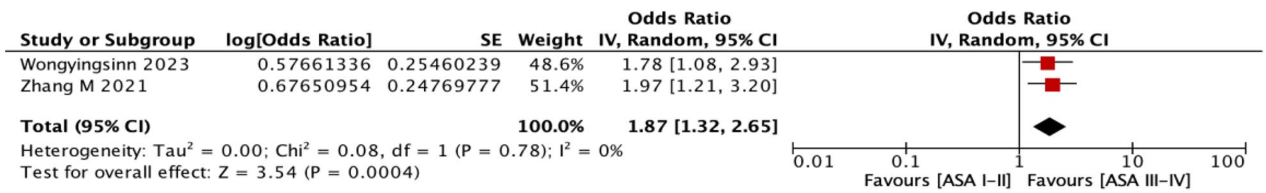

Fig. 4 Forest plot analysis of ASA III-IV

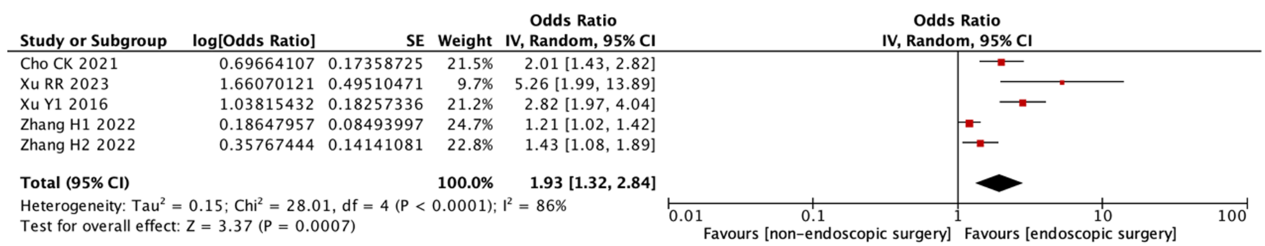

Fig. 5 Forest plot analysis of endoscopic surgery

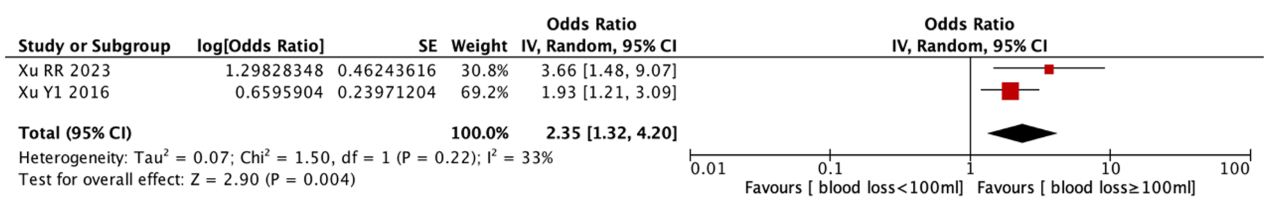

Fig. 6 Forest plot analysis of blood loss ≥ 100 ml

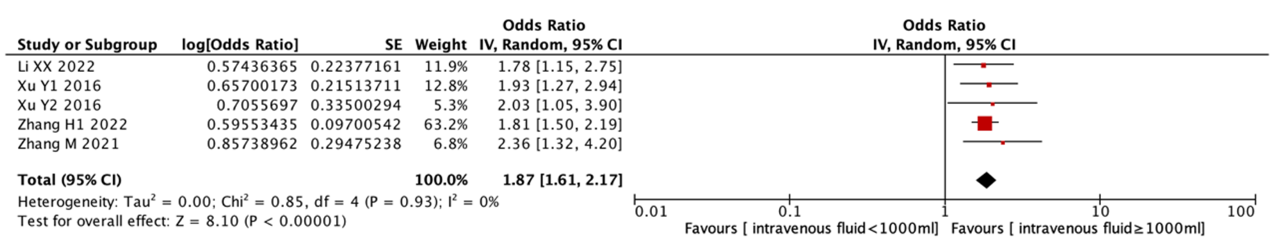

Fig. 7 Forest plot analysis of intravenous fluid ≥ 1000 ml

time > 60 min, and surgery time > 60 min. The level of certainty based on GRADE was mostly low, which may be linked with the nature of observational study and the suspected publication bias of our included studies. In our study, intraoperative blood loss exceeding 100 ml (*OR* = 2.35) appeared to be the most significant predictors for postoperative hypothermia, whereas age (*OR* = 1.80) seemed to the weakest predictive value among the variables.

Overweight patients have a higher percentage of body fat, which prevents the redistribution of heat to peripheral tissues during anaesthesia due to the low thermal

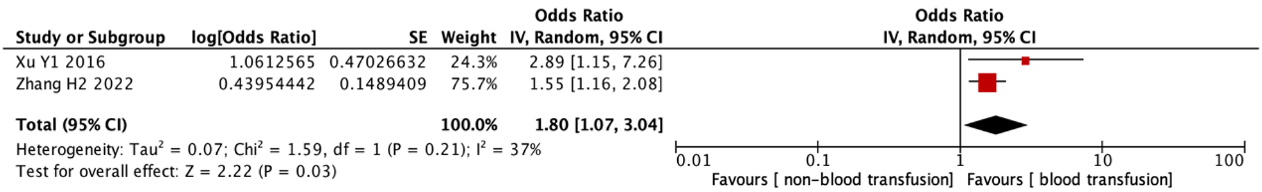

Fig. 8 Forest plot analysis of blood transfusion

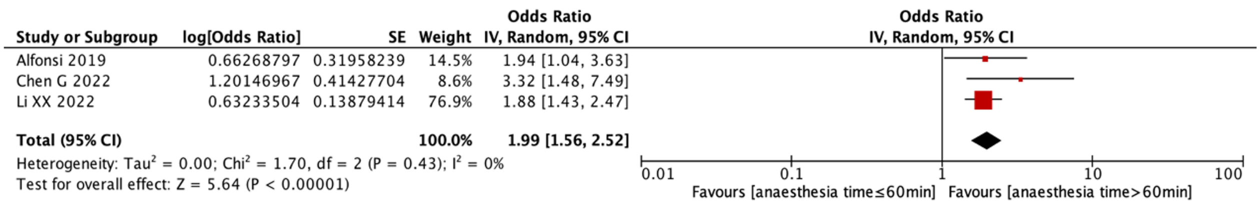

Fig. 9 Forest plot analysis of anaesthesia time > 60 min

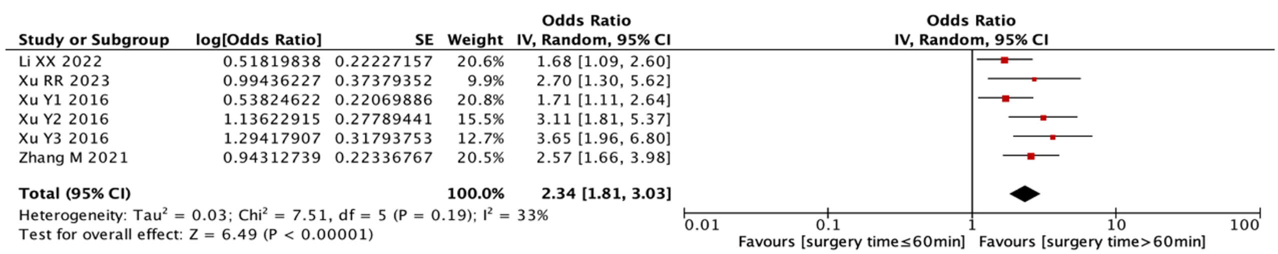

Fig. 10 Forest plot analysis of surgery time > 60 min

conductivity of fat. In addition, patients with high body fat have higher levels of leptin, which produces more calories through stimulation of the sympathetic nervous system and increased metabolic rate [38, 39]. In contrast, patients with BMI < 18.5 kg/m^2 are more likely to develop postoperative hypothermia.

Elderly patients have reduced subcutaneous fat content, a lower basal metabolic rate, decreased thermoregulatory function of the central nervous system, and increased susceptibility to hypothermia [40]. Therefore, nursing staff should strengthen the management of body temperature in the elderly patient population and recommend temperature protection throughout the perioperative period to avoid hypothermia. Surgical patients with ASA III-IV have more severe conditions of their own and coexisting diseases that may reduce the body's thermoregulatory function [28].

Longer operation time means longer anaesthesia time. In this study, we found that the risk of postoperative hypothermia increased by 1.99 times and 2.29 times in patients with anaesthesia time and operation time longer than 1 h. This may be due to the fact that anesthetic drugs inhibit the thermoregulatory center and basal metabolic rate, and dilate the peripheral blood vessels, leading to the diffusion of heat from the core area to the periphery, causing a decrease in core body temperature. Furthermore, patients' prolonged exposure to the relatively low-temperature operating room environment may also further lead to heat loss [31]. Nursing staff are advised to estimate the duration of surgery according to the patient's condition and surgical procedure before surgery, pay close attention to the surgical process and the patient's temperature change during surgery, and take intensive hypothermia prevention measures to reduce the incidence of postoperative hypothermia.

Our study also found that the risk of postoperative hypothermia in patients undergoing endoscopic surgery was 1.93 times higher than that of open surgery, which is contrary to the findings of Yi et al. [41], This discrepancy may be related to the fact that the laparoscopic surgeries included in the present study required extensive irrigation and continuous insufflation. One study has shown that every 50 L of CO_2 reduces core temperature by 0.3 °C, and continuous gas flow during laparoscopic surgery also leads to heat loss, which can lead to hypothermia [42]. For intraoperative laparoscopic procedures requiring the use of large amounts of room-temperature flushing fluids, the fluid flushing carries away a large amount of heat, leading to a decrease in core body temperature and inducing perioperative hypothermia. We recommend that core body temperature assessment be included as part of the daily perioperative assessment.

Patients with ≥100 ml of blood loss tended to require intraoperative transfusion and rehydration, and the risk of postoperative hypothermia was elevated 1.87-fold when intraoperative rehydration was ≥1000 ml. Intravenous administration of 1000 ml of crystalloid or 1 unit of stock blood at 2 to 6 °C at room temperature resulted in a decrease in body temperature of 0.25 to 0.5 °C [43]. Surgeries requiring large amounts of fluid rehydration and blood transfusion are typically those with high surgical difficulty and long surgical time. Patients are more likely to lose body temperature under general anesthesia and experience postoperative hypothermia. In summary, nursing staff should implement effective warming strategies, such as heating abdominal lavage fluid to 38–40 °C before use, and heating fluid and blood products to 37 °C before transfusion using liquid warming devices [44].

Some limitations exist in the present study. First, we included Chinese and English language literature from 9 databases, there may have been incomplete retrieval. Second, some of the risk factors were not combined with effect sizes due to the insufficient amount of primary literature, and further research is still needed. Third, due to lack of literature, our study summarizes only the risk factors influencing the occurrence of postoperative hypothermia in adult patients undergoing non-cardiac surgery. This may suggest that our results cannot be generalized to all populations but to adults in non-cardiac surgery patients. Fourth, differences in the reason for hospitalization and type of disease also affect the findings of this study. Furthermore, none of the included studies reported the effect of postoperative factors on postoperative hypothermia, which may introduce some confusion in the development of interventions. It is suggested to correctly identify high-risk groups based on the risk factors, develop and effectively implement targeted nursing measures, and reduce the incidence of postoperative hypothermia in patients undergoing non-cardiac surgery.

Conclusion

In conclusion, this systematic review and meta-analysis study provides preliminary evidence on risk factors that may influence postoperative hypothermia in non-cardiac surgery patients. We identified 9 potential risk factors that may be associated with postoperative hypothermia: age ≥ 60 years, BMI < 18.5 kg/m^2, ASA III-IV classification, endoscopic surgery, blood loss ≥ 100 ml, intravenous fluid ≥ 1000 ml, blood transfusion, anesthesia time > 60 min, and surgery time > 60 min. The level of certainty about our evidence ranged from very low to low, and intraoperative blood loss exceeding 100 ml appeared to be the most significant predictors for postoperative hypothermia, whereas age seemed to the weakest predictive value among the variables. The results of this study contribute to developing best practice management guidelines for postoperative hypothermia in non-cardiac surgery patients. Postoperative hypothermia in non-cardiac surgery patients should be a cause of concern for physicians and nurse. Early screening and intervention for high-risk groups with the above risk factors are needed to prevent complications and effectively improve the overall prognosis of patients.

Abbreviations

ASA	American Society of Anesthesiologists physical status
PACU	Postanesthesia care unit
OR	Operating room
BMI	Body mass index
CI	Confidence interval
ORs	Odds ratio
NR	Not report
NA	Not applicable

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-03089-9.

Supplementary Material 1: Supplementary Appendix (1) Search strategies in other databases.

Supplementary Material 2: Supplementary Table (1). Quality of included studies based on the Newcastle–Ottawa scale.

Supplementary Material 3: Supplementary Table (2) Quality of evidence examined through the GRADE criteria for each estimate.

Supplementary Material 4: Supplementary Fig. 1. Meta-regression and subgroup analysis of endoscopic surgery.

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Not applicable.

Author contributions
CY and HLM conceived the study design and drafted the study protocol. RYT and YYC contributed to data collection and wrote the manuscript. All authors contributed to the data analysis. CY and HLM revised the manuscript. All authors have read and approved the final manuscript. Conceptualization: Chang Yang, Hongli Ma. Data curation and Software: Ruyi Tan, Yuyin Chen, Dan Yang, Xiuhong Long, Chang Yang, Hongli Ma. Formal Analysis: Ruyi Tan, Yuyin Chen. Funding acquisition: Chang Yang. Supervision: Chang Yang, Hongli Ma. Writing– original draft: Ruyi Tan, Yuyin Chen. Writing– review & editing: Chang Yang, Hongli Ma.All authors have read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
All analyses were based on previously published studies, thus no ethical approval and patient consent are required. This research has been registered with PROSPERO, and the registration number is CRD-42023488411. All the methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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