Heliyon 10 (2024) e31479

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Intraoperative hypothermia in patients with laparoscopic surgery: Influencing factors and prevention strategies

Chenyi Shen, Yaoqin He *

Department of Anesthesiology, The First Affiliated Hospital of Soochow University, Suzhou, China, 215000

A R T I C L E I N F O

Keywords:
Care
Clinical
Hypothermia
Management
Prevention
Nursing
Surgery

A B S T R A C T

Background: Effective body temperature management is crucial for the favorable prognosis of patients undergoing surgery. The purpose of this study is to explore the risk factors of intraoperative hypothermia and to develop a risk prediction model to provide basis for clinical treatment.

Methods: Patients who underwent laparoscopic surgery in a tertiary hospital in China from February 1, 2023 to January 31, 2024 were included. The body temperature characteristics of patients in hypothermia group and non-hypothermia group were collected and evaluated. Univariate and Logistic regression analysis were used to evaluate the influencing factors. Based on the regression coefficients of risk factors, a risk prediction model of hypothermia was established. The model was assessed by Hosmer's Lemeshow (H- L) test and receiver working characteristic (ROC) curve.

Results: In 216 patients undergoing laparoscopic surgery, the incidence of hypothermia was 52.78 %. BMI≤23 kg/m^2(OR = 2.061, 95%CI: 1.413–3.263), basal body temperature≤36.1 °C (OR = 3.715, 95%CI: 3.011–4.335), operating room temperature≤22 °C (OR = 2.481, 95%CI: 1.906–3.014), length of surgery≥120 min (OR = 2.228, 95%CI: 1.925–2.981) were the risk factors of hypothermia in patients undergoing laparoscopic surgery (all $P < 0.05$). The P value of H-L test was 0.098, the area under ROC curve and 95%CI were 0.806 (0.746–0.869). The sensitivity and specificity of the model in this study were good.

Conclusions: Patients undergoing laparoscopic surgery are at a high risk of developing hypothermia, a condition influenced by a multitude of factors. This model is designed to be integrated into clinical practice, enabling healthcare providers to identify patients with a higher risk and to implement targeted preventive measures.

1. Background

Body temperature is an important vital sign of the human body, and maintaining constant body temperature is a necessary condition to ensure body metabolism and normal life activities [1]. The core temperature of normal people is 36.5–37.5 °C [2]. Intraoperative hypothermia is defined as a core body temperature below 36 °C during the period of anesthesia and surgery, a condition that can arise due to a multitude of factors [3]. It is reported that the incidence of hypothermia during operation is 40.13 %–75.06 % [4,5]. Intraoperative hypothermia can increase the incidence of perioperative adverse events, affect platelet aggregation, reduce the activity

* Corresponding author. The First Affiliated Hospital of Soochow University, Suzhou, Jiangsu province, China, 215000.
E-mail address: tvlp75@sina.com (Y. He).

https://doi.org/10.1016/j.heliyon.2024.e31479
Received 22 March 2024; Received in revised form 16 May 2024; Accepted 16 May 2024
Available online 17 May 2024
2405-8440/

of coagulation factors, and increase the risk of bleeding [6]. Hypothermia during surgery affects tissue and organ perfusion, which is critical for maintaining the normal functioning of the body's systems. Additionally, hypothermia can inhibit the sinoatrial node and the conduction system of the heart, which are essential for regulating the heart's rhythm. These effects can collectively increase the risk of postoperative cardiovascular events, a serious concern for surgical patients. Moreover, intraoperative hypothermia has been shown to exacerbate the risk of postoperative wound infections by compromising the immune response and the healing process at the incision site. This can lead to a prolonged period until the sutures can be safely removed, as the body's capacity to heal may be diminished. Furthermore, an increased infection rate can result in an extended hospital stay, adding to the patient's recovery time and healthcare costs [7,8]. In light of these considerations, it is evident that maintaining normothermia throughout the surgical procedure is crucial for optimizing patient outcomes and minimizing the risk of postoperative complications."

As surgical technology advances, the prevalence of laparoscopic surgery is steadily on the rise. This minimally invasive approach offers numerous benefits, yet it also presents unique challenges, particularly concerning patient temperature management. Consequently, the issue of hypothermia in the context of laparoscopic surgery has become increasingly pressing and warrants immediate attention. However, currently, the majority of research on intraoperative hypothermia is concentrated within the domain of open surgery, with a particular emphasis on the utilization of thermal insulation equipment and the impact of nursing interventions. In contrast, there is a scarcity of studies that address the risk prediction and management of hypothermia specifically in the context of laparoscopic surgery [9,10]. In recent years, the evolution of laparoscopic surgery and the corresponding increase in operation times have led to a growing concern: hypothermia during laparoscopic procedures is emerging as a significant challenge in clinical practice. To address this issue, our study aimed to conduct a comprehensive analysis of the factors contributing to intraoperative hypothermia in patients undergoing laparoscopic surgery. The primary objective was to develop a predictive model that could accurately identify patients at high risk for intraoperative hypothermia. By leveraging this model, we sought to provide crucial evidence and practical guidance for clinical nursing and medical interventions. The ultimate goal is to inform strategies that can effectively mitigate the occurrence of hypothermia in laparoscopic surgery, thereby enhancing patient safety and surgical outcomes.

2. Methods

This study was a retrospective cohort design. The study had been checked and approved by the ethical committee of our hospital (approval number: 2024135), and the study was granted an exemption from informed consent due to its minimal risk nature and the use of de-identified data.

In this study, patients who underwent laparoscopic surgery in our hospital from February 1, 2022 to January 31, 2023 were selected as the study population. The inclusion criteria of the patients were as follows: the age of the patient was ≥18 years old; the patient underwent elective laparoscopic surgery; the preoperative body temperature was normal at 36.5–37.5 °C, and the patient informed and agreed to participate in this study. The exclusion criteria were specifically defined as follows: Patients were excluded from the study if their preoperative body temperature was recorded as being below 36.5 °C or above 37.5 °C. We also excluded patients who expressed a lack of desire to participate in the study.

In the present study, we employed an anesthesia monitoring system to continuously measure the core body temperature of patients throughout the surgical procedure, from the onset of anesthesia until the conclusion of the operation. Following the induction of general anesthesia, a temperature-sensitive probe from the monitoring system was meticulously inserted into the nasopharynx. The precise depth of insertion was calibrated to ensure that the probe extended from the nasal alar, which is the fleshy part at the base of the nose, to the ipsilateral mandibular angle, corresponding to the lower corner of the jaw on the same side. The initial temperature measurement, a crucial pre-surgical baseline, was conducted prior to the induction of anesthesia in the operating room. To meticulously monitor and document temperature changes throughout the procedure, we established a protocol for recording the nasopharyngeal temperature at several key intervals: at the onset of anesthesia, the commencement of surgery, every 15 min following the start of the operation, and finally, at the conclusion of the surgery. The nasopharyngeal temperature readings were obtained automatically and subsequently uploaded to our system at 15-min intervals. Any instance where the temperature reading fell below 36 °C at any of these time points was categorized as indicative of intraoperative hypothermia in the patient [11,12].

The two authors collect the following relevant information about the study population through the hospital medical record system: Age, gender, body mass index (BMI), hypertension, diabetes, basal body temperature, operating room temperature, type of surgery, American Society of Anesthesiologists (ASA) classification, type of anesthesia, length of anesthesia, length of surgery and intraoperative fluid infusion. To ensure the uniformity and integrity of our study, all investigators participated in a standardized training program designed to familiarize them with the intricacies of the electronic medical record (EMR) system. This training was essential to standardize data collection and minimize variability in the way information was retrieved and recorded. The investigators harnessed the hospital's EMR system to access the general patient data required for our study. This system provided a centralized and secure platform from which to gather the necessary demographic, clinical, and administrative information pertaining to each patient. Furthermore, to obtain the temperature information of the operating room, we utilized the operating room's temperature and humidity control system. This system is specifically designed to monitor and regulate the environmental conditions within the operating room, ensuring that the data collected regarding the room's temperature is accurate and reliable. By employing these systems and ensuring that our investigators were well-versed in their use, we were able to maintain a high level of data integrity throughout the study, which is fundamental to the reliability and validity of our research findings.

In this study, SPSS 23.0 software was used for data statistical analysis. The counting data were expressed by frequency and percentage, and the chi-square test was used for the comparison between groups. The measurement data of normal distribution was expressed by mean ± standard deviation, and the comparison between groups was expressed by *t*-test. The measurement data of nonnormal distribution were described by median and quartile, and rank sum test was used. The statistically significant risk factors in the results were included in Logistic regression analysis to screen the independent risk factors of hypothermia. According to the partial regression coefficients of each index in the Logistic regression analysis model, the risk prediction model of hypothermia in laparoscopic patients was established. The coincidence degree of the model prediction was tested by Hosmer-Lemeshow(H-L) test [13]. The area under the receiver working characteristic (ROC) curve was used to calculate the sensitivity and specificity of the model according to the ROC curve coordinates to determine the best critical value of the model. In this study, $P < 0.05$ indicated that the difference between groups was statistically significant.

3. Results

A total of 216 patients undergoing laparoscopic surgery met the criteria and were finally included in this study, of whom 114 patients had the intraoperative hypothermia, the incidence of hypothermia in patients undergoing laparoscopic surgery was 52.78 %. The characteristics of included patients undergoing laparoscopic surgery were presented in Table 1. Significant differences in the BMI, basal body temperature, operating room temperature and length of surgery were found between hypothermia and no hypothermia patients (all $P < 0.05$). No significant differences in the age, gender, hypertension, diabetes, type of surgery, ASA classification, type of anesthesia, length of anesthesia, and intraoperative fluid infusion were found between hypothermia and no hypothermia patients (all $P > 0.05$).

The variable assignments of multivariate logistic regression were presented in Table 2. As presented in Table 3, Logistic regression analysis indicated that BMI≤23 kg/m^2(OR = 2.061, 95%CI: 1.413–3.263), basal body temperature≤36.1 °C(OR = 3.715, 95%CI: 3.011–4.335), operating room temperature≤22 °C(OR = 2.481, 95%CI: 1.906–3.014), length of surgery≥120 min(OR = 2.228, 95% CI: 1.925–2.981) were the risk factors of hypothermia in patients undergoing laparoscopic surgery(all $P < 0.05$).

H-L test was used to evaluate the coincidence degree of the model, and the area under the ROC curve was used to evaluate the discriminant validity of the model. The results showed that the P value of H-L test was 0.098, which showed that there was no significant difference between the predicted results and the actual results, and the model had a good degree of coincidence. The area under ROC curve and 95%CI were 0.806 (0.746–0.869), indicating that the model had a good discriminant ability. According to the results of H-L test and the analysis of the area under the ROC curve, the model could accurately predict the risk of intraoperative hypothermia. The ROC curve is shown in Fig. 1.

According to the results of Logistic regression analysis, the regression coefficient of each independent variable was divided by the minimum value, then multiplied by the constant 2, and the whole value was rounded as its score. The scoring standard of the prediction model of intraoperative hypothermia was established, as shown in Table 4. According to the ROC curve and rating criteria of the prediction model, the sensitivity and specificity of the prediction model under different scores were calculated, and the Jordan index (sensitivity + specificity-1) was calculated, as shown in Table 5. The results showed that the Yoden index was higher when the total score was 5.5–6.5. Therefore, this study took 6 as the critical value of the model, and the sensitivity and specificity of the prediction model were good.

Table 1
The characteristics of included patients undergoing laparoscopic surgery(n = 216).

Variables	Hypothermia group(n = 114)	No hypothermia group(n = 102)	t/χ^2	P
Age(y)	56.04 ± 10.18	55.74 ± 9.67	8.072	0.055
Male/female	61/53	52/50	1.224	0.106
BMI(kg/m^2)	21.14 ± 3.82	24.33 ± 2.96	4.189	0.028
Hypertension	50(43.86 %)	42(41.18 %)	1.746	0.081
Diabetes	26(22.81 %)	25(24.51 %)	1.995	0.162
Basal body temperature(°C)	36.15 ± 0.97	36.92 ± 0.88	4.078	0.012
Operating room temperature(°C)	21.50 ± 2.05	23.77 ± 2.14	2.809	0.038
Type of surgery			1.934	0.096
Gastrointestinal surgery	51(44.74 %)	46(45.10 %)		
Hepatobiliary Pancreaticosplenic surgery	25(21.93 %)	27(26.47 %)		
Kidney, adrenal gland and prostate surgery	21(18.42 %)	18(17.65 %)		
Gynecological surgery	10(8.77 %)	7(6.86 %)		
Other	7(6.14 %)	4(3.92 %)		
ASA classification			1.409	0.113
I	15(13.16 %)	14(13.73 %)		
II	81(71.05 %)	72(70.59 %)		
III	17(14.91 %)	16(15.69 %)		
IV	1(0.88 %)	0(0 %)		
Type of anesthesia			2.077	0.081
General anesthesia	55(48.25 %)	50(49.02 %)		
General anesthesia combined with local anesthesia	59(51.75 %)	52(50.98 %)		
Length of anesthesia (min)	166.58 ± 22.73	151.09 ± 30.21	21.024	0.059
Length of surgery (min)	145.03 ± 30.38	112.89 ± 34.26	19.466	0.015
Intraoperative fluid infusion (ml)	1605.22 ± 301.85	1587.42 ± 317.68	40.071	0.124
Irrigating fluid during operation(ml)	771.75 ± 184.21	704.83 ± 190.39	28.407	0.119

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

Table 2
The variable assignment of multivariate logistic regression.

Factors	Variables	Assignment
Hypothermia	Y	Yes = 1, no = 2
BMI≤23 kg/m^2	X_1	Yes = 1, no = 2
Basal body temperature≤36.1 °C	X_2	Yes = 1, no = 2
Operating room temperature≤22 °C	X_3	Yes = 1, no = 2
Length of surgery≥120 min	X_4	Yes = 1, no = 2

Table 3
Logistic regression analysis on the risk factors of hypothermia in patients undergoing laparoscopic surgery.

Variables	β	Wald	OR	95%CI	p
BMI≤23 kg/m^2	0.115	0.129	2.061	1.413–3.263	0.016
Basal body temperature≤36.1 °C	0.107	0.121	3.715	3.011–4.335	0.008
Operating room temperature≤22 °C	0.116	0.214	2.481	1.906–3.014	0.013
Length of surgery≥120 min	0.118	0.189	2.228	1.925–2.981	0.036

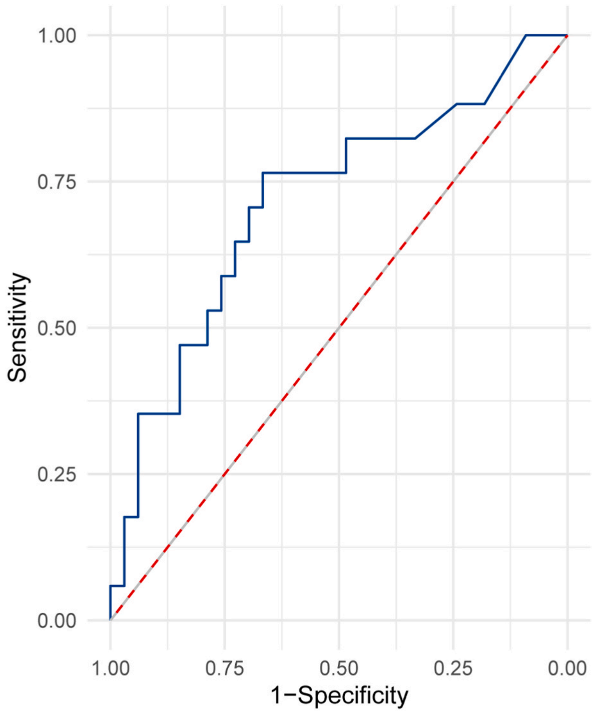

Fig. 1. The ROC curve of the prediction model.

Table 4
The scoring criteria of the logistic model for the risk factors of hypothermia in patients undergoing laparoscopic surgery.

Variables	Scores
BMI≤23 kg/m^2	2
Basal body temperature≤36.1 °C	3
Operating room temperature≤22 °C	3
Length of surgery≥120 min	2

Table 5
Sensitivity and specificity of the prediction model under different cuff values.

Total score	Sensitivity	Specificity	Yorden Index
−1.0	1.000	0.000	0.000
1.0	1.000	0.126	0.126
1.5	0.977	0.223	0.134
2.5	0.922	0.390	0.314
3.5	0.844	0.541	0.385
4.5	0.822	0.743	0.565
5.5	0.692	0.897	0.589
6.5	0.681	0.896	0.577
7.5	0.415	0.909	0.324
8.5	0.324	0.817	0.141
9.5	0.101	0.959	0.060
10.5	0.027	1.000	0.027
11	0.000	1.000	0.000

4. Discussions

At present, the harm of intraoperative hypothermia has been recognized by medical staff all over the world, the concept of perioperative heat preservation has been gradually recognized and recommended by multinational guidelines [14–16], and many studies pay attention to its importance. Laparoscopy has become the first choice for most surgical operations, but there is a relative lack of research and data on intraoperative hypothermia in patients undergoing laparoscopic surgery. This study has found that the incidence of hypothermia in patients undergoing laparoscopic surgery is 52.78 %. In addition, basal body temperature, BMI, operating room temperature and length of surgery are the predictors of hypothermia during laparoscopy. This model is designed to identify the high-risk population for hypothermia during laparoscopic surgery. By applying this model, we can proactively implement preventive measures that are tailored to reduce the incidence of intraoperative hypothermia. The predictive power of the model lies in its ability to stratify patients based on their risk, allowing for targeted interventions that can significantly lower the likelihood of hypothermic events occurring during surgery. Our findings not only contribute to the existing body of literature on perioperative temperature management but also offer actionable insights for healthcare professionals. By identifying and addressing the key determinants of hypothermia, we can take targeted preventive measures that are backed by evidence-based research. This proactive approach has the potential to significantly reduce the incidence of hypothermia-related complications, improving the overall quality of care in laparoscopic surgery.

BMI is an important individual factor affecting the occurrence of intraoperative hypothermia. The BMI of hypothermia group is lower than that of non-hypothermia group, which is consistent with the results of other studies [17–19]. Previous study [20] has shown that patients with BMI $\geq$25 have a lower incidence of hypothermia. Some studies [21,22] have found that the effect of BMI on intraoperative hypothermia lasts only 3 h, and patients with higher BMI have a lower incidence of hypothermia 3 h before operation, but there is no significant correlation between BMI and hypothermia in patients with more than 3 h of operation. Patients with higher BMI have higher fat storage and smaller surface area and volume, and the thermal insulation effect of fat can minimize heat loss and maintain the core body temperature of patients [23]. Patients with a lower BMI tend to exhibit distinct thermal characteristics that can impact their body's heat balance. Individuals in this category typically have a reduced body surface area relative to their mass, which can lead to a lower rate of heat dissipation through the body surface. This reduced heat dissipation is due to the fact that a lower BMI often correlates with less subcutaneous fat and a smaller body frame, both of which can limit the surface area available for heat exchange with the environment [24,25]. It is important for healthcare providers to consider these thermal differences when caring for patients with varying BMIs, as they can influence the patient's response to environmental temperature changes, their risk of developing hypothermia, and the effectiveness of certain medical interventions. Understanding and addressing these thermal variations can help ensure optimal patient care and outcomes across a diverse patient population.

The effect of basal body temperature on intraoperative hypothermia has been confirmed by many studies. The effect of basal body temperature on intraoperative hypothermia may be related to heat redistribution after general anesthesia [26]. The extended duration of anesthesia observed in a study can be partially attributed to the time spent actively warming patients [27]. This proactive approach to maintaining normothermia during surgery is a critical aspect of patient care that has been increasingly recognized for its importance in postoperative recovery and overall surgical outcomes. While the practice of warming patients during surgery is not new, the implications of this practice on anesthesia time have not been extensively explored. General anesthesia causes peripheral vasodilation, inhibits central thermoregulatory reflex, and core heat is brought to the periphery, which leads to a slight increase in peripheral body temperature, reduces the difference between core body temperature and body surface temperature, and produces heat redistribution [28]. Taking pre-heat preservation measures before operation to increase the basic body temperature of patients can resist the heat redistribution caused by general anesthesia and reduce the incidence of intraoperative hypothermia [29,30]. The prevention of intraoperative hypothermia is a multifaceted endeavor that requires a proactive approach extending beyond the confines of the operating room. It is imperative that effective measures for heat preservation and warming are not only implemented once the patient is in the operating suite but are also integrated into the preoperative preparation phase. This includes the period leading up to and encompassing the transport of the patient to the operating room. By taking a comprehensive approach, we can enhance the patient's basal body temperature before they even enter the surgical environment. Such measures may include the use of pre-warmed intravenous fluids, warming blankets, and ambient temperature control in the preoperative area. Additionally, the transportation process should be carefully managed to avoid heat loss, potentially through the use of insulated transport devices or warmed air mattresses [31,32].

The human body is in a constant state of thermal exchange with its external environment, engaging in a dynamic process of heat emission through various mechanisms: radiation, convection, conduction, and evaporation. This intricate balance is essential for maintaining a stable core body temperature, which is crucial for the proper functioning of physiological processes. However, when the rate at which the body loses heat to the surroundings surpasses the rate at which it generates or conserves heat, a critical imbalance occurs. This disequilibrium can lead to a gradual decline in body temperature, a condition known as hypothermia. The body's inability to retain heat at a rate commensurate with the heat lost can be attributed to several factors, including environmental conditions, the efficiency of the body's thermoregulatory mechanisms, and the presence of any underlying health issues that may impair heat production or conservation [33,34]. Body temperature is closely related to ambient temperature [35]. It has been reported that the ambient temperature within the operating room should be meticulously maintained within the range of 22–25 °C [36,37]. This guideline is crucial for ensuring optimal conditions for both the surgical team and the patient, contributing to a stable and safe environment conducive to effective surgical procedures. Related study [38] has shown that the risk of hypothermia increases when the ambient temperature is less than 23 °C. Besides, one potential area for consideration in the management of patient temperature during surgery involves the warming of CO_2 insufflation, a technique commonly used in various surgical procedures, particularly in laparoscopic surgery [39]. CO_2 insufflation is the process of introducing carbon dioxide gas into the body cavity to create a working space for the surgeon to operate. However, the insufflated CO_2 is typically at room temperature or cooler, which can lead to heat loss from the body cavity and contribute to the development of intraoperative hypothermia [40,41]. Therefore, an appropriate increase in the temperature of the operating room is helpful to reduce the incidence of intraoperative hypothermia. In clinical practice, the temperature of the operating room should be adjusted dynamically according to the actual needs, so as to reduce the heat loss of the body as much as possible.

The results of this study have shown that the incidence of intraoperative hypothermia increase significantly when the operation time is more than 2 h. With the passage of time of operation, the heat interaction between the body and the environment continues to accumulate, and the total amount of heat loss increases, so intraoperative hypothermia is more likely to occur [42]. At the same time, the operation with longer operation time usually means that the operation is difficult and traumatic, and the incidence of intraoperative hypothermia increases under the combined action of a variety of adverse factors [43,44]. Because the duration of the operation is not available until the end of the operation, medical staff need to assess the patient's risk of hypothermia before surgery [45]. Therefore, this study suggests that the medical team should reasonably evaluate the duration of surgery before operation. The correct estimation and accurate control of the operation time by the chief surgeon can not only provide a reference for intraoperative heat preservation measures, but also provide an evaluation premise for the dose and use of anesthetics, which is conducive to the efficient operation of teamwork and improve the operation quality of patients [46–48]. For the patients and their families, if they know the expected duration of the operation in advance, the patients can have corresponding psychological expectations and psychological preparation, and the family members can also plan the time reasonably to prepare for taking the surgical patients back to the ward so as to reduce anxiety and uneasiness [49].

In clinical work, targeted preventive measures can be taken according to the above factors. Medical staff should take pre-heat preservation measures to increase the body surface temperature of patients and reduce the heat loss caused by heat redistribution. Before the patients enter the operating room, the temperature of the operating room should be properly raised, and the temperature of the operating room should be dynamically adjusted according to the needs of the operation. Medical staff should focus on patients with low BMI and take preventive measures in advance to reduce the occurrence of intraoperative hypothermia; for patients who are expected to operate for a long time, on the basis of routine heat preservation measures such as cotton cloth heat preservation and heating blankets, heating measures such as air insulation blankets are adopted to reduce heat loss and reduce the incidence of intraoperative hypothermia.

Several limitations within our study warrant consideration. Firstly, while we frequently recorded nasal temperatures, it remains unclear whether a single instance is adequate to definitively identify a low temperature. The accuracy of nasal temperature measurements can be compromised if the probe is not adequately resting on the nasal tissue. Additionally, we recognize that there is potential for an alternative approach: monitoring skin temperature as a means to circumvent the adverse effects of nasal bleeding, which could be a consideration for future studies. However, due to the retrospective nature of our study design, we were unable to collect the requisite data to fully explore this alternative. Secondly, a linear correlation to some factors would be interesting to determine severity, of duration and amount of hypothermia, however, it may not be sufficiently robust to draw definitive conclusions based on our small sample size. Future research with a larger sample size and a prospective study design is essential to fully elucidate the spectrum of factors that influence the development of hypothermia in patients undergoing laparoscopic surgery. Such studies will not only provide a more comprehensive understanding of the underlying mechanisms but also offer an opportunity to validate and expand upon the findings of our current investigation.

5. Conclusions

In summary, this study has found that the incidence of hypothermia in patients undergoing laparoscopic surgery is 52.78 %, BMI$\leq$23 kg/m^2, basal body temperature$\leq$36.1 °C, operating room temperature$\leq$22 °C, length of surgery$\geq$120 min are the risk factors of hypothermia in patients undergoing laparoscopic surgery. In the clinical setting, when encountering patients who are identified as high-risk for hypothermia prior to undergoing laparoscopic surgery—specifically, those with a risk assessment score of 6 or higher—prompt and efficacious interventions are crucial. Medical staff must implement timely and effective measures to mitigate the risk and occurrence of hypothermia. Future research in this area should aim to broaden the scope of patient data, explore a more extensive range of contributing factors, and engage in ongoing model enhancement efforts. These steps will collectively contribute to a more precise and clinically useful risk prediction model for intraoperative hypothermia in the context of laparoscopic surgery.

Ethics approval and consent to participate

In this study, all methods were performed in accordance with the relevant guidelines and regulations. The study had been checked and approved by the ethical committee of our hospital (approval number: 2024135), and the study was granted an exemption from informed consent due to its minimal risk nature and the use of de-identified data.

Consent for publication

Not applicable.

Funding

This study did not receive any funding in any form.

Availability of data and materials

The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Chenyi Shen: Investigation. **Yaoqin He:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

None.

List of abbreviations

BMI body mass index
ASA American Society of Anesthesiologists
ROC: receiver working characteristic

References

[1] R. Szymusiak, Body temperature and sleep, Handb. Clin. Neurol. 156 (2018) 341–351.
[2] D.I. Sessler, Temperature monitoring and perioperative thermoregulation, Anesthesiology 109 (2) (2008) 318–338.
[3] T.A. Chishom, E.S. Andersen, H.Y. Juan, S. Lele, L.B. Coots, P.M. Mountziaris, Impact of intraoperative hypothermia on autologous breast reconstruction, Ann. Plast. Surg. 40 (6) (2023) 11–14.
[4] L. Li, Y. Yan, F. Xin, Construction and verification of risk prediction model of intraoperative hypothermia in patients undergoing laparoscopic surgery, Chin. J. Nurs. 57 (4) (2022) 6–9.
[5] Y. Yan, X. Ting, Analysis of risk factors and preventive measures of intraoperative hypothermia in patients undergoing laparoscopic surgery for rectal cancer, General Nursing 22 (14) (2022) 20–24.
[6] M.Q. Zhang, P.D. Ying, Y.J. Wang, J.L. Zhao, J.J. Huang, F.Q. Gong, Intraoperative hypothermia in the neonate population: risk factors, outcomes, and typical patterns, J. Clin. Monit. Comput. 37 (1) (2023) 93–102.
[7] E.S. Andersen, T.A. Chishom, J. Rankin, H.Y. Juan, L. Coots, P.M. Mountziaris, Impact of intraoperative hypothermia on incidence of infection in implant-based breast reconstruction, Plast. Reconstr. Surg. 20 (3) (2023) 22–27..
[8] S. Morishige, T. Ohyama, N. Fujita, M. Kameda, Y. Yonekura, F. Endo, S. Abe, Risk factors for intraoperative hypothermia during holmium laser enucleation of the prostate, Urol. Int. (2023) 1–6.
[9] J. Zhao, Z. Le, L. Chu, Y. Gao, M. Zhang, J. Fan, D. Ma, Y. Hu, D. Lai, Risk factors and outcomes of intraoperative hypothermia in neonatal and infant patients undergoing general anesthesia and surgery, Front Pediatr 11 (2023) 1113627.
[10] L. Yan, J. Tan, H. Chen, H. Xiao, Y. Zhang, Q. Yao, Y. Li, A nomogram for predicting unplanned intraoperative hypothermia in patients with colorectal cancer undergoing laparoscopic colorectal procedures, AORN J. 117 (1) (2023) e1–e12.

[11] M. Niu, X. Gong, M. Lu, Analysis of related factors and preventive measures of intraoperative hypothermia in patients with endometriosis undergoing laparoscopic surgery, China Maternal and Child Health 36 (23) (2021) 4–7.
[12] C. Huaiying, S. Lijing, Incidence and influencing factors of intraoperative hypothermia in patients undergoing gynecological laparoscopic surgery, Chinese Journal of Endoscope 27 (5) (2021) 6–9.
[13] W. Junfeng, Z. Zhongheng, Z. Zhirui, Clinical predictive model: verification of the mode, Chinese Journal of evidence-based Cardiovascular Medicine 11 (2) (2019) 4–8.
[14] M.A. Bashaw, Guideline implementation: preventing hypothermia, AORN J. 103 (3) (2016) 305–310, quiz 311-303.
[15] J.M. Calvo Vecino, R. Casans Frances, J. Ripolles Melchor, C. Marin Zaldivar, M.A. Gomez Rios, A. Perez Ferrer, J.M. Zaballos Bustingorri, A. Abad Gurumeta, Grupo de trabajo de la GPCdHPNIdlS: Clinical practice guideline. Unintentional perioperative hypothermia, Rev. Esp. Anestesiol. Reanim. 65 (10) (2018) 564–588.
[16] P. Gabriel, J. Hocker, M. Steinfath, K.R. Kutschick, J. Lubinska, E.P. Horn, Prevention of inadvertent perioperative hypothermia - guideline compliance in German hospitals, Ger. Med. Sci. 17 (2019) Doc07.
[17] Y. Qingqing, C. Yue, W. Hao, Occurrence and risk factors of hypothermia in elderly patients undergoing laparoscopic hysterectomy under general anesthesia, Journal of Local surgery 32 (2) (2023) 4–7.
[18] Z. Dan, Y. Xiumei, H. Yujie, Analysis of influencing factors and predictive model of hypothermia during laparoscopic surgery in patients with endometrial carcinoma Chinese, Journal of Modern Nursing 27 (17) (2021) 5–7.
[19] A. Lau, N. Lowlaavar, E.M. Cooke, N. West, A. German, D.J. Morse, M. Gorges, R.N. Merchant, Effect of preoperative warming on intraoperative hypothermia: a randomized-controlled trial, Can. J. Anaesth. 65 (9) (2018) 1029–1040.
[20] S. Fanhao, Y. Hong, Y. Bo, Risk factors of intraoperative hypothermia in patients undergoing transurethral prostatectomy, J. China Med. Univ. 51 (12) (2022) 5–8.
[21] H. Xinping, W. Xiaoqi, Effects of forced air hyperthermia on perioperative hypothermia, complications, stress and inflammatory response in laparoscopic surgery, Medical Clinical Research 53 (12) (2022) 39–41.
[22] Y. Xia, L. Guohong, C. Ying, Construction and application of risk prediction model of intraoperative hypothermia in patients undergoing urological Leonardo da Vinci robotic surgery, Journal of Nursing of the PLA 31 (11) (2021) 33–36.
[23] J. Yi, Y. Lei, S. Xu, Y. Si, S. Li, Z. Xia, Y. Shi, X. Gu, J. Yu, G. Xu, et al., Intraoperative hypothermia and its clinical outcomes in patients undergoing general anesthesia: national study in China, PLoS One 12 (6) (2017) e0177221.
[24] L. Li, Y. Lu, L.L. Yang, W. Xu, J.K. Yu, Construction and validation of postoperative hypothermia prediction model for patients undergoing joint replacement surgery, J. Clin. Nurs. 19 (6) (2022) 5–9.
[25] R. Miyazaki, S. Hoka, What is the predictor of the intraoperative body temperature in abdominal surgery? J. Anesth. 33 (1) (2019) 67–73.
[26] X. Fang, Y. Zhiqing, H. Wei, Construction and verification of risk prediction model of intraoperative hypothermia in patients undergoing radical resection of oral cancer, J. Nurs. 29 (9) (2022) 6–9.
[27] S. Wang, Effect of intraoperative comprehensive warm intervention on vital signs and recovery during anesthesia Jilin Medicine 25 (1) (2024) 45–48.
[28] D. Wei, H. Sha, Effect of hypothermia nursing during laparoscopic rectal cancer operation on the recovery of intestinal function, Clinical Oncology and Rehabilitation in China 11 (7) (2021) 28–31.
[29] Y. Ni, Z. Hua, Effect of combined heat preservation measures on body temperature and blood coagulation function in patients undergoing gynecological laparoscopic surgery, Thrombosis and Hemostasis 27 (3) (2021) 2–5.
[30] L. Xiaofang, Z. Chunyan, Y. Li, Application of compound heat preservation measures in operating room nursing of patients undergoing laparoscopic total hysterectomy, Chinese Journal of Modern Nursing 27 (2) (2021) 4–8.
[31] M. Soehle, H. Dehne, A. Hoeft, S. Zenker, Accuracy of the non-invasive Tcore temperature monitoring system to measure body core temperature in abdominal surgery, J. Clin. Monit. Comput. 34 (6) (2020) 1361–1367.
[32] E. Matilda, E. Westergaard-Nielsen, M. Henricson, Preoperative peripheral and core temperature: an observational study at a day-surgery unit, Br. J. Nurs. 29 (3) (2020) 160–164.
[33] T.S. Suri, A. Sardesai, A. Volpin, G. Muniz-Terrera, V. Khanduja, Incidence of hypothermia and factors affecting variation in core body temperature in patients undergoing arthroscopic surgery of the hip, Acta Orthop. Belg. 85 (4) (2019) 535–539.
[34] E.J. Kim, H. Yoon, Preoperative factors affecting the intraoperative core body temperature in abdominal surgery under general anesthesia: an observational cohort, Clin. Nurse Spec. 28 (5) (2014) 268–276.
[35] M. Fahim, L.M. Dijksman, D.H. Biesma, P.G. Noordzij, A.B. Smits, Effect of intra-operative hypothermia on post-operative morbidity in patients with colorectal cancer, Surg. Infect. 22 (8) (2021) 803–809.
[36] H. Li, X. Fu, C. Zhang, Research progress of evidence-based nursing in operating room based on the concept of accelerated rehabilitation surgery, Nurs. Res. 36 (2) (2022) 5–9.
[37] G. Chen, H. Xi, Z. Chen, Research progress on operation and management of operating room, Nurs. Res. 41 (23) (2023) 4267–4271.
[38] T. Jiajun, Construction and application of predictive model of intraoperative hypothermia in patients undergoing laparoscopic surgery, Chin. J. Nurs. 54 (9) (2019) 5–8.
[39] R. Jiang, Y. Sun, H. Wang, M. Liang, X. Xie, Effect of different carbon dioxide (CO2) insufflation for laparoscopic colorectal surgery in elderly patients: a randomized controlled trial, Medicine (Baltim.) 98 (41) (2019) e17520.
[40] P. Lenz, T. Meister, M. Manno, M. Pennazio, R. Conigliaro, S. Lebkucher, H. Ullerich, A. Schmedt, M. Floer, T. Beyna, et al., CO2 insufflation during single-balloon enteroscopy: a multicenter randomized controlled trial, Endoscopy 46 (1) (2014) 53–58.
[41] X. Li, H. Dong, Y. Zhang, G. Zhang, CO2 insufflation versus air insufflation for endoscopic submucosal dissection: a meta-analysis of randomized controlled trials, PLoS One 12 (5) (2017) e0177909.
[42] L. Sun, Q. Gao, G. Wang, H.S. Liang, H.Y. An, M. He, Y. Feng, [Risk factors for hypothermia in patients undergoing general anesthesia in the postanesthesia care unit], Zhonghua Yixue Zazhi 101 (1) (2021) 52–56.
[43] C. Motamed, G. Weil, C. Dridi, J.L. Bourgain, Incidence of severe hypothermia and its impact on postoperative surgical complications and time delay to adjunct treatments in breast surgery cancer patients: a case-controlled study, J. Clin. Med. 10 (16) (2021).
[44] A. Emmert, G. Gries, S. Wand, J. Buentzel, A. Brauer, M. Quintel, I.F. Brandes, Association between perioperative hypothermia and patient outcomes after thoracic surgery: a single center retrospective analysis, Medicine (Baltim.) 97 (17) (2018) e0528.
[45] E. Berber, A. String, A. Garland, K.L. Engle, K.M. Kim, P. Ituarte, A.E. Siperstein, Intraoperative thermal regulation in patients undergoing laparoscopic vs open surgical procedures, Surg. Endosc. 15 (3) (2001) 281–285.
[46] S. Kimura, W. Butt, Core-peripheral temperature gradient and skin temperature as predictors of major adverse events among postoperative pediatric cardiac patients, J. Cardiothorac. Vasc. Anesth. 36 (3) (2022) 690–698.
[47] B.H. Sang, C. Lee, D.Y. Lee, Prospective comparative analysis of noninvasive body temperature monitoring using zero heat flux technology (SpotOn sensor) compared with esophageal temperature monitoring during pediatric surgery, PLoS One 17 (8) (2022) e0272720.
[48] W. Jumei, Y. Hong, Preventive effect of intraoperative heat preservation nursing on hypothermia and complications in patients undergoing gynecological laparoscopic surgery, Journal of practical Clinical Medicine 23 (22) (2019) 4–7.
[49] S. Sari, S.M. Aksoy, A. But, The incidence of inadvertent perioperative hypothermia in patients undergoing general anesthesia and an examination of risk factors, Int. J. Clin. Pract. 75 (6) (2021) e14103.