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Original Article

Preventive intervention for hypothermia in patients undergoing thoracic surgery reduces complications

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Abstract: Objective: This study aimed to probe into the factors leading to hypothermia (HT) in patients undergoing thoracic surgery and its countermeasures. Methods: Two hundred and twelve thoracic surgery patients admitted to our hospital from January 2018 to June 2018 were enrolled. The clinical data of patients were collected, and the risk factors of HT in surgical patients were analyzed by univariate and Logistics regression analyses. Another 128 patients who underwent thoracic surgery in our hospital were recruited, among which the regular group (n=58) received routine preventive approaches, and the research group (n=70) was given preventive measures targeting the risk factors of HT. The effects of preventive measures of HT on intraoperative complications, stress response, recovery and nursing satisfaction were compared. Results: Age >60 years old, operation time >2 hours, intraoperative infusion volume >2000 mL, open operation, operating room temperature <24°C and rinse solution volume >2000 mL were the risk factors for HT in patients undergoing thoracic surgery. Compared with the regular group, the incidence of HT, chills and partial surgical infection was lower in the research group, and the stress reaction and coagulation function in the research group was also statistically improved. In addition, the postanesthesia care unit (PACU) residence time, anesthesia recovery time, hospitalization time and nursing satisfaction in the research group were better than those in the regular group. Conclusions: Age >60 years old, operation time >2 hours, intraoperative infusion volume >2000 mL, open operation, operating room temperature <24°C and rinse solution volume >2000 mL were risk factors leading to HT in patients undergoing thoracic surgery, and targeted HT prevention measures based on these risk factors show better therapeutic effects and higher patient satisfaction than routine prevention measures.

Keywords: Hypothermia, risk factors, operating room, logistic regression analysis

Introduction

Body temperature is an essential vital sign of the human body, and normal body temperature is a necessity to ensure normal metabolism and body activities for life. The normal human core temperature is between 36.5°C and 37.5°C, and when the human core temperature is lower than 36°C, it is called hypothermia (HT) [1]. HT, as one of the most common complications in operating room patients with a high incidence of 25%-90% [2], is associated with a variety of adverse outcomes in patients, such as increased postoperative infection rates, myocardial events, reduced metabolic function, prolonged hospitalization time, and increased medical costs [3, 4]. Although HT is an underestimated and unresolved problem that can lead to various adverse outcomes, temperature monitoring and management is still not widely used in clinical practice [5, 6]. A study of 8,083 surgical patients in 17 European countries indicated that only 19% of patients had temperature monitoring and only 38% had taken active heating precautions [7]. Therefore, it is high time to strengthen temperature monitoring and HT prevention for surgical patients.

HT in perioperative patients is considered to be the result of multiple factors, such as age, type of surgery, operation time, ambient tempera-

ture and the use of mechanical ventilation [8]. Perioperative HT is a preventable complication [9]. In clinical practice, there are many technologies and measures that can be used to prevent HT, such as circulating warm mattress, self-heating blanket, forced air heating, blood transfusion heating, etc. However, studies have shown that the prevention effects vary among different technologies or measures, and some are completely ineffective [10, 11]. Therefore, it is necessary for us to understand the risk factors leading to HT in patients in the operating room, so as to help medical staff to develop measures that can effectively prevent HT and its related complications.

In this study, we established a Logistic regression model to analyze the risk factors of HT in patients undergoing thoracic surgery, and based on these risk factors, targeted preventive measures of HT were carried out in patients to help medical staff to understand the risk factors leading to HT and to create corresponding preventive measures.

Materials and methods

Inclusion of research participants

Two hundred and twelve thoracic surgery patients admitted to our hospital from January 2018 to June 2018 were selected, and patients with HT (core temperature below 36°C) were enrolled in the hypothermia group, while the remaining patients without HT were included in the normal group. Additionally, 128 patients who underwent thoracic surgery in our hospital were recruited, among which 58 patients who received routine insulation measures were taken as the regular group, and the remaining 70 patients treated with targeted insulation measures were the research group. Inclusion criteria: Patients enrolled were those who underwent general anesthesia and spinal anesthesia for non-cardiac surgery, aged 18 years or above, and were able to cooperate with physicians to complete various tasks, and those with complete clinical data. Exclusion criteria: Patients with coagulopathy; patients with fever or HT before surgery; patients with HT during surgery; patients with abnormal temperature regulation; patients during pregnancy. This study was approved by the Medical Ethics Committee of our hospital, and all the patients had signed an informed consent form prior to study commencement.

Insulation methods

The regular group was given routine preventive treatment, that is, after entering the operating room, the patient's body was covered with a double-layer pure cotton thread blanket to complete the thermal insulation treatment according to the current temperature of the patients and the specific requirements of the operation.

The research group was given additional targeted preventive measures, which mainly covered the following dimensions: (1) The temperature of the operating room was adjusted to 24-26°C, while the temperature and humidity with elderly or patients with open surgery was controlled to 26°C and 40-60%. Ten to fifteen minutes before disinfection, the temperature of the operating room was increased by 1°C to shorten the operation time and reduce the exposure site as much as possible. (2) The exposed area of the patient's body was reduced as much as possible. For the exposed skin, a blanket was used to keep warm without affecting the operation, and to protect the privacy of the patient. (3) During the operation, the temperature of the patients was monitored regularly, and targeted measures were taken to keep warm when the body temperature dropped. (4) The liquid preparation to be injected and the rinse solution to be used by the patient was pre-heated by means of thermostat, water bath heating and air humidity heating, and drip was not given until the liquid temperature reached 37°C. Preheating was also applied when using rinse solution. (5) During operation, an inflatable insulation blanket was used for active heating treatment to prevent HT. (6) When the operation was expected to end, the nurses in the operating room called the nursing staff in the ward to set appropriate temperature for the postanesthesia care unit (PACU) and ward, and strengthened the monitoring of body temperature at the same time.

Outcome measures

The nasopharyngeal temperature of the patient was measured every 15 min during the operation, and the occurrence of HT was recorded (HT was determined if the body tem-

Table 1. Comparison of general data between regular group and research group [n (%)]

Groups	n	Regular group (n=58)	Research group (n=70)	χ^2	P
Gender				0.777	0.378
Male	76	32 (55.17)	44 (62.86)		
Female	52	26 (44.83)	26 (37.14)		
Age (years old)				1.555	0.212
≤60	74	37 (63.79)	37 (52.86)		
>60	54	21 (36.21)	33 (47.14)		
Operation time (h)				0.651	0.420
>2	69	29 (50.00)	40 (57.14)		
≤2	59	29 (50.00)	30 (42.86)		
Intraoperative infusion volume (mL)				0.681	0.409
≤2000	80	34 (58.62)	46 (65.71)		
>2000	48	24 (41.38)	24 (34.29)		
BMI (kg/m^2)				0.067	0.796
>25	47	22 (37.93)	25 (35.71)		
≤25	81	36 (62.07)	45 (64.29)		
Type of surgery				0.703	0.402
Open	61	30 (51.72)	31 (44.29)		
Minimally invasive	67	28 (48.28)	39 (55.71)		
Operating room temperature (°C)				0.066	0.798
<24	24	10 (17.24)	14 (20.00)		
24-26	104	48 (82.76)	56 (80.00)		
Surgical site				1.561	0.458
Esophagus	28	15 (25.86)	13 (18.57)		
Mediastinum	32	12 (20.68)	20 (28.57)		
Lung	68	31 (53.45)	37 (52.86)		
ASA grading				1.314	0.252
Grade II	86	42 (72.41)	44 (62.86)		
Grade III	42	16 (75.59)	26 (37.14)		
Intraoperative blood loss (mL)				2.430	0.119
≤200	80	32 (55.17)	48 (68.57)		
>200	48	26 (44.83)	22 (31.43)		

perature was lower than 36°C at any monitoring point). Complications such as chills, arrhythmia, partial surgical infection and restlessness were recorded. In addition, the PACU residence time, anesthesia recovery time and hospitalization time were recorded.

The levels of adrenocorticoid (AD), norepinephrine (NE) and C-reactive protein (CRP) of patients in the two groups after leaving the operating room were measured. Radioimmunoassay was utilized to measure AD and NE contents, and immunotransmission scattering turbidimetry was used to determine the C-reactive protein (CRP) levels of the two groups of patients after left the operating room to determine the stress response status of patients. Plasma prothrombin time (PT), activated partial prothrombin time (APTT) and fibrinogen (Fbg) were measured in the two groups to determine the coagulation function of patients.

The nursing satisfaction was evaluated with a hospital-made questionnaire (the Cronbach alpha coefficient was 0.845) after the patient was awake and returned to the ward. The questionnaire included content like whether the temperature in the operating room was comfortable, whether warming measures were in place, and the evaluation of patients' self-comfort. There are 20 questions in the ques-

Table 2. Univariate analysis of hypothermia in patients undergoing thoracic surgery [n (%)]

Groups	n	Normal group (n=114)	Hypothermia group (n=98)	χ^2	P
Gender				0.596	0.141
Male	125	62 (54.39)	63 (64.29)		
Female	87	52 (45.61)	35 (35.71)		
Age (years old)				6.931	0.009
≤60	92	40 (35.09)	52 (53.06)		
>60	120	74 (64.91)	46 (46.94)		
Operation time (h)				5.935	0.015
>2	129	78 (68.42)	51 (52.04)		
≤2	83	36 (31.58)	47 (47.96)		
Intraoperative infusion volume (mL)				5.411	0.020
≤2000	88	39 (34.21)	49 (50.00)		
>2000	124	75 (65.79)	49 (50.00)		
BMI (kg/m^2)				2.170	0.141
>25	67	41 (35.96)	26 (26.53)		
≤25	145	71 (64.04)	74 (73.47)		
Type of surgery				10.551	0.001
Open	113	49 (42.98)	64 (65.31)		
Minimally invasive	99	65 (57.02)	34 (34.69)		
Operating room temperature (°C)				6.407	0.011
<24	70	29 (25.44)	41 (41.84)		
24-26	142	85 (74.56)	57 (58.16)		
Surgical site				3.171	0.205
Mediastinum	50	30 (26.32)	20 (20.41)		
Esophagus	57	34 (29.82)	23 (23.47)		
Lung	105	50 (43.86)	55 (56.12)		
ASA grading				2.398	0.122
Grade II	135	78 (68.42)	57 (58.16)		
Grade III	77	36 (31.58)	41 (41.84)		
Intraoperative blood loss (mL)				3.020	0.082
≤200	128	75 (65.79)	53 (54.08)		
>200	84	39 (34.21)	45 (45.92)		
Antibiotic use				2.146	0.143
Yes	114	56 (49.12)	58 (59.18)		
No	98	58 (50.88)	40 (40.82)		
Rinse solution volume (mL)				8.563	0.003
≤2000	92	60 (52.63)	32 (32.65)		
>2000	120	54 (47.37)	66 (67.35)		

tionnaire, each scored one point. Very satisfied: 17-20 points; Satisfied: 13-16 points; Basically satisfied: 9-12 points; Dissatisfied: 0-8 points. Satisfaction = number of (very satisfied + satisfied) cases/total number of cases.

Statistical processing

The statistical analysis and visualization of the data were performed by SPSS 21.0 (IBM Corp, Armonk, NY, USA) and GraphPad Prism 7, respectively. The counting data in the study were expressed by the number of cases/percentage [n (%)], and compared by chi-square test or Fisher exact test. The measurement data were represented by mean ± standard deviation (x ± SD), the comparison between groups was conducted by independent t-test, the comparison among multiple groups was performed by one-way ANOVA, and the correct-

Table 3. Multivariate analysis of hypothermia in patients undergoing thoracic surgery [n (%)]

Variables	β	S.E	Wals	P	OR	95% CI
age >60 years old	0.331	1.334	4.475	0.003	2.484	1.054-3.487
Operation time >2 h	0.313	1.348	4.342	0.008	2.310	1.218-3.875
Intraoperative infusion volume >2000 mL	0.361	1.405	4.396	0.005	2.705	1.145-3.344
Open surgery	0.286	1.324	4.205	0.011	2.483	1.193-3.212
Operating room temperature <24°C	0.298	1.358	4.235	0.009	2.551	1.214-3.268
Rinse solution volume >2000 mL	0.295	1.345	4.486	0.016	2.462	1.181-3.205

Table 4. Comparison of occurrence of hypothermia and complications [n (%)]

Groups	Regular group (n=58)	Research group (n=70)	χ^2	P
Hypothermia	20 (34.48)	11 (15.71)	6.088	0.014
Chills	12 (20.69)	5 (7.14)	5.054	0.025
Arrhythmia	4 (6.90)	3 (4.29)	0.418	0.518
Surgical infection	9 (15.52)	3 (4.29)	4.710	0.030
Restlessness	8 (13.79)	6 (8.57)	0.888	0.346

ness of the statistical value was verified by post-hoc tests. Multivariate Logistic regression was used to analyze the risk factors of HT in patients undergoing thoracic surgery. P<0.05 indicated that the comparison was statistically significant.

Results

Comparison of general data between the regular group and research group

In comparing the general data and operation information, it was found that there were no significant differences in gender, age, operation time, intraoperative infusion volume, operation type, BMI and operating room temperature between the two groups (P>0.05) (**Table 1**).

Univariate analysis of HT in patients undergoing thoracic surgery

Among the 212 patients undergoing thoracic surgery, 98 (46.23%) developed HT (hypothermia group), while 114 (53.77%) had no HT (normal group). Univariate analysis of patient clinical data in the two groups revealed that age, operation time, intraoperative infusion volume, operation type, operating room temperature and rinse solution volume may be the factors leading to HT in patients undergoing thoracic surgery (P<0.05) (**Table 2**).

Multivariate analysis of HT in patients undergoing thoracic surgery

Taking the statistically significant indexes in from the results described above, as the independent variables and HT in patients undergoing thoracic surgery as dependent variables, multivariate Logistic regression analysis was carried out. The results showed that age >60 years old, operation time >2 hours, intraoperative infusion volume >2000 mL, open operation, operating room temperature <24°C and rinse solution volume >2000 mL were the risk factors of HT in patients undergoing thoracic surgery (**Table 3**).

Comparison of occurrence of HT and complications

The occurrence of HT was recorded in the regular and research groups. It was found that HT occurred in 20 patients (34.48%) in the regular group and 11 patients (15.71%) in the research group, and the incidence of HT of the latter was lower than that of the former (P<0.05). Observing the occurrence of other complications, it was observed that there was no significant difference in the proportion of restlessness and arrhythmia between the two groups (P>0.05), but the number of cases of chills and surgical infection in the research group was lower than that in the regular group (P<0.05) (**Table 4**).

Comparison of PACU residence time, anesthesia recovery time and hospitalization time

The PACU residence time, anesthesia recovery time and hospitalization time of the two groups were recorded and compared. It was found that the three indicators in the research group

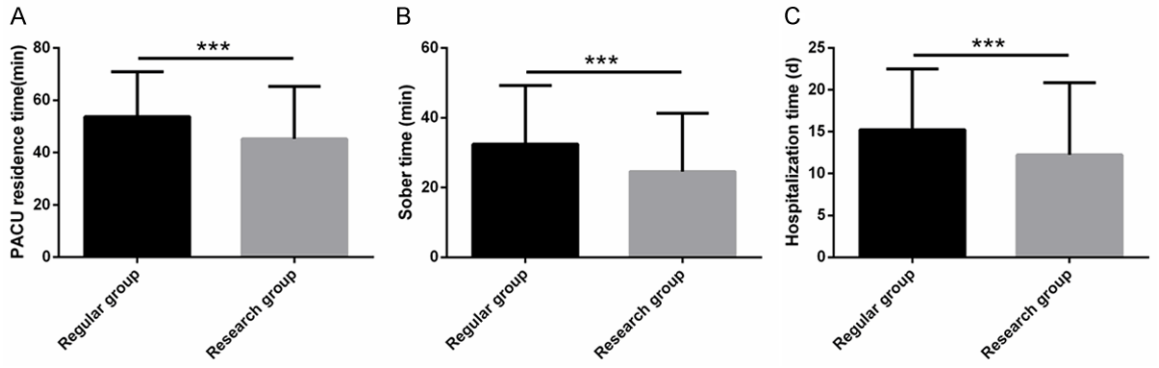

Figure 1. Comparison of PACU residence time, anesthesia recovery and hospitalization time. A: The PACU residence time in the research group was shorter than that in the regular group. B: The anesthesia recovery time in the research group was shorter than that in the regular group. C: The hospitalization time in the research group was shorter than that in the regular group. Note: *** indicates P<0.001.

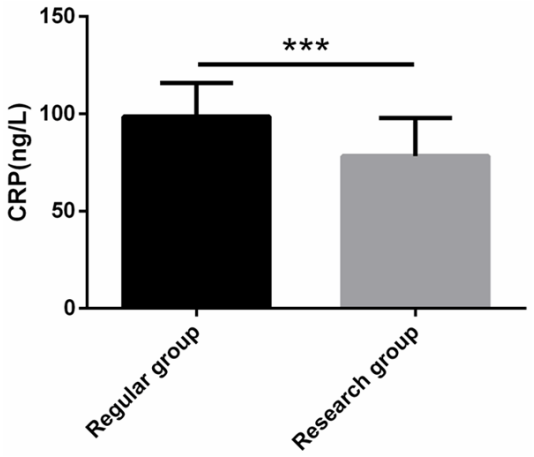

Figure 2. The CRP level in the research group was lower than that in the regular group. Note: *** indicates P<0.001.

was remarkably better than those in the regular group (P<0.05) (**Figure 1**).

Comparison of stress response indicators

Examination of the stress response indicators of patients revealed that the levels of AD, NE, and CRP in the research group were lower than those in the regular group (P<0.05) (**Figure 2**).

Comparison of postoperative coagulation function indexes

Compared with the regular group, TT and APTT were higher while FBG was lower in the research group (P<0.05) (**Figure 3**).

Comparison of patients' nursing satisfaction

The number of cases with a score of ≥13 in the regular group and the research group was 34 and 56, respectively. The satisfaction of the research group was higher than that of the research group (P<0.05, 58.62% vs 80.00%) (**Table 5**).

Discussion

In this study, the risk factors for HT in patients undergoing thoracic surgery were analyzed by establishing a Logistic regression model, and specific measures were taken to prevent HT based on these risk factors. It was found that: age >60 years old, operation time >2 h, intraoperative infusion volume >2000 mL, open operation, operating room temperature <24°C and rinse solution volume >2000 mL were the risk factors for HT in patients undergoing thoracic surgery. Specific HT prevention measures for patients undergoing thoracic surgery based on these risk factors can statistically reduce the incidence of HT, chills and surgical infection, and notably shorten PACU residence time, anesthesia recovery time and hospitalization time of patients in operating room.

HT, as one of the common complications in surgical patients, is associated with multiple adverse consequences, such as intraoperative blood loss, cardiac events, coagulation dysfunction, increased hospital stay and related costs [12]. Perioperative HT is a result of multiple factors, and the key to preventing it is to identify the causes in patients undergoing surgery. In our study, it was found that 98 (46.23%) of 212 patients undergoing thoracic surgery developed HT, which was similar to the previous survey that out of 830 surgical patients, 39.9% of patients experienced HT during surgery [13]. Then, by establishing a

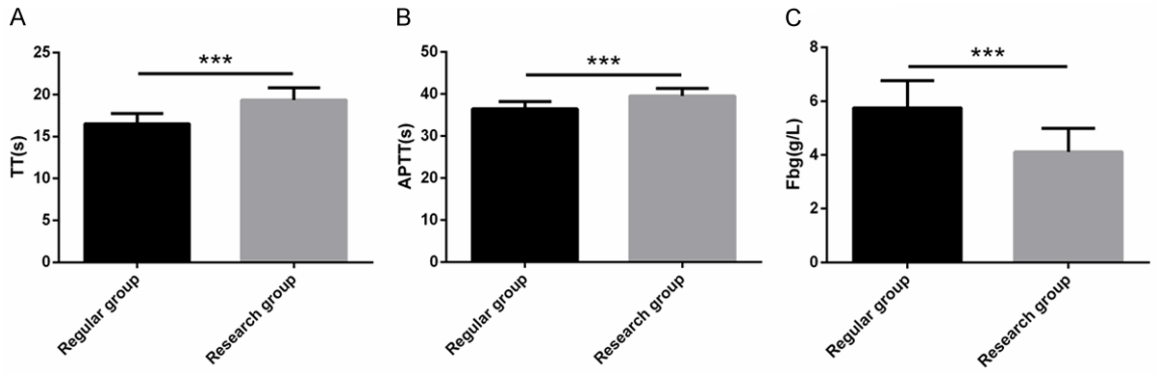

Figure 3. Comparison of postoperative coagulation function indexes. A: The TT in the research group is higher than that in the regular group. B: The APTT in the research group is higher than that in the regular group. C: The FBG in the research group is lower than that in the regular group. Note: *** indicates P<0.001.

Table 5. Patients' satisfaction with the two heat preservation methods

Groups	Very satisfied	Satisfied	Basically satisfied	Dissatisfied	Satisfaction
Regular group (n=58)	10 (17.24)	24 (41.38)	12 (20.69)	12 (20.69)	34 (58.62)
Research group (n=70)	21 (30.00)	35 (50.00)	8 (11.43)	6 (8.57)	56 (80.00)
χ^2	-	-	-	-	6.945
P	-	-	-	-	0.008

Logistic regression model to analyze the risk factors of HT in patients undergoing thoracic surgery, we identified that age >60 years old, operation time >2 hours, intraoperative infusion volume >2000 mL, open operation, operating room temperature <24°C and rinse solution volume >2000 mL were the risk factors of HT in patients undergoing thoracic surgery. The main reasons, we hypothesized, may be as follows: (1) The elderly are prone to HT due to the weak regulation of the central nervous system of body temperature and the low level of subcutaneous adipose tissue [14]. (2) The longer the operation time is, the longer the exposure time of the organs and the incision, and the increased contact time with the outside air is, which may easily lead to a decrease in body temperature [15]. (3) The temperature of intraoperative liquid drugs is usually lower than the patient's body temperature, and the more the infusion volume of the patient is, the more obvious the cold dilution effect of the input liquid is, and the more obvious the temperature reduction is [16]. (4) Patients with open surgery tend to have a larger exposed area of the body cavity and need to inject a large amount of drugs or blood during the operation. In addition, longer operation time always indicates more calories are burned by creating heat. (5) A lower operating room temperature is directly related to the occurrence of HT in patients undergoing surgery [17]. A lower ambient temperature will quickly increase the heat emission of surgical patients, so HT is more likely to occur. (6) The rinse solution is generally stored in a cool place, and if used without heating it up in advance, it will take away part of the heat from the patient's body.

Today, people have increasingly realized the importance of maintaining intraoperative temperature for patients, and some clinical guidelines also recommend that perioperative normal body temperature should be maintained to prevent some complications [18, 19]. Currently, many measures such as air blanket heating and forced air heating, have been taken to prevent HT in perioperative patients and achieved certain favorable effects [20-22]. However, these methods are often single and fail to prevent HT from multiple perspectives, resulting in HT being common despite precautions being taken. Therefore, we believe that the current preventive measures for HT still need to be improved. Previous studies have shown that, in view of the risk factors that lead to HT in perioperative patients, composite thermal insulation measures can more effec-

tively prevent HT in perioperative patients [2]. Based on the above obtained risk factors, this study conducted targeted nursing interventions for surgical patients. The results showed that, compared with the regular group, the incidence of HT, chills and surgical infection in the research group was lower, and the stress response and coagulation function in the research group were also statistically improved. In addition, the PACU residence time, anesthesia recovery, hospitalization time and nursing satisfaction of patients in the research group were better than those in the conventional group. All these show that the targeted preventive measures we have taken are effective and more accepted by patients, with high clinical application value.

There are also some deficiencies in this study. Firstly, patients under 18 years of age were not included, leading to certain age limits in this study. Secondly, this study only analyzed the factors and countermeasures that lead to HT in patients undergoing thoracic surgery, but not in patients undergoing other types of surgery. It is hoped that these deficiencies can be supplemented in future research.

In conclusion, age >60 years old, operation time >2 hours, intraoperative infusion volume >2000 mL, open operation, operating room temperature <24°C and rinse solution volume >2000 mL were the risk factors leading to HT in patients undergoing thoracic surgery, and targeted preventive measures for HT based on these risk factors demonstrate better preventive effects and higher patient satisfaction than routine preventive measures.

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Disclosure of conflict of interest

None.

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