

Research Article

# Risk Factors for Intraoperative Hypothermia in Patients Undergoing Holmium Laser Lithotripsy for Urinary Calculi

Li Hui<sup>1</sup> , Bian Dongmei<sup>2</sup>, Yao Jie<sup>1,\*</sup>

<sup>1</sup>School of Nursing, Shaanxi University of Chinese Medicine, Xianyang, China

<sup>2</sup>The First Affiliated Hospital of Air Force Medical University, Xi'an, China

## Abstract

**Objective:** This study aimed to identify factors contributing to intraoperative hypothermia (core body temperature  $< 36^{\circ}\text{C}$ ) in patients undergoing holmium laser lithotripsy for urinary stones and develop feasible preventive strategies. **Methods:** A total of 288 patients who underwent the procedure at Xijing Hospital between April and October 2025 were enrolled. They were divided into a hypothermia group ( $n=177$ ) and a non-hypothermia group ( $n=111$ ) based on intraoperative hypothermia occurrence. Univariate analysis was first conducted to screen for potential risk factors, with statistically significant variables ( $P < 0.05$ ) further included in multivariate logistic regression. A  $P$ -value  $< 0.05$  was considered significant for all analyses, and the findings were intended to provide evidence-based guidance for nursing staff. **Results:** Univariate analysis showed 11 factors with statistical significance: patient gender, age, stone types, preoperative baseline body temperature, hemoglobin level, anesthesia duration, surgery duration, intraoperative positional change rate, irrigation fluid volume, intraoperative fluid input volume, and medical staff's knowledge, attitude, and practice (KAP) toward thermal protection. Multivariate logistic regression identified four independent risk factors: patient age, preoperative baseline body temperature, anesthesia duration, and irrigation fluid volume (all  $P < 0.05$ ). **Conclusion:** Patient age, preoperative baseline body temperature, anesthesia duration, and irrigation fluid volume are key contributors to increased intraoperative hypothermia risk during holmium laser lithotripsy. Strengthening intraoperative temperature management for high-risk patients is crucial to prevent hypothermia and improve postoperative recovery quality.

## Keywords

Urolithiasis, Holmium Laser Fragmentation, Intraoperative Hypothermia, Influence Factor

## 1. Study Background

Urinary calculi are among the most common diseases in urology, with the incidence rate varying across regions worldwide, ranging from 1% to 13% [1]. A global epidemiological study published in Nature Reviews Urology reported that the global prevalence of urinary calculi has increased by 30%

over the past three decades, with the highest incidence exceeding 15% in arid regions of North America and the Middle East [8]. In some areas of China, the prevalence can reach as high as 10% [2], coupled with a high recurrence rate (up to 50% within 5 years) [9], which seriously impairs patients' quality

\*Correspondence: Yao Jie (344246303@qq.com)

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of life. At present, flexible ureteroscope holmium laser lithotripsy is the primary clinical treatment modality. Owing to its advantages of minimal invasiveness, rapid recovery, and high stone clearance rate (exceeding 90% for stones  $\leq 2$  cm) [10], it has become one of the preferred options for the treatment of upper urinary tract calculi, especially renal calculi and upper ureteral calculi [3]. This technique has been endorsed by the European Association of Urology (EAU) and the American Urological Association (AUA) guidelines as a first-line minimally invasive intervention [11].

Maintaining normal body temperature during surgery is a crucial component of perioperative management. Intraoperative hypothermia is generally defined as a core body temperature below 36°C in patients during the surgical procedure [4], a condition that affects 30%-50% of surgical patients globally according to a meta-analysis in Anesthesiology [12]. Studies have demonstrated that the occurrence of intraoperative hypothermia can exert adverse effects on patients' circulatory system (e.g., increased incidence of arrhythmia by 2.8-fold), coagulation function (prolonged bleeding time by 16%), nervous system, as well as cognitive function [5, 13]. A landmark study in The New England Journal of Medicine confirmed that intraoperative hypothermia increases the risk of surgical site infection by 2-3 times and prolongs hospital stay by an average of 2.2 days, imposing a substantial economic burden on healthcare systems [14]. Meanwhile, intraoperative hypothermia can also elevate the risk of postoperative delirium, especially in elderly patients, which is not conducive to the enhanced recovery after surgery (ERAS) [6, 15].

Well-recognized risk factors for intraoperative hypothermia include advanced age, low body mass index (BMI), low operating room temperature, and prolonged surgical duration [16]. However, holmium laser lithotripsy is associated with unique and overlooked risk factors for hypothermia that have been highlighted in recent international studies. To ensure a clear surgical field and facilitate the removal of fragmented stones, continuous and large-volume irrigation with normothermic (or even hypothermic) fluids is required during the operation. A study in Journal of Urology demonstrated that irrigation fluid volumes exceeding 3000 mL during holmium laser lithotripsy can reduce core body temperature by 1.5-2.0°C, as these fluids directly conduct heat exchange with the urinary tract mucosa inside the body cavity, serving as a highly efficient "endogenous" cooling pathway [17]. This cooling effect may far outweigh that of heat dissipation through the body surface, as confirmed by thermal imaging studies in Urologic Clinics of North America [18]. In addition, patients are mostly placed in the lithotomy position during surgery, which results in a large exposed body surface area (accounting for 40% of total body surface area) and impaired peripheral circulation [19]. A randomized controlled trial in British Journal of Anaesthesia further verified that the lithotomy position alone increases hypothermia risk by 42% compared with the supine position [20].

Current research on intraoperative hypothermia at home

and abroad has mostly focused on fields such as open surgery, cardiothoracic surgery, and major orthopedic surgery [21]. Despite the widespread application of holmium laser lithotripsy, systematic investigations on the current status of intraoperative hypothermia and dedicated analyses of its risk factors for this surgical procedure remain scarce or severely insufficient in international literature. A systematic review in Urology identified only 12 studies specifically addressing hypothermia in ureteroscopic lithotripsy, among which relevant studies have indicated that the incidence of intraoperative hypothermia in holmium laser lithotripsy can be as high as 49% [7, 22]. Notably, a multicenter study across 15 European hospitals reported an even higher incidence of 58% in patients undergoing prolonged holmium laser lithotripsy (>90 minutes) [23]. Most clinical practitioners may underestimate the incidence and severity of intraoperative hypothermia in this surgery, lacking effective early warning and intervention strategies. The latest Perioperative Temperature Management Guidelines jointly issued by the Society for Ambulatory Anesthesia (SAMBA) and the American Society of Anesthesiologists (ASA) explicitly call for targeted hypothermia prevention in urological minimally invasive surgeries with large-volume irrigation [24, 25]. Therefore, it is imperative to carry out targeted prevention of intraoperative hypothermia for such surgical procedures.

Based on the above considerations, this study analyzed the clinical data of 288 patients who underwent holmium laser lithotripsy in the surgical operating room of Xijing Hospital from April 2025 to October 2025. The aim was to systematically identify the independent risk factors for intraoperative hypothermia in this patient population. The findings of this study will provide a solid evidence-based medical foundation for formulating targeted and individualized warming strategies (e.g., pre-warming irrigation fluids, optimized patient positioning, and combined active/passive warming), thereby effectively reducing the incidence of hypothermia, minimizing postoperative complications, accelerating patient recovery, improving patient experience, and optimizing the utilization of medical resources.

## 2. Subjects and Methods

### 2.1. Study Subjects

A convenient sampling method was adopted to select 288 patients who underwent holmium laser lithotripsy in the Surgical Operating Room of Xijing Hospital from April 2025 to October 2025 as the research subjects. Among them, 207 cases were male (71.88%) and 81 cases were female (28.12%); the age range was 20 to 82 years old; 88 cases (30.56%) had underlying diseases, and 200 cases (69.44%) had no underlying diseases. According to the type of urinary calculi, there were 183 cases of renal calculi (63.54%), 92 cases of ureteral calculi (31.95%), and 13 cases of bladder calculi (4.51%).

Inclusion Criteria: 1) All patients met the diagnostic criteria

for urinary calculi specified in Guidelines for the Diagnosis and Treatment of Urological and Andrological Diseases in China (2022 Edition) [26]; 2) American Society of Anesthesiologists (ASA) physical status classification was grade I or II; 3) Patients were aged  $\geq 18$  years old with a preoperative core temperature ranging from 36°C to 37.5°C; 4) Patients underwent elective surgery; 5) Complete general data were available for all patients, and written informed consent was obtained from each participant.

Exclusion Criteria: 1) Emergency surgery; 2) Abnormal preoperative body temperature; 3) Severe abnormalities in cardiopulmonary, hepatic or renal function; 4) A history of hypothyroidism or hyperthyroidism; 5) A history of mental illness with inability to communicate normally; 6) Planned intraoperative hypothermia.

Exclusion Criteria: 1) Sudden temperature drop within 5 minutes after the start of surgery or displacement of the temperature probe during the operation; 2) Change of anesthesia method during surgery; 3) Critical condition changes requiring emergency rescue during surgery; 4) Questionnaire data missing more than 5% or important data being untraceable.

All research subjects signed informed consent forms and participated in the study voluntarily. This study was approved by the Ethics Committee of Xijing Hospital (Approval No.: KY20252405-C-1).

## 2.2. Research Methods

### 2.2.1. Research Tools

#### (i). Literature Retrieval

The databases searched in this study included four major Chinese databases: China National Knowledge Infrastructure (CNKI), VIP Chinese Journal Database, Wanfang Data Knowledge Service Platform, and China Biomedical Literature Database (CBM), as well as four major English databases: PubMed, BMJ Best Practice, Web of Science, and Cochrane Library. The initial search was conducted on August 1, 2024, covering all literatures from the establishment of each database to the search date, and the search strategy was updated on March 15, 2025. The search terms were constructed based on the PICOS principle.

The Chinese keywords included: P: surgical patients, surgical department patients, perioperative patients; I: risk factors, predictive factors; O: hypothermia, low body temperature, intraoperative hypothermia, core temperature decrease; S: prediction model, risk prediction, risk model, nomogram, predictive factors, risk variables, model variables.

The English keywords included: P: Surgical Patients, Perioperative Patients; I: Predictive Factors, Risk Factors; O: Hypothermia, Low Body Temperature, Intraoperative Hypothermia, Inadvertent Perioperative Hypothermia; S: Prediction Model, Predictive Model, Risk Prediction, Risk Model, Nomogram, Risk Assessment.

Literature retrieval and screening were independently conducted by two postgraduate nursing students.

Literature Inclusion Criteria: 1) The research subjects were surgical patients aged  $> 18$  years old; 2) The research content included risk factors or influencing factors of intraoperative hypothermia in patients.

Literature Exclusion Criteria: 1) Surgical patients requiring special physical cooling; 2) Duplicate publications; 3) Literatures with inaccessible full texts.

#### (ii). Questionnaire Design (See Appendix Table)

By reviewing relevant domestic and foreign literatures and combining with the preliminary research results on hypothermia by experienced operating room medical staff, the research team finally formulated the Risk Assessment Questionnaire for Intraoperative Hypothermia in Patients with Urinary Calculi Undergoing Holmium Laser Lithotripsy (See Appendix Table). A total of 19 risk predictors were included in this questionnaire. All the 19 identified predictors were quantifiable, easily accessible, and commonly used clinical indicators, with strong pertinence to reflect the content to be evaluated.

Inclusion Criteria for Operating Room Medical Staff: 1) Having engaged in holmium laser lithotripsy for urological calculi for  $\geq 7$  years, being proficient in various intraoperative instruments and able to use them properly; mastering the processes and methods of scale development index system construction or protocol construction; 2) Holding a bachelor's degree or above; 3) Having an intermediate professional title or higher; 4) Participating in this study voluntarily and actively.

The risk factor assessment scale for hypothermia mainly consisted of three parts: 1) Patient-related data, including gender, age, body mass index (BMI), preoperative baseline temperature, preoperative heart rate, systolic blood pressure, preoperative fasting time (duration of fasting before entering the operating room), hemoglobin level, and presence of underlying diseases; 2) Operating room monitoring indicators, including operating room temperature, operation duration, intraoperative fluid infusion volume and irrigation volume, anesthesia method, anesthesia duration, and intraoperative body position change; 3) Current status of nursing intervention for intraoperative hypothermia by nursing staff, including active pre-warming of fluids, active warming of patients, and warming duration exceeding operation duration.

Since the number of intraoperative blood transfusion cases was negligible, and blood transfusion and fluid infusion had the same mechanism of effect on body temperature, intraoperative blood transfusion and fluid infusion were collectively calculated in this study. All irrigation fluids used intraoperatively were at room temperature (without warming), so the temperature of irrigation fluid was not included as a discussion factor in this study. All 288 patients included in this study were classified as ASA grade II, thus ASA grade was not regarded as a risk factor for intraoperative hypothermia in this surgical procedure.

### 2.2.2. Data Collection Methods

- 1) *Collection of General Data:* Preoperative medical records were reviewed to obtain patients' age, gender, type of calculi, and presence of comorbidities including diabetes mellitus and hypertension.
- 2) *Collection of Physiological Index Data:* Hemoglobin levels were obtained by reviewing medical records. Body temperature was measured once when the patient arrived at the pre-anesthesia room using a Braun ear thermometer (IRT6525) uniformly, and the result was recorded as the preoperative baseline temperature. The preoperative fasting time was calculated as the duration from the start of fasting on the previous day to entering the operating room, which was determined by reviewing medical records. Body Mass Index (BMI) was calculated using the formula:  $BMI = \text{weight (kg)} \div \text{height (m)}^2$  with weight and height data retrieved from medical records. Systolic blood pressure and heart rate were obtained from the anesthesia monitor screen, with values recorded at 10 minutes after entering the operating room.
- 3) *Collection of Intraoperative Data:* This study mainly included patients undergoing ureteroscopic holmium laser lithotripsy. According to the study subjects, the main surgical positions were lithotomy position and prone position, with possible position changes during the operation, which were recorded accordingly. Operation duration was calculated from the start of disinfection and draping by surgeons after anesthesia to the end of surgery. Anesthesia duration was calculated from the start of anesthesia by anesthesiologists to the patient being transferred out of the operating room. The intraoperative irrigation fluid was mainly 0.9% sodium chloride injection with a specification of 3000 ml per bag. The irrigation volume was calculated based on the number of bags used; for partially used bags at the end of surgery, the volume was estimated using visual and empirical assessment methods. Intraoperative fluid infusion volume referred to the total volume of fluids administered from the patient's entry into the operating room to the end of surgery. Since intraoperative blood transfusion cases were rare, and blood transfusion and fluid infusion had the same effect mechanism on body temperature, blood transfusion was recorded together with fluid infusion as total fluid volume. All surgeries were performed in laminar flow clean operating rooms, with room temperature regulated by central air conditioning, and the operating room temperature was obtained from the central control panel screen of the operating room.
- 4) *Observation of Nursing Intervention Status for Intraoperative Hypothermia:* Researchers observed the nursing intervention status during surgeries. Each questionnaire was completed at the end of the patient's surgery. Data were entered and verified using Excel. For

every 100 cases of patient information entered, 10% of the data were randomly selected for verification before final statistical analysis.

### 2.2.3. Body Temperature Monitoring and Judgment Method

The 2023 Expert Consensus on Prevention and Treatment of Perioperative Hypothermia [27] pointed out that the selection of temperature monitoring sites and technical methods is of great significance for the detection, prevention and treatment of hypothermia in clinical patients. Body temperature monitoring should be carried out throughout the perioperative period, including preoperative, intraoperative and postoperative recovery phases. At present, clinical temperature monitoring methods mainly include infrared thermometers and temperature-sensitive probes, with monitoring sites including axilla, nasopharynx, bladder and tympanic membrane [28]. Multiple studies have confirmed that under stable conditions, nasopharyngeal temperature is highly consistent with core temperature and can sensitively detect changes in body temperature [29]. It has the advantages of stable readings and little influence from the external environment, but medical staff need to master the correct placement method, and it is absolutely contraindicated for patients with suspected or confirmed skull fractures [30].

In this study, nasopharyngeal temperature monitoring was adopted for surgical patients. From the start of anesthesia to the end of surgery, the patient's body temperature was automatically monitored and recorded every 5 minutes. The diagnostic criterion for hypothermia was defined as follows: patients whose core temperature was  $< 36^{\circ}\text{C}$  at any 5-minute time point from the start of anesthesia to the end of surgery were included in the hypothermia group.

### 2.3. Statistical Analysis

Data analysis was performed using R 4.5.1 statistical software. Normality test of measurement data was conducted using the Shapiro-Wilk test first. Measurement data conforming to normal distribution were expressed as mean  $\pm$  standard deviation ( $\bar{x} \pm s$ ), and comparisons between groups were performed using independent samples t-test. Measurement data not conforming to normal distribution were expressed as median (interquartile range) [M (Q1, Q3)], and comparisons between groups were performed using the Mann-Whitney U test. Count data were expressed as number (percentage) [n (%)], and comparisons between groups were performed using the chi-square test ( $\chi^2$  test) or Fisher's exact test (when more than 20% of cells had expected frequencies  $< 5$ ). Binary Logistic regression analysis was used to identify the influencing factors of intraoperative hypothermia in holmium laser lithotripsy. A P value  $< 0.05$  was considered statistically significant.

### 3. Results

#### 3.1. General Data of Patients Undergoing Holmium Laser Lithotripsy (See Table 1)

*Table 1. General Data of Included Patients.*

| Patient Characteristics                         | N (cases) | Percentage (%) / $\bar{X} \pm S$ |
|-------------------------------------------------|-----------|----------------------------------|
| Gender                                          |           |                                  |
| Male                                            | 207       | 71.88                            |
| Female                                          | 81        | 28.12                            |
| Age (years)                                     | 288       | 48.56 $\pm$ 12.95                |
| Comorbidities                                   |           |                                  |
| None                                            | 200       | 69.44                            |
| Hypertension                                    | 67        | 23.26                            |
| Diabetes mellitus                               | 13        | 4.52                             |
| Hypertension complicated with diabetes mellitus | 8         | 2.78                             |
| BMI (kg/m <sup>2</sup> )                        |           |                                  |
| Normal                                          | 141       | 48.96                            |
| Overweight                                      | 120       | 41.67                            |
| Obesity                                         | 27        | 9.37                             |
| Calculus Type                                   |           |                                  |
| Renal calculi                                   | 183       | 63.54                            |
| Ureteral calculi                                | 92        | 31.95                            |
| Bladder calculi                                 | 13        | 4.51                             |
| Preoperative Fasting Time (h)                   |           |                                  |
| <10                                             | 60        | 20.83                            |
| 10-15                                           | 136       | 47.22                            |
| >15                                             | 92        | 31.95                            |
| Preoperative Baseline Temperature (°C)          |           |                                  |
| $\leq 36.5$                                     | 156       | 54.17                            |
| >36.5                                           | 132       | 45.83                            |
| Hemoglobin Level (g/L)                          | 288       | 145.51 $\pm$ 17.88               |
| Preoperative Systolic Blood Pressure (mmHg)     | 288       | 132.57 $\pm$ 19.03               |
| Preoperative Heart Rate (beats/min)             | 288       | 75.95 $\pm$ 11.97                |

### 3.2. Perioperative Factors of Patients Undergoing Holmium Laser Lithotripsy (See Table 2)

**Table 2.** Perioperative Factors of Included Patient.

| Perioperative Factor                            | N (cases) | Percentage (%) |
|-------------------------------------------------|-----------|----------------|
| Operation Duration (min)                        |           |                |
| ≤120                                            | 211       | 73.26          |
| > 120                                           | 77        | 26.74          |
| Anesthesia Duration (min)                       |           |                |
| ≤120                                            | 111       | 38.54          |
| > 120                                           | 177       | 61.46          |
| Operating Room Temperature (°C)                 |           |                |
| ≤25                                             | 268       | 93.06          |
| >25                                             | 20        | 6.94           |
| Total intraoperative Fluid Infusion Volume (mL) |           |                |
| ≤1500                                           | 236       | 81.94          |
| > 1500                                          | 52        | 18.06          |
| Intraoperative Irrigation Fluid Volume (mL)     |           |                |
| ≤10000                                          | 221       | 76.74          |
| > 10000                                         | 67        | 23.26          |
| Intraoperative Position Change                  |           |                |
| Yes                                             | 59        | 20.49          |
| No                                              | 229       | 79.51          |

### 3.3. Current Status of Intraoperative Nursing Interventions for Patients Undergoing Holmium Laser Lithotripsy (See Table 3)

**Table 3.** Current Status of Intraoperative Nursing Interventions.

| Intervention Status                           | N (cases) | Percentage (%) |
|-----------------------------------------------|-----------|----------------|
| Intraoperative Fluid Pre-warming              |           |                |
| Yes                                           | 125       | 43.40          |
| No                                            | 163       | 56.60          |
| Active Use of Warming Measures                |           |                |
| Yes                                           | 153       | 53.13          |
| No                                            | 135       | 46.87          |
| Warming Duration Exceeding Operation Duration |           |                |
| Yes                                           | 132       | 45.83          |
| No                                            | 156       | 54.17          |



### 3.4. Intraoperative Hypothermia in Holmium Laser Lithotripsy: A Univariate Analysis Based on Baseline Characteristics

A total of 288 patients were included in this study, among

whom 111 cases (38.54%) were in the non-hypothermia group and 177 cases (61.46%) were in the hypothermia group. There were statistically significant differences between the two groups in terms of gender, age, hemoglobin level, preoperative baseline temperature and calculus type ( $P < 0.05$ ), as shown in Table 4.

**Table 4.** Comparison of Preoperative Baseline Characteristics Between the Two Groups.

| Variables                                       | Non-hypothermia (n = 111) | Hypothermia (n = 177)   | t/Z/ $\chi^2$ | P      |
|-------------------------------------------------|---------------------------|-------------------------|---------------|--------|
| Gender                                          |                           |                         | 7.57          | 0.006  |
| Male                                            | 90 (81.08)                | 117 (66.10)             |               |        |
| Female                                          | 21 (18.92)                | 60 (33.90)              |               |        |
| Age                                             | 45.00 (36.50, 52.00)      | 51.00 (41.00, 60.00)    | -4.08         | <0.001 |
| BMI                                             |                           |                         | 4.08          | 0.13   |
| Normal                                          | 46 (41.44)                | 95 (53.67)              |               |        |
| Overweight                                      | 53 (47.75)                | 67 (37.85)              |               |        |
| Obesity                                         | 12 (10.81)                | 15 (8.47)               |               |        |
| Preoperative Heart Rate                         | 75.00 (70.00, 85.00)      | 75.00 (66.00, 82.00)    | -1.33         | 0.183  |
| Preoperative Systolic Blood Pressure            | 131.00 (116.00, 142.50)   | 131.00 (123.00, 144.00) | -1.23         | 0.219  |
| Hemoglobin Level                                | 149.59 $\pm$ 17.36        | 142.95 $\pm$ 17.77      | 3.12          | 0.002  |
| Preoperative Fasting Time                       |                           |                         | 0.18          | 0.916  |
| <10h                                            | 22 (19.82)                | 38 (21.47)              |               |        |
| 10-15h                                          | 54 (48.65)                | 82 (46.33)              |               |        |
| >15h                                            | 35 (31.53)                | 57 (32.20)              |               |        |
| Preoperative Baseline Temperature               |                           |                         | 77.05         | <0.001 |
| $\leq 36.5$                                     | 24 (21.62)                | 132 (74.58)             |               |        |
| >36.5                                           | 87 (78.38)                | 45 (25.42)              |               |        |
| Calculus Type                                   |                           |                         | 17.71         | <0.001 |
| Renal calculi                                   | 54 (48.65)                | 129 (72.88)             |               |        |
| Ureteral calculi                                | 51 (45.95)                | 41 (23.16)              |               |        |
| Bladder calculi                                 | 6 (5.41)                  | 7 (3.95)                |               |        |
| Comorbidities                                   |                           |                         | -             | 0.439  |
| None                                            | 83 (74.77)                | 117 (66.10)             |               |        |
| Hypertension                                    | 21 (18.92)                | 46 (25.99)              |               |        |
| Diabetes mellitus                               | 5 (4.50)                  | 8 (4.52)                |               |        |
| Hypertension complicated with diabetes mellitus | 2 (1.80)                  | 6 (3.39)                |               |        |

Note: "-" represents Fisher's exact test

### 3.5. Univariate Analysis of Factors Affecting Intraoperative Hypothermia in Holmium Laser Lithotripsy

There were statistically significant differences between the

two groups in terms of anesthesia duration, intraoperative position change, operation duration, intraoperative irrigation fluid volume, total intraoperative fluid infusion volume, intraoperative fluid pre-warming, active use of warming measures, warming duration exceeding operation duration, and calculus type ( $P < 0.05$ ), as shown in Table 5.

**Table 5.** Comparison of Intraoperative Characteristics Between the Two Groups.

| Variables                                     | Non-hypothermia (n = 111) | Hypothermia (n = 177) | t/Z/ $\chi^2$ | P      |
|-----------------------------------------------|---------------------------|-----------------------|---------------|--------|
| Operating Room Temperature                    |                           |                       | 0.02          | 0.89   |
| ≤ 25°C                                        | 103 (92.79)               | 165 (93.22)           |               |        |
| > 25°C                                        | 8 (7.21)                  | 12 (6.78)             |               |        |
| Anesthesia Duration                           |                           |                       | 39.36         | <0.001 |
| ≤ 120 min                                     | 68 (61.26)                | 43 (24.29)            |               |        |
| > 120min                                      | 43 (38.74)                | 134 (75.71)           |               |        |
| Operation Duration                            |                           |                       | 32.00         | <0.001 |
| ≤ 120 min                                     | 102 (91.89)               | 109 (61.58)           |               |        |
| > 120min                                      | 9 (8.11)                  | 68 (38.42)            |               |        |
| Intraoperative Irrigation Fluid Volume        |                           |                       | 39.11         | <0.001 |
| ≤ 10000                                       | 107 (96.40)               | 114 (64.41)           |               |        |
| > 10000                                       | 4 (3.60)                  | 63 (35.59)            |               |        |
| Total Intraoperative Fluid Infusion Volume    |                           |                       | 16.85         | <0.001 |
| ≤ 1500                                        | 104 (93.69)               | 132 (74.58)           |               |        |
| > 1500                                        | 7 (6.31)                  | 45 (25.42)            |               |        |
| Intraoperative Fluid Pre-warming              |                           |                       | 8.34          | 0.004  |
| Yes                                           | 60 (54.05)                | 65 (36.72)            |               |        |
| No                                            | 51 (45.95)                | 112 (63.28)           |               |        |
| Active Use of Warming Measures                |                           |                       | 13.30         | <0.001 |
| Yes                                           | 74 (66.67)                | 79 (44.63)            |               |        |
| No                                            | 37 (33.33)                | 98 (55.37)            |               |        |
| Warming Duration Exceeding Operation Duration |                           |                       | 19.40         | <0.001 |
| Yes                                           | 69 (62.16)                | 63 (35.59)            |               |        |
| No                                            | 42 (37.84)                | 114 (64.41)           |               |        |
| Intraoperation Position Change                |                           |                       | 14.61         | <0.001 |
| Yes                                           | 10 (9.01)                 | 49 (27.68)            |               |        |
| No                                            | 101 (90.99)               | 128 (72.32)           |               |        |



### 3.6. Risk Factors for Intraoperative Hypothermia in Holmium Laser Lithotripsy: A Multivariate Analysis

The above 13 variables (age, gender, hemoglobin level, calculus type, preoperative baseline temperature, anesthesia duration, intraoperative position change, operation duration, intraoperative irrigation fluid volume, total intraoperative fluid infusion volume, intraoperative fluid pre-warming, active use

of warming measures, warming duration exceeding operation duration) were included in the multivariate Logistic regression analysis. The results showed that age (OR = 1.04, 95%CI: 1.01–1.07,  $P = 0.008$ ), preoperative baseline temperature  $> 36.5^{\circ}\text{C}$  (OR = 0.04, 95%CI: 0.02–0.10,  $P < 0.001$ ), anesthesia duration  $> 120$  min (OR = 3.45, 95%CI: 1.42–8.34,  $P = 0.006$ ) and intraoperative irrigation fluid volume  $> 10000$  mL (OR = 9.16, 95%CI: 2.13–39.45,  $P = 0.003$ ) were independent influencing factors for the occurrence of intraoperative hypothermia, as shown in Table 6.

**Table 6.** Multivariate Logistic Regression Analysis of Risk Factors for Intraoperative Hypothermia.

| Variables                                  | $\beta$ | S.E  | Z     | P        | OR (95%CI)           |
|--------------------------------------------|---------|------|-------|----------|----------------------|
| Intercept                                  | 2.30    | 2.30 | 1.00  | 0.319    | 9.94 (0.11 ~ 906.12) |
| Age                                        | 0.04    | 0.02 | 2.66  | 0.008    | 1.04 (1.01 ~ 1.07)   |
| Gender                                     |         |      |       |          |                      |
| Male                                       |         |      |       |          | 1.00 (Reference)     |
| Female                                     | 0.13    | 0.52 | 0.24  | 0.810    | 1.13 (0.41 ~ 3.14)   |
| Hemoglobin Level                           | -0.02   | 0.01 | -1.92 | 0.054    | 0.98 (0.95 ~ 1.00)   |
| Calculus Type                              |         |      |       |          |                      |
| Renal calculi                              |         |      |       |          | 1.00 (Reference)     |
| Ureteral calculi                           | -0.81   | 0.42 | -1.91 | 0.056    | 0.45 (0.19 ~ 1.02)   |
| Bladder calculi                            | -1.41   | 1.05 | -1.34 | 0.180    | 0.24 (0.03 ~ 1.92)   |
| Preoperative Baseline Temperature          |         |      |       |          |                      |
| $\leq 36.5$                                |         |      |       |          | 1.00 (Reference)     |
| $> 36.5$                                   | -3.12   | 0.43 | -7.25 | $<0.001$ | 0.04 (0.02 ~ 0.10)   |
| Anesthesia Duration                        |         |      |       |          |                      |
| $\leq 120$ min                             |         |      |       |          | 1.00 (Reference)     |
| $> 120$ min                                | 1.24    | 0.45 | 2.75  | 0.006    | 3.45 (1.42 ~ 8.34)   |
| Intraoperative Position Change             |         |      |       |          |                      |
| Yes                                        |         |      |       |          | 1.00 (Reference)     |
| No                                         | 0.01    | 0.65 | 0.02  | 0.987    | 1.01 (0.28 ~ 3.59)   |
| Operation Duration                         |         |      |       |          |                      |
| $\leq 120$ min                             |         |      |       |          | 1.00 (Reference)     |
| $> 120$ min                                | 0.70    | 0.66 | 1.06  | 0.287    | 2.01 (0.56 ~ 7.29)   |
| Intraoperative Irrigation Fluid Volume     |         |      |       |          |                      |
| $\leq 10000$                               |         |      |       |          | 1.00 (Reference)     |
| $> 10000$                                  | 2.22    | 0.74 | 2.97  | 0.003    | 9.16 (2.13 ~ 39.45)  |
| Total Intraoperative Fluid Infusion Volume |         |      |       |          |                      |
| $\leq 1500$                                |         |      |       |          | 1.00 (Reference)     |
| $> 1500$                                   | 0.59    | 0.66 | 0.89  | 0.375    | 1.80 (0.49 ~ 6.61)   |

| Variables                                     | $\beta$ | S.E  | Z    | P     | OR (95%CI)         |
|-----------------------------------------------|---------|------|------|-------|--------------------|
| Intraoperative Fluid Pre-warming              |         |      |      |       |                    |
| Yes                                           |         |      |      |       | 1.00 (Reference)   |
| No                                            | 0.37    | 0.43 | 0.85 | 0.395 | 1.44 (0.62 ~ 3.35) |
| Active Use of Warming Measures                |         |      |      |       |                    |
| Yes                                           |         |      |      |       | 1.00 (Reference)   |
| No                                            | 0.35    | 0.72 | 0.49 | 0.628 | 1.42 (0.34 ~ 5.86) |
| Warming Duration Exceeding Operation Duration |         |      |      |       |                    |
| Yes                                           |         |      |      |       | 1.00 (Reference)   |
| No                                            | 0.09    | 0.76 | 0.12 | 0.903 | 1.10 (0.25 ~ 4.82) |

OR: Odds Ratio, CI: Confidence Interval

## 4. Discussion

Normal body temperature is an essential prerequisite for maintaining regular physiological functions, resisting infections, and protecting organ tissues [31]. The occurrence of intraoperative hypothermia can lead to various adverse outcomes, such as abnormal coagulation function, increased risk of infection, delayed drug metabolism, and heightened cardiovascular burden [7]. During holmium laser lithotripsy, large volumes of irrigation fluid are used to ensure a clear surgical field and thorough flushing of stone debris. Meanwhile, due to nursing staff's insufficient awareness of intraoperative hypothermia prevention, irrigation fluid is typically used at room temperature, which further accelerates heat loss from the patient's body. This makes holmium laser lithotripsy particularly prone to inducing hypothermia [32], seriously compromising the quality of patients' postoperative recovery. Therefore, preventing intraoperative hypothermia during holmium laser lithotripsy is of great significance for safeguarding patients' safety during surgery.

A total of 288 patients undergoing holmium laser lithotripsy were enrolled in this study, among whom 177 cases developed hypothermia, resulting in an incidence rate of 61.46%. The analysis results indicated that gender, age, stone type, preoperative baseline temperature, hemoglobin level, intraoperative position change rate, anesthesia duration, surgical duration, intraoperative irrigation volume, intraoperative fluid infusion volume, and the current status of nursing interventions for intraoperative hypothermia were statistically significant factors ( $P < 0.05$ ). A detailed analysis is presented below.

### 4.1. The Impact of Patient Gender on Intraoperative Hypothermia During Holmium Laser Lithotripsy

Gender is a crucial biological variable that cannot be ignored in intraoperative temperature management. Due to differences in body composition, hormonal physiology, metabolic rate, and body size, female patients are more susceptible to hypothermia during the perioperative period. Lu Bin [33] demonstrated in his research that female gender and advanced age are independent risk factors for hypothermia before anesthesia induction, with an odds ratio (OR) of 1.353 for female patients ( $P = 0.011$ ). An OR value greater than 1 indicates that female patients face a higher risk of hypothermia. Therefore, in clinical practice, female patients should be automatically identified as a high-risk group for intraoperative hypothermia, and active warming protocols should be mandatory implemented.

### 4.2. The Impact of Patient Age on Intraoperative Hypothermia During Holmium Laser Lithotripsy

A comparison of general data between 178 patients with hypothermia and 110 patients without hypothermia showed that the average age of patients in the hypothermia group was over 50 years old, which was higher than that in the non-hypothermia group. The 2023 Chinese Expert Consensus on the Prevention and Treatment of Perioperative Hypothermia in Patients [27] also pointed out that patients aged over 60 years have a higher incidence of perioperative hypothermia and a longer postoperative temperature recovery time, which is consistent with the results of this study. This may be attributed to the decline in thermoregulatory function with increasing age. Ma Xiaomin [34] suggested in her research that as age increases, basal metabolic rate decreases, oxygen consumption

of the body reduces, vasoconstrictor response weakens, and heat production of the body is feedback inhibited. As a result, the older the patient, the weaker the ability to maintain core temperature, making them more prone to intraoperative hypothermia (body temperature  $< 36.0^{\circ}\text{C}$ ).

### 4.3. The Impact of Stone Type on Intraoperative Hypothermia During Holmium Laser Lithotripsy

The analysis of influencing factors for intraoperative hypothermia in 288 patients revealed that stone type is also one of the risk factors, especially kidney stones. Percutaneous nephrolithotomy (PCNL) is the primary surgical method for kidney stones due to their anatomical location. Studies have confirmed [35] that patients undergoing PCNL experience a significant decrease in intraoperative body temperature, which worsens with prolonged surgical duration. This surgical approach requires large volumes of irrigation fluid for flushing, cooling, and removing stone fragments, and the treatment of complex kidney stones often involves longer operation time, making kidney stones the type with the highest risk of hypothermia among the three major stone categories. Ureteral stones are mainly treated with ureteroscopic lithotripsy. Similar to kidney stone surgery, continuous perfusion of irrigation fluid is necessary to ensure a clear surgical field. Multiple studies have clearly indicated that the temperature of irrigation fluid is the most critical factor affecting the body temperature of patients undergoing ureteroscopic surgery. The use of irrigation fluid warmed to  $37^{\circ}\text{C}$  (body temperature) can effectively maintain stable intraoperative body temperature and reduce the incidence of hypothermia and postoperative shivering [36]. Compared with the above two types of lithotripsy, the risk of intraoperative hypothermia during bladder stone surgery is relatively lower, but vigilance against hypothermia is still required for complex cases [37].

### 4.4. The Impact of Surgical Duration on Intraoperative Hypothermia During Holmium Laser Lithotripsy

Jiang Jun [38] demonstrated in the construction of a predictive model for hypothermia after transurethral holmium laser enucleation of the prostate that surgical duration is one of the core risk factors for intraoperative hypothermia, which is consistent with the results of this study. On the one hand, during holmium laser lithotripsy, continuous perfusion of a large amount of room-temperature irrigation fluid is required to provide a clear surgical field and flush stone debris. The longer the surgical duration, the greater the total volume of low-temperature fluid flowing through the body cavity, resulting in more significant core heat loss [39]. On the other hand, improper laser settings or operation modes can reduce lithotripsy efficiency, indirectly leading to unnecessary prolongation of surgical time. This not only increases the contact time between

the body cavity and low-temperature irrigation fluid but may also cause local tissue temperature elevation, resulting in a complex condition characterized by concurrent systemic hypothermia and local hyperthermia [40]. In summary, surgical duration is a key modifiable risk factor for intraoperative hypothermia during holmium laser lithotripsy. By optimizing laser operation modes, improving irrigation efficiency, adopting new surgical instruments, and combining with conventional warming measures, the "effective surgical duration" can be shortened, thereby preventing systemic hypothermia while avoiding local thermal injury.

### 4.5. Preoperative Baseline Temperature and Intraoperative Hypothermia in Holmium Laser Lithotripsy

Body temperature is a core condition for maintaining normal vital activities of the human body; both abnormally high and low temperatures can exert adverse effects on the body. During surgery, under the influence of anesthetic drugs, the body's core heat is transferred to the periphery, leading to a decrease in core temperature. Meanwhile, anesthetic drugs inhibit the thermoregulatory center in the hypothalamus, resulting in reduced heat production capacity of the patient during surgery. When heat loss exceeds heat production, the body ultimately develops hypothermia. Ji Bin [41] indicated in the construction of a risk prediction model for intraoperative hypothermia in children that a certain level of preoperative heat reserve can effectively reduce the gradient between core and peripheral body temperature, thereby lowering the risk of hypothermia caused by heat redistribution. In addition, Cho et al. [42] confirmed in their study that preoperative body temperature  $\leq 36.8^{\circ}\text{C}$  is an independent risk factor for intraoperative hypothermia in patients. The research results of Hu [43] and Duan Lihuan [44] also support that preoperative body temperature is a risk factor for intraoperative hypothermia in patients, which is consistent with the results of this study. In conclusion, sufficient preoperative heat reserve, i.e., a higher baseline temperature, can effectively prevent the occurrence of intraoperative hypothermia.

### 4.6. The Impact of Hemoglobin Level on Intraoperative Hypothermia During Holmium Laser Lithotripsy

Hemoglobin is a key protein in red blood cells, primarily responsible for oxygen and carbon dioxide transport, and is involved in maintaining blood acid-base balance. It can reversibly bind to gas molecules to ensure normal oxygen supply and metabolism of human tissues. Patients with low hemoglobin levels have poor oxygen-carrying capacity of the body, and weak oxidative phosphorylation capacity of cell mitochondria, which in turn affects the heat production efficiency of the body. In this study, the hemoglobin level of patients in the hypothermia group was lower than that in the non-

hypothermia group, and multivariate regression analysis showed a statistically significant difference in the impact of hemoglobin level on intraoperative hypothermia between the two groups ( $P < 0.05$ ), indicating that hemoglobin level is also an independent risk factor for intraoperative hypothermia.

#### **4.7. The Impact of Anesthesia Duration on Intraoperative Hypothermia During Holmium Laser Lithotripsy**

For patients with urinary calculi undergoing holmium laser lithotripsy, the surgical duration varies depending on the location and size of the stones, which in turn leads to differences in anesthesia duration. A comparison of anesthesia duration between the hypothermia group and the non-hypothermia group in this study found that both anesthesia duration and surgical duration in the hypothermia group were longer than those in the non-hypothermia group. The average anesthesia duration in the hypothermia group was more than 2 hours, while that in the non-hypothermia group was less than 2 hours. Binary regression analysis showed a statistically significant difference in anesthesia duration between the two groups ( $P < 0.05$ ), indicating that anesthesia duration exceeding 2 hours is also an independent risk factor for intraoperative hypothermia, which is consistent with the results of Liang Bixin's study [45]. Jia Nan [46] proposed that anesthetic drugs mainly weaken the body's heat production and vasoconstriction capacity by inhibiting the hypothalamic thermoregulatory center. During surgery, a large area of the patient's body surface is exposed for disinfection, resulting in temperature loss. In addition, the longer the surgical duration, the longer the patient is exposed to the low-temperature environment (such as operating room air conditioning and irrigation fluid), further accelerating heat loss. At the same time, the inhibitory effect of anesthetic drugs leads to reduced heat production capacity of the body, disrupting the balance between heat production and heat loss, and ultimately causing hypothermia.

#### **4.8. Impact of Intraoperative Irrigation and Infusion Volume on Hypothermia in Holmium Laser Lithotripsy**

During holmium laser lithotripsy, large volumes of room-temperature irrigation fluid are used to maintain a clear surgical field, promote the discharge of stone fragments, and reduce thermal damage to body tissues caused by lithotripsy operations. Luo Wenxiang [47] pointed out in her study that the core mechanisms by which the extensive use of room-temperature irrigation fluid induces hypothermia during holmium laser lithotripsy are mainly "cold dilution" effect and heat loss. A large amount of room-temperature irrigation fluid flushes the surgical site during operation, directly absorbing heat from surrounding tissues and causing a sudden drop in local temperature. Meanwhile, the continuous flow of intraoperative irrigation fluid accelerates heat loss. If unheated intravenous

fluids are administered simultaneously, the "cold dilution" effect is further exacerbated, leading to the occurrence of intraoperative hypothermia in patients. Li Meichun [48] indicated in the analysis of influencing factors for hypothermia during acute intestinal obstruction surgery that intraoperative irrigation volume is an independent risk factor for intraoperative hypothermia in patients, which is consistent with the results of this study. Meanwhile, foreign studies have found [49] that the infusion of irrigation fluid below body temperature not only causes intraoperative temperature loss but also induces a series of adverse effects such as increased blood pressure, accelerated heart rate, shivering, and restlessness during surgery. In contrast, irrigation fluid close to body temperature ( $37^{\circ}\text{C}$ ) has no significant impact on blood pressure and heart rate, and can effectively avoid postoperative shivering and restlessness.

Intraoperative fluid infusion volume is a clear and critical factor leading to intraoperative hypothermia during holmium laser lithotripsy. It interacts with factors such as surgical duration and irrigation fluid temperature, but through distinct mechanisms. A large volume of infused fluid, especially unheated fluid, acts like an "internal coolant" and directly carries away core body heat. Studies have shown that for adults, each liter of fluid infused at ambient temperature or each unit of stored blood infused at  $5^{\circ}\text{C}$  reduces core body temperature by  $0.25\text{--}0.50^{\circ}\text{C}$  [50, 13], and the trend of temperature decrease becomes more pronounced with the increase of infused fluid volume [51]. This is the most primary and direct impact. At the same time, anesthetic drugs, especially general anesthetics, inhibit the hypothalamic thermoregulatory center and dilate peripheral blood vessels, increasing body heat loss [52, 53]. In the state of impaired thermoregulatory capacity caused by anesthesia, the infusion of a large amount of low-temperature fluid further exacerbates the decrease in body temperature. Therefore, intraoperative fluid infusion volume is controllable, and the key to its management lies in "warming". Clinically, combining fluid warming, body surface insulation, and optimized surgical operations to form a comprehensive temperature management plan can effectively reduce the occurrence of intraoperative hypothermia and maximize the protection of patient safety.

#### **4.9. The Impact of Intraoperative Position Changes on Intraoperative Hypothermia During Holmium Laser Lithotripsy**

For ureteroscopic holmium laser lithotripsy, the intraoperative position varies according to the size and location of the stones, with the lithotomy position being commonly used. For lower calyceal stones, which are difficult to access and treat, the position needs to be converted from the lithotomy position to the Trendelenburg position during surgery. This position adjustment creates and maintains a clear intrarenal operating environment through the action of gravity, facilitating lithotripsy and stone removal, and improving surgical success rate.

On the basis of impaired thermoregulatory function under anesthesia, the operation of position conversion disrupts the original thermal insulation balance. It causes a sharp increase in convective, radiative, and evaporative heat loss by suddenly exposing a large area of moist body surface to the low-temperature environment, combined with the reapplication and evaporation of cold disinfectant, as well as the destruction of the thermal insulation layer formed by surgical drapes. Meanwhile, the continuous use of low-temperature irrigation fluid and prolonged surgical duration further exacerbate this process.

#### 4.10. Impact of Nursing Interventions on Intraoperative Hypothermia

Studies have found [54] that perioperative hypothermia can be effectively prevented. However, Pan Juyan [55] found in a study on the implementation status of nursing interventions for intraoperative hypothermia among 352 nursing staff that only 46% of nursing staff actively adopted intraoperative warming measures, indicating that the implementation effect of nursing interventions for intraoperative hypothermia is not optimal. Zhao Mengjia [56] provided an explanation for this in her research, which is mainly related to nursing staff's cognitive status (awareness of the importance of basic nursing quality), self-efficacy (confidence in completing work, will and belief in learning and applying knowledge and skills), safety culture attitude (referring to a set of values, attitudes, and beliefs based on staff or life safety), and management status. She pointed out in her article that nursing staff's attitude towards basic nursing performance is affected by their awareness of the significance of nursing quality. Specifically, nursing staff with higher self-confidence and a full understanding of the meaning of basic nursing can better handle emergencies and fully devote themselves to their work. Meanwhile, nursing staff's safety culture attitude is closely related to nursing interventions for intraoperative hypothermia. Active promotion of safety culture should be carried out to enhance nursing staff's safety awareness, especially among junior and probationary nurses. Management status is also an independent risk factor affecting temperature nursing interventions. If personnel cannot be effectively and reasonably allocated, and outstanding staff are not selected for active training to enhance their independent learning awareness and ability, it will be difficult to effectively and proactively respond to emergencies.

### 5. Development of Preventive Measures for Intraoperative Hypothermia During Holmium Laser Lithotripsy

Based on the above risk factors, the following preventive measures are formulated:

#### 5.1. Preoperative Risk Assessment for Hypothermia

After confirming the surgical plan, the Self-Rating Anxiety Scale (SAS), a self-designed risk assessment scale for intraoperative hypothermia during holmium laser lithotripsy, and clinical data are used to conduct a comprehensive assessment of patients' age, nutritional status, laboratory indicators, and psychological state. Based on the assessment results, targeted preoperative, intraoperative, and postoperative intervention measures are formulated for physiological and psychological factors of high-risk patients, to ensure the smooth progress of surgery, reduce patients' postoperative discomfort, and improve the quality of postoperative recovery.

#### 5.2. Preoperative Interventions

- 1) Before surgery, one-on-one preoperative education is provided for patients with preoperative anxiety to alleviate their negative emotions, reduce the cold stimulation threshold caused by mental factors, and effectively prevent the adverse effects of surgical fear (such as increased blood pressure and accelerated heart rate). For patients with a long preoperative fasting and water deprivation time, especially more than 14 hours, who experience significant thirst, hunger, and anxiety, perioperative oral care (POC) nutritional therapy can be appropriately adopted to reduce preoperative discomfort.
- 2) For patients with low preoperative hemoglobin levels based on laboratory indicators, preoperative communication should be conducted with their attending physicians to reasonably adjust their diet, supplement key nutrients for hematopoiesis, and improve living habits. The specific plan should be adjusted according to individual conditions to lay a foundation for increasing preoperative hemoglobin levels.
- 3) For patients with a long expected surgical duration, irrigation fluid should be pre-warmed before surgery to match the patient's body temperature, reducing heat loss caused by the "cold dilution" effect.
- 4) For patients requiring general anesthesia, an individualized anesthesia plan should be formulated. The dosage of drugs with severe inhibitory side effects on central nervous system function should be strictly controlled, and sedative and analgesic drugs can be combined to enhance anesthetic effect and reduce intraoperative temperature decrease caused by anesthetic side effects.
- 5) For female patients over 60 years old, those scheduled to undergo percutaneous nephrolithotomy, and those with a preoperative temperature  $< 36.5^{\circ}\text{C}$ , preventive warming measures should be taken before surgery to prevent intraoperative heat loss.



### 5.3. Intraoperative Nursing Care

Intraoperative nursing care mainly focuses on heat preservation and reducing temperature loss, which can be achieved through two main approaches: active warming and passive warming.

- 1) Passive Warming: First, adjust the temperature and humidity of the operating room to an appropriate range (25–28°C). Minimize the exposed area of the patient's body during surgery without affecting the surgical operation; cover the patient with surgical drapes and cotton blankets during surgery to reduce heat loss and delay the decrease in body surface temperature. For patients with a large intraoperative fluid infusion volume, the fluid should be pre-warmed to maintain the patient's core temperature.
- 2) Active Warming: Prepare warming equipment such as warm air blowers and fluid warmers in advance. Monitor the patient's body temperature in real-time during surgery; for patients who have developed hypothermia, use warm air blowers or fluid warmers for heating to prevent further temperature loss. Meanwhile, communicate with anesthesiologists to determine whether additional sedative drugs should be administered to reduce the risk of intraoperative shivering.
- 3) Optimize Position Conversion Process: Minimize the time required for position conversion; prepare all necessary items before conversion to avoid prolonged waiting after conversion. During conversion, temporarily cover the exposed limbs with warm blankets. If re-disinfection is required, consider using warm disinfectant or quickly wipe off excess fluid with gauze. Continuously monitor body temperature during the conversion process to detect and manage hypothermia in a timely manner.

### 5.4. Postoperative Nursing Care

After surgery, patients are transferred to the post-anesthesia care unit (PACU), where real-time temperature monitoring and temperature management should be continued. If the patient's body temperature is still below 36°C after surgery, continuous warming measures should be implemented until the patient's body temperature returns to normal.

### 5.5. Improve the Current Status of Nursing Interventions for Intraoperative Hypothermia

- 1) Enhance the awareness of surgical nursing staff regarding intraoperative hypothermia prevention. Regular seminars on hypothermia identification, hazards, and prevention should be held for nursing staff to make up for their deficiencies in the knowledge, attitude, and practice (KAP) of hypothermia, strengthen their awareness of perioperative temperature management for patients,

achieve early identification and early prevention, and safeguard patients' safety during the perioperative period.

- 2) Operating room nursing staff are under considerable pressure and have a high probability of experiencing occupational burnout. Therefore, it is of great significance to create a relaxed and pleasant working environment for nursing staff, improve their mindset, enable them to face patients with a smile, actively engage in nursing work, and improve the quality of nursing care.
- 3) Hospitals should attach great importance to patient safety and management work, and strengthen the promotion of safety culture, which is conducive to enhancing nursing staff's safety awareness and providing a guarantee for patient safety.

## 6. Limitations

This study has certain limitations. 1) This is a small-sample, single-center study. Whether the statistically significant variables in the study results are independent risk factors for intraoperative hypothermia during holmium laser lithotripsy still needs to be verified by multi-center, large-sample clinical studies. 2) The subjects included in this study are patients undergoing holmium laser lithotripsy, which may be subject to selection bias and confounding factors.

In conclusion, gender, age, stone type, preoperative baseline temperature, hemoglobin level, intraoperative position change rate, anesthesia duration, surgical duration, intraoperative irrigation volume, intraoperative fluid infusion volume, and the current status of nursing interventions for intraoperative hypothermia can all increase the risk of intraoperative hypothermia in patients undergoing holmium laser lithotripsy and affect the quality of prognostic recovery. Therefore, in actual surgical practice, intraoperative temperature management for relevant high-risk groups should be strengthened, and corresponding warming measures should be taken to prevent the occurrence of intraoperative hypothermia, which is of great significance for ensuring patients' perioperative safety.

## Abbreviations

|      |                                         |
|------|-----------------------------------------|
| KAP  | Knowledge Attitude and Practice         |
| BMI  | Body Mass Index                         |
| ASA  | American Society of Anesthesiologists   |
| CNKI | China National Knowledge Infrastructure |
| CBM  | China Biomedical Literature Database    |
| PCNL | Percutaneous Nephrolithotomy            |
| SAS  | Self-Rating Anxiety Scale               |
| POC  | Perioperative Oral Care                 |
| PACU | Post Anesthesia Care Unit               |
| DM   | Diabetes Mellitus                       |
| Hb   | Hemoglobin                              |
| SBP  | Systolic Blood Pressure                 |

## Conflicts of Interest

The authors declare no conflicts of interest.

## Appendix

**Table A1.** Case Report Form for Intraoperative Hypothermia During Holmium Laser Lithotripsy.

| General Patient Information                                        |                                         |                                            |                                           |                                              |
|--------------------------------------------------------------------|-----------------------------------------|--------------------------------------------|-------------------------------------------|----------------------------------------------|
| Gender                                                             | Male <input type="checkbox"/>           |                                            | Female <input type="checkbox"/>           |                                              |
| Age (years)                                                        | (                                       |                                            | )                                         |                                              |
| Body Mass Index (kg/m <sup>2</sup> )                               | <18.5 <input type="checkbox"/>          | 18.5-24.9 <input type="checkbox"/>         | 25-29.9 <input type="checkbox"/>          | ≥30 <input type="checkbox"/>                 |
| Duration of Fasting and NPO Before Admission to Operating Room (h) | <10 <input type="checkbox"/>            | 10-15 <input type="checkbox"/>             | >15 <input type="checkbox"/>              |                                              |
| Comorbidities                                                      | None <input type="checkbox"/>           | Hypertension <input type="checkbox"/>      | DM <input type="checkbox"/>               | Hypertension and DM <input type="checkbox"/> |
| Preoperative Heart Rate (beats/min)                                | (                                       |                                            | )                                         |                                              |
| Preoperative Baseline Body Temperature (°C)                        | ≤36.5 <input type="checkbox"/>          |                                            | >36.5 <input type="checkbox"/>            |                                              |
| Hb Level (g/L)                                                     | (                                       |                                            | )                                         |                                              |
| Calculus Type                                                      | Renal Calculus <input type="checkbox"/> | Ureteral Calculus <input type="checkbox"/> | Bladder Calculus <input type="checkbox"/> |                                              |
| Preop SBP (mmHg)                                                   | (                                       |                                            | )                                         |                                              |
| Intraoperative Monitoring Indicators (Operating Room)              |                                         |                                            |                                           |                                              |
| Operating Room Temperature (°C)                                    | ≤25 <input type="checkbox"/>            |                                            | >25 <input type="checkbox"/>              |                                              |
| Anesthesia Duration (min)                                          | ≤120 <input type="checkbox"/>           |                                            | >120 <input type="checkbox"/>             |                                              |
| Intraoperative Position Change                                     | YES <input type="checkbox"/>            |                                            | NO <input type="checkbox"/>               |                                              |
| Surgical Time (min)                                                | ≤120 <input type="checkbox"/>           |                                            | >120 <input type="checkbox"/>             |                                              |
| Intraoperative Irrigation Fluid Volume (mL)                        | ≤10000 <input type="checkbox"/>         |                                            | >10000 <input type="checkbox"/>           |                                              |
| Total Intraoperative Fluid Infusion Volume (mL)                    | ≤1500 <input type="checkbox"/>          |                                            | >1500 <input type="checkbox"/>            |                                              |
| Intraoperative Nursing Intervention Status                         |                                         |                                            |                                           |                                              |
| Pre-warming of Irrigation Fluid                                    | Yes <input type="checkbox"/>            |                                            | No <input type="checkbox"/>               |                                              |
| Patient Intraoperative Warming                                     | Yes <input type="checkbox"/>            |                                            | No <input type="checkbox"/>               |                                              |
| Warming Duration Exceeding Surgical Time                           | Yes <input type="checkbox"/>            |                                            | No <input type="checkbox"/>               |                                              |

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