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Adverse Effects of Intraoperative Hypothermia on Patients with Urolithiasis Undergoing Flexible Ureteroscopic Holmium Laser Lithotripsy under General Anesthesia

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Abstract: *Impact of Intraoperative Hypothermia on Outcomes of Flexible Ureteroscopic Holmium Laser Lithotripsy under General Anesthesia in Urolithiasis Patients. A cohort of 86 patients undergoing flexible ureteroscopic holmium laser lithotripsy (FURSL) in the Surgical Suite of Xijing Hospital between September 2024 and March 2025 were enrolled. Patients were stratified into hypothermic (core temperature <36℃, n=60) and non-hypothermic groups (n=26) based on intraoperative hypothermia occurrence. Comparison of basic surgical indicators between the two patient groups: Intraoperative blood loss, Time to extubation (from discontinuation of anesthetic agents to tracheal extubation), Operating room time, Post-anesthesia care unit (PACU) length of stay / PACU stay duration, Hospital length of stay / Duration of hospitalization, Steward score (in general anesthesia patients);Incidence of postoperative adverse reactions including shivering, agitation, and postoperative nausea and vomiting (PONV). The hypothermia group exhibited significantly higher values than the non-hypothermia group for intraoperative blood loss, time to extubation, operating room time, PACU stay duration, and hospital length of stay. Statistically significant differences (P<0.05) were particularly observed in time to extubation, operating room time, and PACU stay duration. The hypothermia group demonstrated significantly higher incidence rates of shivering, agitation, and postoperative nausea and vomiting (PONV) compared to the non-hypothermia group. Statistically significant differences (P<0.05) were observed specifically in shivering and agitation incidence rates. In patients undergoing ureteroscopic holmium laser lithotripsy under general anesthesia, the occurrence of intraoperative hypothermia exerts significant perioperative implications. This condition conflicts with the principles of Enhanced Recovery After Surgery (ERAS). Consequently, implementing rigorous intraoperative warming protocols and optimizing thermal care interventions are imperative to prevent hypothermia, thereby safeguarding postoperative recovery efficacy.*

Keywords: *Intraoperative hypothermia, Holmium laser lithotripsy, Adverse effects*

1. Introduction

Urinary calculi are one of the most common diseases in urology, with a relatively high global incidence rate that varies slightly from region to region, ranging from 1% to 13%[1]. According to epidemiological data, the incidence rate of urinary calculi among Chinese adults is approximately 10%, with a higher rate in the south. In the northern region, the incidence of urolithiasis is higher in men than in women [2], and it shows an increasing trend year by year [3]. Currently, the main clinical treatment method is holmium laser lithotripsy. This procedure has a shorter operation time and a higher stone clearance rate, and is considered the gold standard for laser treatment of urinary calculi [4]. During flexible ureteroscopic holmium laser lithotripsy, a large amount of irrigation fluid is required for flushing, which is more likely to cause changes in body temperature. When the core body temperature of a surgical patient drops below 36 ℃ due to non-medical planning, it is called inadvertent perioperative hypothermia (IPH) [5]. Numerous studies have shown that once IPH occurs during surgery, it can cause serious harm to patients, including damage to the circulatory system such as decreased heart rate and cardiac output, coagulation disorders such as reduced platelet and coagulation factor activity, and central nervous system and cognitive dysfunction [6]; it increases the rate of incision infection, thereby prolonging the

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observation and hospital stay of patients [7], which is not conducive to rapid recovery. However, there are no relevant studies in China on the adverse effects of intraoperative hypothermia on patients undergoing flexible ureteroscopic holmium laser lithotripsy under general anesthesia. Therefore, this article analyzes the adverse effects of intraoperative hypothermia on patients undergoing flexible ureteroscopic holmium laser lithotripsy under general anesthesia, and then guides the preoperative body temperature care plan to reduce the incidence of postoperative adverse reactions and improve the postoperative quality of life of patients.

2. Materials and methods

2.1 General information

A total of 86 patients who underwent flexible ureteroscopic holmium laser lithotripsy in the surgical department of Xijing Hospital from September 2024 to March 2025 were selected as the research subjects. In the hypothermia group, there were 41 males and 19 females, with an age range of 21 to 72 years (49.07 ±12.01 years), including 38 cases of kidney stones, 19 cases of ureteral stones, and 3 cases of bladder stones. In the non-hypothermia group, there were 21 males and 5 females, with an age range of 20 to 74 years (43.46 ±12.05 years), including 19 cases of kidney stones and 7 cases of ureteral stones. There was no statistically significant difference in the general data between the two groups ($P > 0.05$) (see Table 1). This study was approved by the hospital's ethics committee.

Inclusion criteria:①All patients met the diagnostic and treatment guidelines for urological and andrological diseases in China (2022 Edition) for urinary system diseases.Diagnostic criteria for calculi:②All patients met the relevant diagnostic criteria for flexible ureteroscopy (F-URS) for urinary calculi as stipulated in the "Chinese Expert Consensus on Flexible Ureteroscopy";③Patients were aged 18 years or older and had a core body temperature ranging from 36℃ to 37.5℃ before surgery; ④Patients underwent elective surgery;⑤All patients had complete general information.

Exclusion criteria: ① Patients with severe abnormalities in cardiac and pulmonary function or liver and kidney function; ② Patients with a history of mental illness who were unable to communicate normally; ③ Patients with abnormal body temperature before surgery; ④ Patients with a history of hypothyroidism or hyperthyroidism; ⑤ Patients who underwent planned hypothermia during the operation.

2.2 Method

2.2.1 Measurement methods for intraoperative hypothermia and criteria for diagnosing hypothermia

All patients underwent flexible ureteroscopy with holmium laser lithotripsy. No planned cooling was performed during the operation, and all the fluids administered were at room temperature without any warming measures. In this study, nasopharyngeal temperature monitoring was adopted for patients under general anesthesia. However, nasopharyngeal temperature measurement requires a certain insertion depth, which may cause discomfort to conscious patients. Therefore, for patients under spinal anesthesia or with nasal abnormalities, axillary temperature patches were uniformly used for temperature monitoring. The core temperatures of the patients were recorded at the time of entering the operating room, the start of anesthesia, the start of the operation, and every 15 minutes after the operation until the end of the operation. Patients with core temperatures < 36℃ at any time point from entering the operating room to the end of the operation were included in the hypothermia group.

2.2.2 Data collection methods

The general information of the patients was obtained through the electronic medical record system, and the basic surgical indicators and postoperative adverse reactions were recorded by the researchers on-site.

2.2.3 Evaluation indicators

There are six basic surgical indicators: ① Intraoperative blood loss (the difference between the input and output of intraoperative irrigation fluid). ② Postoperative extubation time (the time difference from the cessation of anesthetic drugs to the removal of the tracheal tube), with extubation criteria being that the patient is fully awake, can understand questions and respond to calls, such as opening eyes, raising hands, and opening mouth; the patient's ventilation volume is normal, with regular spontaneous breathing at a rate of more than 12 times per minute and a tidal volume of > 6 mL/kg; the patient's blood oxygen

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saturation is above 90% (while breathing air); the patient's muscle tone is normal, breathing is stable, and the swallowing reflex is active, or there is a significant choking cough response when suctioning [8]. ③ Time spent in and out of the operating room. ④ Observation time in the post-anesthesia care unit. ⑤ Hospital stay. ⑥ Steward score for general anesthesia patients [9] (this score has three dimensions, with a total score of 6 points: 1. Degree of consciousness 0-2 points; 2. Degree of airway patency 0-2 points; 3. Degree of limb mobility 0-2 points, the higher the score, the better the quality of the patient's recovery); postoperative adverse reaction indicators include shivering, restlessness, and nausea and vomiting. Among them, shivering is classified using the Wrench grading system [10] (divided into four grades: 0 grade, no shivering; 1 grade, piloerection or peripheral vasoconstriction but no muscle tremor; 2 grade, muscle tremor in only one group of muscle; 3 grade, muscle tremor in more than one group but not the whole body; 4 grade, muscle tremor throughout the body), and in this study, patients reaching grade 2 or above are considered to have shivering. Restlessness is evaluated using the restlessness scoring system in the RASS score [11] (divided into five levels, ranging from 0 to +4, the higher the score, the poorer the quality of the patient's recovery), and in this study, patients with a score greater than 0 are considered to have restlessness.

2.2.4 Statistic analysis

Data were processed using SPSS 27.0. The K-S test was used to verify the normality of the data, and all data were found to be normally distributed. Therefore, gender and underlying diseases in the general information were expressed as cases, and the comparison between groups was conducted using the $\chi2$ test or Fisher's exact probability method. Age and BMI were expressed as mean ± standard deviation, and the comparison between groups was performed using the t-test. Perioperative indicators such as intraoperative blood loss, extubation time, time spent in the operating room, observation time, and hospital stay were expressed as mean ± standard deviation, and the comparison between groups was conducted using the t-test. The Steward score and the incidence of postoperative adverse events in the perioperative indicators were expressed as cases and percentages, and the differences between groups were compared using the $\chi2$ test or Fisher's exact probability method.

3. Results

3.1 Comparison of general data of the two groups of patients

There were no statistically significant differences in gender, age, BMI and underlying diseases between the two groups ($P > 0.05$). The results are shown in Table 1.

Table 1 Comparison of General Data of the Two Groups of Patients (n=86)

Group	number of cases	(Male/Famale)/Example	Age/($\bar{X}$±S,years)	BMI/($\bar{X}$±S, kg/m²)	UnderlyingDiseases(None/ Hypertension/Diabetes/ Hypertension and Diabetes)
Hypothermia	60	41/19	49.07±12.01	24.14±3.35	38/16/5/1
Non-hypothermia	26	21/5	43.46±12.05	25.63±3.95	18/6/2/0
$\chi2$/t value		1.394	1.986	-1.793	0.631
P value		0.238	0.050	0.077	0.889

3.2 Comparison of basic surgical indicators between the two groups of patients

As shown in Table 2, the intraoperative blood loss, postoperative extubation time, time spent in the operating room, observation time, and hospital stay of patients in the hypothermia group were all longer than those of patients in the non-hypothermia group. Among them, the differences in two groups were statistically significant ($P < 0.05$). The Steward score is used to evaluate the quality of postoperative awakening, with a higher score indicating better awakening quality. In the statistical analysis of Steward scores for the two groups of patients, only two values, 5 and 6, were observed. From the analysis of Table 2, it can be seen that the proportion of patients with a score of 5 in the hypothermia group was higher than that in the non-hypothermia group, but the difference in Steward scores between the two groups was not statistically significant ($P > 0.05$).

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Table 2 Comparison of perioperative indicators between the two groups of patients (n = 86)

Project	Non-low-temperature group	Low-temperature group	χ2(t)value	P value
Intraoperative blood loss($\bar{X}\pm S$, mL)	4.58±1.88	8.05±14.17	1.241	0.218
Duration of extubation($\bar{X}\pm S$, min)	9.12±4.00	11.88±4.85	2.553	0.012
Duration of entering and leaving the operating room($\bar{X}\pm S$, min)	132.69±33.95	161.25±53.19	2.986	0.004
Obeservation duration($\bar{X}\pm S$, min)	37.65±10.95	47.58±15.654	2.934	0.004
Length of hospital stay($\bar{X}\pm S$, days)	5.38±2.06	6.33±2.07	1.953	0.054

3.3 Comparison of postoperative adverse reaction indicators between the two groups of patients

As shown in Table 3, the incidence of shivering, restlessness, and postoperative nausea and vomiting in the hypothermia group was higher than that in the non-hypothermia group. Among them, the differences in the rates of shivering and restlessness between the two groups were statistically significant ($P < 0.05$). However, there was no significant difference in the incidence of postoperative nausea and vomiting between the hypothermia group and the non-hypothermia group ($P > 0.05$).

Table 3 Comparison of postoperative adverse indicators between the two groups of patients (n = 86)

Group	number of cases	Chill rate(%)	Restlessness rate(%)	Postoperative Nausea and Vomiting rate(%)
Non-hypothermia	26	4(7.69)	3(11.54)	2(7.69)
Hypothermia	60	22(25.00)	19(31.67)	10(16.67)
χ2 value		3.895	3.860	1.217
P value		0.048	0.049	0.270

4. Discussion

With the continuous development of technology and medical techniques, good news has come for patients with urinary calculi. The treatment of urinary calculi is becoming increasingly refined and minimally invasive. Doctors will formulate surgical methods for patients with urinary calculi based on the location and size of the calculi. Among them, the two most common minimally invasive surgical methods are flexible ureteroscopic holmium laser lithotripsy and percutaneous nephrolithotomy. Flexible ureteroscopic holmium laser lithotripsy, which enters the body through natural channels for lithotripsy, conforms to the physiological anatomy of the human body, causes less trauma to the patient, has less postoperative pain and a significant lithotripsy effect[12], and has been widely recognized by the public. Although flexible ureteroscopic holmium laser lithotripsy causes less trauma to the patient, minimally invasive surgery still has a certain degree of invasiveness. Different degrees of emergency situations may occur during the perioperative period, which may affect the postoperative recovery of the patient[13]. Ren Shuxia [14] pointed out in her article that patients undergoing flexible ureteroscopic holmium laser lithotripsy are prone to hypothermia during the operation, with the body temperature dropping below 36°C. The causes of hypothermia include patient-related factors (such as age, individual constitution, and psychological factors), the use of anesthetic drugs, the temperature and humidity of the operating room, the duration of the operation, the continuous exposure of the surgical site, and the use of a large amount of irrigation fluid at a temperature lower than body temperature. During the operation, a large amount of unheated irrigation fluid is used to keep the surgical field clear and thoroughly flush away the stone debris. The irrigation fluid at room temperature can significantly increase the loss of body heat, causing a "cold dilution" effect. As the operation progresses, the loss of body heat gradually increases, eventually leading to hypothermia[15]. Li Y [16] also indicated in his article that the use of a large amount of irrigation fluid at room temperature is the main cause of perioperative hypothermia. Perioperative hypothermia can cause certain harm to the patient's physical and mental health. Intraoperative hypothermia can increase oxygen consumption and cardiovascular blood supply, damage the immune regulatory function, aggravate the body's stress response, cause an increase in HR and MAP, and increase the risk of shivering and restlessness. Therefore, the harm caused by intraoperative hypothermia in patients undergoing flexible ureteroscopic holmium laser lithotripsy cannot be underestimated, and clinical preventive work is urgently needed.

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This study investigated perioperative indicators in two groups of patients and found that the intraoperative blood loss, extubation time, time spent in the operating room, observation time, and hospital stay of patients in the hypothermia group were all longer than those in the non-hypothermia group. Among them, the differences in extubation time, time spent in the operating room, and observation time between the hypothermia group and the non-hypothermia group were statistically significant ($P < 0.05$). The specific analysis is as follows:

4.1 The influence of intraoperative hypothermia on intraoperative blood loss

The possible explanation for the increased intraoperative blood loss in the hypothermia group is that hypothermia can damage the coagulation system, impair the function of thrombin, and also affect platelet aggregation, thereby increasing the patient's bleeding tendency and blood loss. Foreign scholar Rajagopalan [17] pointed out that even mild hypothermia (34℃ - 36℃) can increase blood loss by 16% and the relative risk of blood transfusion by 22%. Domestic scholar Kong Shan [18] et al. found that intraoperative blood loss is positively correlated with hypothermia. Intraoperative bleeding can affect the patient's blood circulation, leading to fluid loss and further affecting the body's temperature regulation system. The more blood loss, the more severe the decrease in hemoglobin concentration, which inhibits blood oxygen transport and leads to abnormal body temperature regulation.

4.2 The impact of intraoperative hypothermia on extubation time and time spent in the operating room

The extubation time is measured from the moment when the patient stops using anesthetic drugs until the extubation is completed. It is positively correlated with the time the patient spends in and out of the operating room. The extubation time and the time spent in and out of the operating room in the hypothermia group were both longer than those in the non-hypothermia group. This might be related to the fact that excessively low body temperature alters the pharmacokinetics of drugs. Ruetzler [19] indicated that hypothermia impairs the activity of enzymes, thereby reducing and slowing down metabolism and prolonging the effects of various drugs used for induction or maintenance of anesthesia, leading to delayed awakening and thus extending the time the patient spends in and out of the operating room.

4.3 The impact of intraoperative hypothermia on the length of stay in the post-anesthesia care unit and hospital stay

Relevant studies have shown that perioperative hypothermia is associated with an increased incidence of infectious complications. Even mild perioperative hypothermia has been proven to be an important and independent risk factor for surgical wound infection, with a relative risk of 6.3 [20]. The consequences of perioperative hypothermia result in longer stays in the post-anesthesia care unit (PACU) and hospital, as well as increased perioperative costs [21] [22].

4.4 The influence of intraoperative hypothermia on the postoperative shivering rate and restlessness rate

Hypothermia stimulates the body to produce shivering reactions to increase heat production, indicating that patients who experience hypothermia during surgery are more likely to have chills after surgery. This is consistent with the finding in this study that the incidence of chills in the hypothermia group was higher than that in the non-hypothermia group. Chills not only cause discomfort to the patient but also increase oxygen consumption and carbon dioxide production in the body, placing a certain burden on the respiratory system. The patient's respiratory function is affected to some extent, leading to hypoxia, which in turn causes postoperative restlessness and anxiety. This explains why the incidence of postoperative restlessness in the hypothermia group was higher than that in the non-hypothermia group in this study. The difference in the incidence of chills and restlessness between the hypothermia group and the non-hypothermia group in this study was statistically significant ($P < 0.05$).

5. Limitation

This study has certain limitations. Firstly, it is based on the data of 86 patients who underwent flexible ureteroscopy with holmium laser lithotripsy, which is a relatively small sample size. Secondly, the collected patient data do not include follow-up records after the patients returned to their wards and after discharge.After returning to the ward, we have no information on whether the patient's threshold for feeling cold has increased, whether postoperative shivering and restlessness will continue to occur and how often, or whether there has been any infection. The long-term impact of intraoperative hypothermia on patients is also one of the postoperative adverse effects that we should pay attention to and study.

6. Conclusion

A total of 86 subjects were included in this study, among which 60 were in the hypothermia group, with an incidence of hypothermia of approximately 70%. In summary, intraoperative perioperative hypothermia (IPH) is a common complication during flexible ureteroscopic holmium laser lithotripsy, and it is associated with increased intraoperative blood loss, prolonged postoperative catheter removal time, prolonged post-anesthesia care unit stay, and prolonged hospital stay. It also contributes to an increase in postoperative shivering and restlessness. Therefore, temperature management before, during, and after the operation for patients undergoing this procedure is of critical importance. Enhancing medical staff's awareness of perioperative hypothermia, using precise instruments for continuous temperature measurement, and actively warming the body surface before anesthesia induction and during the operation are crucial for maintaining normal body temperature during the perioperative period and reducing the risk of perioperative hypothermia. At the same time, temperature management should be standardized, and personalized preventive measures should be taken based on patient requirements and the availability of local medical equipment and environmental conditions.

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