J Anesth (2015) 29:165–169
DOI 10.1007/s00540-014-1888-5

ORIGINAL ARTICLE

A prospective randomized double-blind study on the effects of the temperature of irrigation solutions on thermoregulation and postoperative complications in percutaneous nephrolithotomy

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Received: 11 April 2014 / Accepted: 7 July 2014 / Published online: 18 July 2014

Abstract

Purpose This study investigated the effects of irrigation solutions, administered at either 21 or 37 °C in percutaneous nephrolithotomy (PCNL), on hypothermia and related postoperative complications such as late emergence and late recovery from anesthesia, shivering, lactic acidosis, and excess bleeding.

Methods Sixty patients who were scheduled for PCNL were enrolled in this prospective randomized double-blind study. Irrigation solutions at room temperature were administered to patients in group R (30 patients), and warmed irrigation solutions were administered to patients in group W (30 patients). The two groups were compared for core and peripheral body temperature, incidence of hypothermia, duration of emergence from anesthesia, duration of recovery from anesthesia, shivering, lactic acidosis, and hemoglobin levels.

Results Hypothermia was incident in 19 patients (63.3 %) in group W and in 27 patients (90 %) in group R at the end of surgery. The difference between the initial and the final core body temperature was 0.9 ± 0.6 °C group W and 1.4 ± 0.7 °C in group R ($p = 0.003$). The extubation time was 4.4 ± 2.2 min in group W and 5.9 ± 3 min in group R ($p = 0.032$). Shivering was detected in seven patients (23.3 %) in group W and in 15 patients (50 %) in group R ($p = 0.032$). The recovery duration was 49.8 ± 24.6 min in group W and 67.6 ± 33.9 min in group R ($p = 0.023$).

Conclusions Administration of irrigation solutions at room temperature in PCNL operations causes the body temperature to decrease significantly, which results in postoperative complications such as late emergence from anesthesia, late recovery from anesthesia, and shivering.

Keywords Thermoregulation · Irrigation solutions · Percutaneous nephrolithotomy

Introduction

Hypothermia is a common perioperative complication, and its cause is multifactorial. There are a series of complications and adverse effects related to hypothermia; i.e., cardiac arrhythmias and ischemia, reduced drug metabolism, late emergence and late recovery from anesthesia, mental state changes, impaired renal function, impaired wound healing, elevated infection rates, bleeding disorders, shivering, elevated oxygen consumption, impaired peripheral circulation, hypercarbia, hypoxia, and lactic acidosis [1–5]. Because of these critical complications, all necessary precautions should be considered and meticulously applied when appropriate to avoid hypothermia. Despite active and passive warming methods being used in the operating room, hypothermia incidence may be elevated in relation to the duration of anesthesia and the site and extent of surgery [5]. A decrease of 2–6 °C in core body temperature is almost always noted in patients undergoing surgery under general anesthesia [2].

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Percutaneous nephrolithotomy (PCNL) carries a high risk of hypothermia, because of long anesthesia durations, and the characteristics of the surgery [6]. Loss of heat is promoted by factors such as repositioning of the patient after anesthesia induction and difficulties to deploy warmers because of the surgery site. Administration of excessive amounts of irrigation fluids may contribute to heat loss. Studies of surgical procedures in which irrigation fluids are administered have produced conflicting results regarding whether irrigation fluids increase the risk of hypothermia [4–9].

In this study, we analyzed whether administration of irrigation fluids in PCNL at room temperature (21 °C) or at body temperature (37 °C) contributes to hypothermia. Along with this, we studied the effects of administration of irrigation fluids on late emergence from anesthesia, late recovery from anesthesia, shivering, lactic acidosis, and excess bleeding, which are complications related to hypothermia that may occur.

Methods

This study was conducted via the principles of the Helsinki Declaration following the approval of the Izmir Tepecik Training and Research Hospital Institutional Research Board (January 16, 2013; decision no. 10). Sixty patients aged between 20 and 60 years with an American Society of Anesthesiologists physical status of 1 or 2 and with a BMI of 18.5–30 kg/m^2 undergoing PCNL were enrolled in this prospective randomized double-blind study. All patients were informed thoroughly about the procedures, and signed written consent was obtained.

Two groups of 30 patients were formed by simple randomization (with table generation by single die and double dice rolls). Irrigation fluids at room temperature were infused into patients in group R, and warmed irrigation fluids were infused into patients in group W. Warming of the irrigation fluid was provided by another anesthesiologist owing to the randomized double-blind nature of the study. Follow-up medical records were filled in by the anesthesiologist in charge of the patient; the anesthesiologist was not aware of the patient group.

All patients received 0.05 mg/kg midazolam, and a lactated Ringer's solution (100 ml/h) infusion at room temperature was initiated in the preoperative holding room via an intravenous catheter. No active heating measures were applied prior to surgery. The waiting times in the preoperative holding room were recorded. Pulse oximetry, noninvasive blood pressure monitoring, and electrocardiography were performed in the operating room. Anesthesia induction was implemented with 5 mg/kg thiopental sodium, 0.1 mg/kg vecuronium, and 1 mg/kg fentanyl. Maintenance was achieved with 1–2 % sevoflurane and infusion of remifentanil at 0.05–0.2 µg/kg per minute, and 1–2 mg vecuronium was added whenever necessary.

The amounts of intravenous fluid to be infused intraoperatively were calculated for each patient according to the preoperative fasting period and the patient's weight. Lactated Ringer's solution warmed to 37 °C (Astoflo Plus; Stihler Electronic, Stuttgart, Germany) was used for intravenous hydration. After the patient had been placed in the prone position, active warming was applied to body parts superior to the surgical site with the help of a warm air blanket (WarmAir, model 135; Cincinnati Sub-Zero, Cincinnati, OH, USA) at a temperature of 43.3 °C. The operating room temperature was maintained at 21 °C at all times. All patients received 1 g acetaminophen intravenously and 1 mg/kg tramadol hydrochloride for postoperative analgesia, approximately 30 min before surgery ended. After surgery had ended, patients were placed in the supine position, and administration of sevoflurane and remifentanil was stopped. Following the initiation of spontaneous respiratory activity, patients received 0.5 mg atropine and 1 mg neostigmine to reverse the effects of vecuronium. The extubation eligibility criterion was the presence of a tidal volume of 6 ml/kg or more without pressure support. Patients were moved to a postanesthesia care unit (PACU) following extubation. The time interval from the end of anesthesia maintenance until extubation was recorded.

Dermal temperature probes were planted to measure peripheral temperature. A dermal probe was placed 2 cm inferior to the right mid-clavicular point. A 4 cm × 4 cm polystyrene foam block with a thickness of 2 cm was placed on the temperature probe as insulation from the heat generated by the warm air blanket. Esophageal temperature probes were planted immediately after anesthesia induction to measure core temperature. The probe was advanced 30–35 cm until it reached the lower third of the esophagus, and it was confirmed visually that it was not in the mouth. Measurements were made after intubation and before extubation. Temperature measurements were performed with same temperature probes and monitor. Core body temperatures between 34 and 36 °C were defined as mild hypothermia, and core body temperatures between 32 and 33.9 °C were defined as moderate hypothermia [1, 9].

The patients' lactate levels were measured and recorded by spot blood gas analyses following induction of anesthesia and immediately before extubation. Preoperative and postoperative hemoglobin levels were measured and recorded via total blood count.

On some occasions, there may be a need for rapid infusion of fluids, and because this could have led to inadequate warming, irrigation fluids were warmed to 37 °C in an autoclave before initiation of the procedure.

Whenever fluids were administered to a patient, fluid lines were warmed with a fluid line warmer (Astoflo Plus; Stihler Electronic, Stuttgart, Germany) to avoid cooling. For fluids infused at room temperature, the fluid lines were also attached to a fluid line warmer, but the warmer was not activated. Isotonic serum (0.9 %) was used as irrigation fluid in both groups, and procedures were performed at the same irrigation pressures (50 cmH_2O). PCNL was performed by the same surgeon for all 60 patients. The surgical time and the amount of irrigation fluid used were recorded. Surgical procedures were performed with the patient in the prone position following the placement of a 6-Fr open-ended ureteral catheter with the patient in the lithotomy position. Puncture was performed under the 12th rib with an 18-Fr puncture needle, and a 0.035-in. soft-tip guidewire (Sensor; Boston Scientific, Natick, MA, USA) was advanced. Dilatation was achieved with an Amplatz-type dilator over a guidewire as much as 30 Fr, and a sheath was placed. A 22-Fr nephroscope (Karl Storz, Tuttlingen, Germany) was advanced through the sheath, and the kidney stones were shattered using a ultrasonic lithotripter (LithoClast®; EMS, Nyon, Switzerland). The procedure was ended by placing a 10-Fr Nélaton catheter when no other stones were seen with the nephroscope. Patients were monitored for shivering in the postoperative period, and related data were recorded. A postanesthesia discharge scoring system was used to discharge patients from the PACU [11]. Patients were discharged from the PACU when they achieved a postanesthesia discharge scoring system score of 9 or 10. The duration of the stay in the PACU was recorded. Postoperative hospital stay was monitored and recorded.

Continuous variables were expressed as descriptive statistical values (mean ± standard deviation), and categorical values were expressed as frequency and related percentage values. Comparison of the continuous variables between groups was performed using an independent paired t test, and comparison of the categorical values between groups was performed using the chi square test.

Table 1 Demographics, surgical time, and irrigation fluid volume

	Group R ($n = 30$)	Group W ($n = 30$)	p
Female/male	13/17	15/15	0.605
Age (years)	50.8 ± 12.2	45.4 ± 15.5	0.137
BMI (kg/m^2)	27 ± 5.1	26.4 ± 4.7	0.629
ASA physical status 1/2	7/23	12/18	0.165
Surgical time (min)	98.2 ± 35.8	102.5 ± 41.7	0.667
Irrigation fluid volume (ml)	14.5 ± 8.8	16.3 ± 7.8	0.405

ASA American Society of Anesthesiologists

Table 2 Core and peripheral body temperatures (°C)

	Group R ($n = 30$)	Group W ($n = 30$)	p
Initial core temperature	36.3 ± 0.4	36.4 ± 0.3	0.239
Final core temperature	34.9 ± 0.8	35.6 ± 0.7	0.002
Core temperature difference	1.4 ± 0.7	0.9 ± 0.6	0.003
Initial peripheral temperature	34.3 ± 0.5	34.6 ± 0.7	0.079
Final peripheral temperature	33.1 ± 0.7	33.9 ± 0.6	0.000
Peripheral temperature difference	1.2 ± 0.8	0.8 ± 0.7	0.016

Table 3 Hemoglobin levels (g/dl), lactate levels (mmol/l), and postoperative hospital stay (days)

	Group R ($n = 30$)	Group W ($n = 30$)	p
Initial hemoglobin level	13.5 ± 1.4	13.3 ± 1.7	0.742
Final hemoglobin level	11.8 ± 1.5	11.8 ± 1.7	0.972
Initial lactate level	1 ± 0.5	1 ± 0.4	0.820
Final lactate level	1.5 ± 0.6	1.3 ± 0.6	0.369
Postoperative stay	1.3 ± 0.7	1.3 ± 0.8	0.859

Statistical significance was obtained when p values were smaller than 0.05. Statistical analysis of the study was performed using SPSS for Windows (version 18.0).

Results

There were no significant differences in the demographics of patients, the surgical time, and the volume of infused irrigation fluid between groups (Table 1). The waiting time in the preoperative holding room was 39.3 ± 19.7 min for group W and 43.8 ± 22.3 min for group R ($p = 0.415$).

The measured mean core and peripheral body temperatures and the differences in temperature during surgery are given in Table 2.

At the end of the procedures, 18 patients (60 %) had mild hypothermia and one patient (3.3 %) had moderate hypothermia in group W, whereas 24 patients (80 %) had mild hypothermia and three patients (10 %) had moderate hypothermia in group R ($p = 0.007$).

There was no statistically significant difference between groups for lactate and hemoglobin levels in the preoperative and postoperative periods or for postoperative hospital stay (Table 3). Transfusion of erythrocyte suspension was not necessary for any patients during the procedures.

The extubation time was 4.4 ± 2.2 min in group W and 5.9 ± 3 min in group R ($p = 0.032$). Assessment of recovery times and shivering rates revealed that patients in group W both recovered faster and shivered less compared with patients in group R. The recovery time was 49.8 ± 24.6 min in group W and 67.6 ± 33.9 min in group R ($p = 0.023$). Seven of the patients (23.3 %) in group W and 15 of the patients (50 %) in group R had shivering ($p = 0.032$).

Discussion

Our study has shown that use of irrigation fluids at room temperature in PCNL is a very serious factor in body temperature decrease and increases the rate of hypothermia, and this condition leads to a series of complications, such as late emergence from anesthesia, late recovery from anesthesia, and shivering.

The difference between the initial and final core body temperatures was 0.9 ± 0.6 °C in group W and 1.4 ± 0.7 °C in group R. There was a statistically significant difference in core body temperature decreases between groups ($p = 0.003$). Despite every precaution, serious core body temperature drops were observed in both groups. This proves that warming the irrigation fluid is a necessary but not sufficient precaution to preserve core body temperature. There seems to be a series of factors contributing to decreases in core body temperature in connection with the technique applied in PCNL operations. A study assessing 100 patients undergoing urological endoscopic surgery (29 undergoing transurethral prostate resection, 10 undergoing transurethral bladder tumor resection, 6 undergoing PCLN, and 55 undergoing cystoscopy) found the decrease in core body temperature to be most in PCNL operations [6]. One of the factors that might cause hypothermia in PCNL is the application of warming blankets to a limited area cephalad to the surgical site. We believe using a second blanket for the area caudad to the surgical site or using a warming system that is placed between the patient and the operating table, in an effort to warm the whole body, might be more useful to prevent hypothermia. Another factor that might contribute to heat loss is soaking of the surgical drapes and a cold operating room. We used waterproof surgical drapes to prevent this soaking; yet five patients and the drapes placed under them were wet at the end of surgery (two patients in group W, three patients in group R). This was probably due to improper placement. In this context, warning the staff for proper placement and use of surgical drapes might be useful. A third factor contributing to heat loss in PCNL operations is the time that passes from induction of anesthesia to the positioning of the patient (in the prone position). A 1 °C decrease in core body temperature occurs during the time from induction of anesthesia to placement of the ureteral catheter and prone positioning [8]. The positioning period when the patient is not covered or warmed should be shortened as much as possible.

In our study the difference between the initial and the final peripheral body temperature was 0.8 ± 0.7 °C in group W and 1.2 ± 0.8 °C in group R. A milder decrease in peripheral body temperature may be related to lower initial peripheral body temperatures and active warming with an air blanket during the intraoperative period. The mean peripheral body temperature at the initiation of the surgery was 34.6 ± 0.7 °C in group W and 34.3 ± 0.5 °C in group R. We believe that heat loss increased because of long waiting times (mean time 41.6 ± 21 min) in the preoperative holding room without active heating. This probably leads to an increase in heat loss in the first phase of the core body temperature drop (during balancing of core and peripheral body temperatures) under anesthesia in both groups.

Jaffe et al. [7] found that heating of the irrigation fluids (mean amount of irrigation fluid 17 l, mean surgical time 100 min) was not effective in preventing hypothermia in a study of 56 male patients undergoing transurethral resection of the prostate. In contrast with this study, there are a number of studies suggesting that using irrigation fluids at room temperature increases the rate of hypothermia [4–6, 8, 9]. We also found that using irrigation fluids at room temperature during PCNL operations significantly increased the rate of hypothermia in our study. Nineteen patients (63.3 %) in group W had hypothermia at the end of surgery: 18 patients (60 %) had mild hypothermia and one patient (3.3 %) had moderate hypothermia. Twenty-seven patients (90 %) in group R had hypothermia at the end of surgery: 24 patients (80 %) had mild hypothermia and three patients (10 %) had moderate hypothermia. Our results show that there is a considerably high rate of hypothermia in PCNL operations, and because of this, the body temperature of patients should be monitored closely. All kinds of active and passive heating measures should be used with the aim of preventing complications in the perioperative period, including warming fluids infused into a patient, intravenously or otherwise, and regulation of body temperature. From a review of the literature, we found similar results with regard to hypothermia rates especially in surgical operations using irrigation fluids at room temperature [4, 8, 12]. In a study with 128 patients undergoing PCNL with irrigation fluids at room temperature studied for perioperative complications, the hypothermia rate was 56.2 % [13]. The result of this particular study seems to show a much lower rate of hypothermia. In our opinion, the reason for this is that the study defined hypothermia as temperatures lower than 35 °C.

Extubation and recovery times were significantly shorter in group W than in group R. Similarly to what is observed in our study, a prolonged effect of anesthetic agents in the setting of hypothermia was shown in previous studies [14]. Although no deleterious effects were noted in our study, it must be kept in mind that patients in a critical condition may be affected seriously by a prolonged intubation time and resulting complications.

We have shown that heating the irrigation fluid reduced the rate of shivering in patients significantly. Whereas 23.3 % of the patients in group W had shivering, the rate was as high as 50 % in group R. None of our patients had serious complications such as hypoxia, lactic acidosis, hypercarbia, arrhythmias, and myocardial infarction accompanying shivering [3]. It should be considered that the patients included in this study consisted of patients who had an American Society of Anesthesiologists physical status of 1 and 2, and shivering might cause serious complications in patients with higher physical status or in a critical condition.

Many studies have shown that hypothermia increases the amount of bleeding significantly [10, 12, 13], yet in our study there was no statistically significant difference in the amount of bleeding between the two groups. Comparison of laboratory values showed there were no statistically significant differences between the groups in the initial and final hemoglobin (1.7 g/dl decrease in group R and 1.5 g/dl decrease in group W) and lactate (0.5 mmol/l increase in group R and 0.3 mmol/l increase in group W) levels.

In conclusion, our study has shown that infusion of irrigation fluids at room temperature in PCNL operations causes the body temperature to decrease considerably and increases the rate of hypothermia. This results in complications such as late emergence from anesthesia, late recovery from anesthesia, and shivering.

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