# Medicine®

# Effect of forced-air warming system in prevention of postoperative hypothermia in elderly patients
## A Prospective controlled trial

Huiying Xu, MD, Guangjun Xu, MD, Chunguang Ren, MD, Liping Liu, MD, Limin Wei, MD*

## Abstract
**Background:** Postoperative hypothermia in elderly patients is a well-known serious complication as it impairs wound healing, induces coagulopathy, increases the risk of blood loss, enhances oxygen consumption, and precipitates cardiac arrhythmias. We conducted this randomized controlled trial to evaluate the effect of a forced-air warming system on rewarming elderly patients undergoing total knee or hip arthroplasty.

**Methods:** We recruited 243 elderly patients undergoing total knee or hip arthroplasty between May and December 2016. They were divided into three groups according to a computer-generated randomization table: group C (n = 78, rewarmed with only a regular blanket), group F1 (n = 82, rewarmed with a forced-air warming system set at 38°C), and group F2 (n = 83, rewarmed with a forced-air warming system set at 42°C). The nasopharyngeal temperature was recorded every 5 min for the first half hour, then every 10 min up to the end of the PACU (postanesthesia care unit) stay. The primary outcome was the rewarming time. The rewarming rate, increase in nasopharyngeal temperature (compared to the start of rewarming), hemodynamics, recovery time, and incidences of adverse effects were recorded.

**Results:** No significant differences were found among the three groups in terms of the baseline clinical characteristics, use of narcotic drugs, intraoperative temperature, and hemodynamics ($P > .05$). Compared with the elderly patients in groups C and F1, both the heart rate and mean arterial pressure of those in group F2 were significantly increased 20 min after arrival at the PACU ($P < .05$). Patients in group F2 had the shortest rewarming time ($35.89 \pm 6.45$ min, $P < .001$), highest rewarming efficiency ($0.028 \pm 0.001$°C/min, $P < .001$), and fastest increased nasopharyngeal temperature among the three groups. Moreover, the elderly patients in group F2 had lower incidences of arrhythmia and shivering ($P < .05$).

**Conclusions:** The use of a forced-air warming system set at 42°C was shown to be the most effective way of rewarming elderly patients with postoperative hypothermia.

**Abbreviations:** ASA = American Society of Anesthesiology, BMI = body mass index, FAW = forced-air warming, HR = heart rate, IQRs = inter-quartile ranges, MAP = mean arterial pressure, OR = operating room, PACU = post-anesthesia care unit.

**Keywords:** elderly patients, forced-air warming system, postoperative hypothermia, rewarming

## 1. Introduction

Hypothermia may occur throughout the entire duration of surgery and anesthesia, is a clinical state, and is generally defined as a core temperature <36°C.[1,2] Many factors may affect the thermoregulatory mechanism of patients after arrival at the operating room (OR), ultimately resulting in hypothermia. These factors include a cold OR, IV fluids (which are used in large quantities at room temperature, and are considered to be associated with hypothermia), antimicrobial skin preparations, various forms of anesthesia and types of surgery, and young and old age.[3,4] Mild perioperative hypothermia (33–36°C) can cause various complications such as impaired wound healing, coagulopathy, postoperative increase in oxygen consumption, and cardiac arrhythmias.[5,6] Severe hypothermia may even lead to atrial fibrillation, premature ventricular contractions, and ventricular fibrillation.[7]

Elderly patients are a high-risk hypothermia group because of the less effective regulatory capacity of their central nervous system on body temperature and their lower levels of subcutaneous fatty tissue.[8,9] Because of the risks in elderly patients, active warming procedures are necessary to maintain normothermia. Nevertheless, the present approach to rewarming patients is inconsistent. A study by Poncelet et al showed that temperature monitoring was performed in only 20% of patients, and only 38.5% of the patients were actively warmed.[10] Interventions to maintain patient body temperature in the OR

include covering the patient's head and body, increasing the ambient room temperature, warming intravenous and irrigating solutions, and applying external warming devices. The Bair Hugger perioperative warming system is a forced-air warming (FAW) device developed for perioperative skin surface warming. The system consists of a portable warming unit connecting to a single patient via a corrugated hose. The temperature output of the device (measured at the end of the hose) can be varied between ambient temperature and 42°C (ambient temperature, 38°C, 42°C) through the hand-held controller. Thus, we conducted this trial with the aim of evaluating the most effective temperature for postoperative rewarming of elderly patients undergoing total knee or hip arthroplasty.

## 2. Methods

### 2.1. Patients

We obtained ethical approval from the Institutional Review Board of Liaocheng People's Hospital, China, for this randomized controlled trial. The study was registered at chictr.org (ChiCTR-TRC-14004191). Patients who underwent total knee or hip arthroplasty between May and December 2016 were enrolled in this study if they met the following criteria: age 65 to 75 years, American Society of Anesthesiologists (ASA) grade I or II, general anesthesia with intubation used during surgery, and operation time <2 h. The exclusion criteria included a history of congenital or neuropsychiatric disease, blood transfusion during operation, reoperation ≤24 h after surgery, and a planned combined general with regional anesthesia during surgery.

We enrolled 243 elderly patients, who were divided into three groups according to a computer-generated randomization table: group C (n=78), group F1 (n=82), and group F2 (n=83). Data from electronic charts and a DoCare Clinic electronic anesthesia recording system were utilized.

### 2.2. Anesthesia

All patients were monitored using standard ASA monitoring by an automated system (Philips IntelliVue MP50, Philips Company), after an arterial cannula was placed in the left radial artery and the electrodes of the bispectral index (BIS, Aspect Medical System, Newton, MA, USA) were placed on the side of the patient's forehead. Anesthesia was induced by intravenous administration of propofol (1.5–2 mg kg$^{-1}$), fentanil (0.3 μg·kg$^{-1}$), and cisatracurium (0.2 mg kg$^{-1}$). Anesthesia was maintained with sevoflurane (0.7–1.0 minimum alveolar concentration [MAC]) and remifentanil (0.1–0.15 μg·kg$^{-1}$·h$^{-1}$), titrated in accordance with the bispectral index (BIS, maintained between 40 and 60) and the hemodynamics.

### 2.3. Rewarming

All of the elderly patients were warmed immediately after arrival at the postanesthesia care unit (PACU). The rewarming methods in the three groups were as follows: in group C, the patients were covered with a regular blanket (except for their heads); in group F1, the patients were warmed with a FAW system (Bair Hugger 750, Germany) set at 38°C; and in group F2, the patients were rewarmed with a FAW system set at 42°C. The nasopharyngeal temperature of each patient was recorded every 5 min in the first half hour, then every 10 min up to the end of the PACU stay.

When the nasopharyngeal temperature was ≥36°C, rewarming was considered to be successful. The rewarming rate was calculated using the following formula: rewarming rate (°C·min$^{-1}$) = increase in nasopharyngeal temperature (°C)/ rewarming time (min).[11,12]

### 2.4. Outcome measures

The primary outcome was the rewarming time (from the start of rewarming to the recovery of normothermia). The rewarming rate, increase in nasopharyngeal temperature (compared to the temperature at the start of rewarming), hemodynamics, recovery time, and incidences of adverse effects were also recorded.

### 2.5. Data collection

The perioperative hemodynamic data (mean arterial pressure [MAP] and heart rate [HR]) and nasopharyngeal temperature were obtained using a Phillips IntelVue MP50 monitor at the following timepoints: arrival in the OR (T0), just before induction of anesthesia (T1), 5 min after anesthesia induction (T2), at the start of the operation (T3), 10 min after the start of the operation (T4), 20 min after the start of the operation (T5), at the end of the operation (T6), and 10 min (T7), 20 min (T8), 30 min (T9), and 45 min (T10) after arrival at the PACU. We also recorded the length of the PACU stay based on the Aldrete criteria. The number of adverse effects (such as bradycardia, tachycardia, hypotension, hypertension, agitation, and shivering) was also recorded at the end of the study.

## 3. Results

### 3.1. Baseline characteristics

The patient enrollment flow diagram is shown in Fig. 1. In total, 546 patients who underwent total knee or hip arthroplasty between May and December 2016 were enrolled in the study. Of these, 303 patients were excluded as they did not meet the inclusion criteria: 13 patients had a history of congenital or neuropsychiatric disease; 35 patients needed blood transfusion during operation; 5 patients needed reoperation within 24 h; 90 patients underwent surgery with regional anesthesia; 56 patients' operations lasted longer than 2 h; 45 patients had an ASA higher than grade II; 46 patients were not within the 65- to 75-year category; and 13 patients were excluded after surgery on account of incomplete clinical data. Consequently, 243 patients remained after exclusions, and were divided into three groups: group C (n= 78), group F1 (n=82), and group F2 (n=83). The three groups were comparable regarding age, sex, body mass index (BMI), ASA grade, type of surgery, and duration of anesthesia and operation (Table 1).

### 3.2. Perioperative hemodynamic data

The baseline HR and MAP did not differ significantly among the three groups ($P > .05$, Fig. 2). Compared with groups C and F1, HR in group F2 was significantly increased at T8, T9, and T10 (T8: 68±7 vs 67±5 vs 72±4 beats·min$^{-1}$, $P < .01$; T9: 67±4 vs 69±4 vs 74±3 beats·min$^{-1}$, $P < 0.01$; T10: 70±5 vs 72±3 vs 76 ±2 beats·min$^{-1}$, $P < 0.01$; in group C, F1, and F2, respectively). Compared with groups C and F1, MAP in group F2 was also significantly increased at T8, T9, and T10 (T8: 56.73±4.53 vs
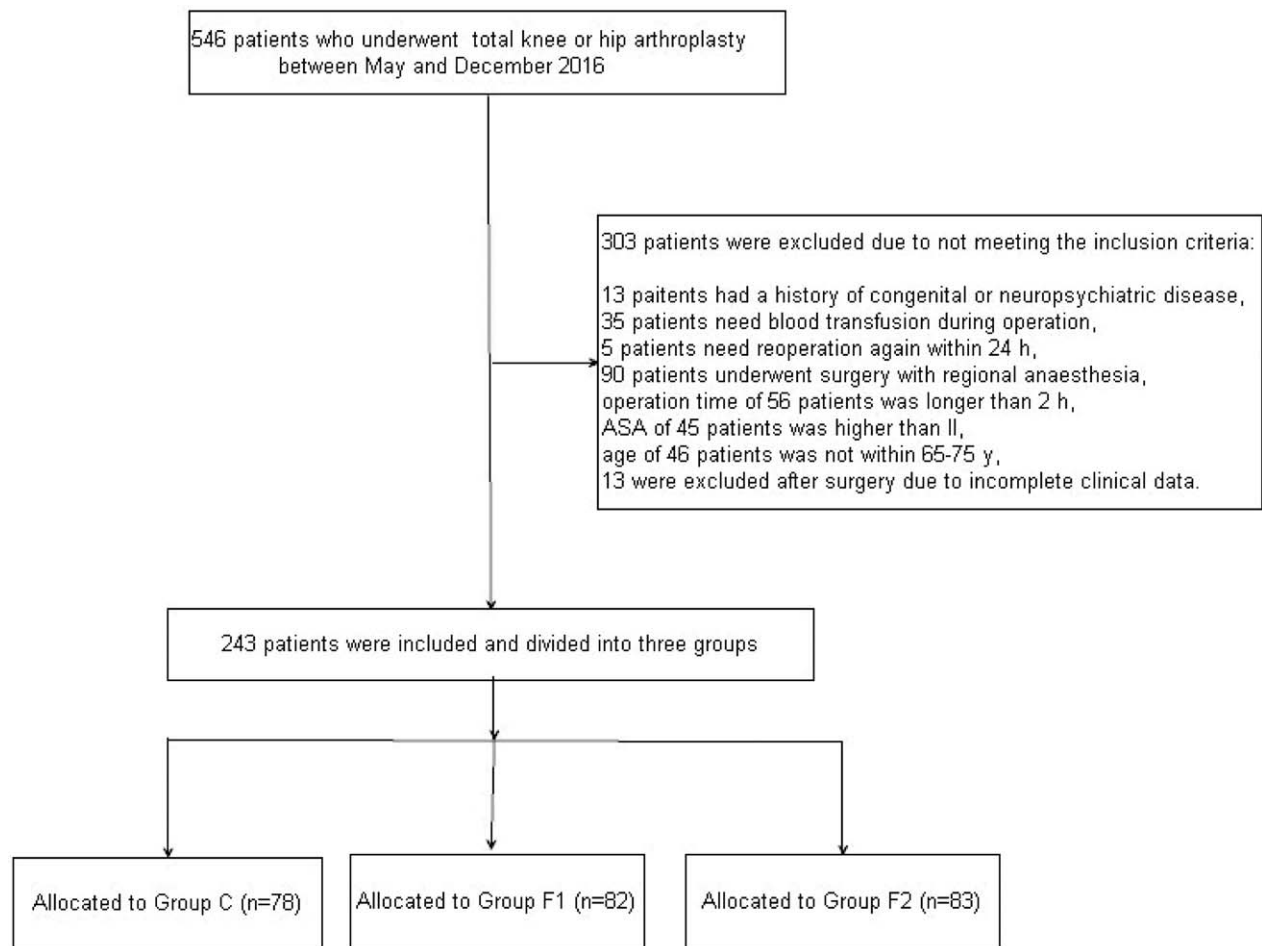
**Figure 1.** Patient enrolment flow diagram. This illustrates the flow of all the patients screened (including those who were excluded).

$59.65 \pm 4.27$ vs $65.63 \pm 5.39$ mm Hg, $P < .01$; T9: $64.68 \pm 5.63$ vs $65.58 \pm 6.49$ vs $72.57 \pm 6.38$ mm Hg, $P < .01$; T10: $72.04 \pm 6.34$ vs $73.07 \pm 6.88$ vs $76.36 \pm 7.05$ mm Hg, $P < .01$; in group C, F1, and F2, respectively) (Fig. 2).

No significant differences were found among the three groups in terms of the duration of surgery and anesthesia, temperature in the OR and PACU, fluid infusion, colloid fluid, crystalloid fluid and estimated blood loss ($P > .05$; Table 2).

### 3.3. Effects of different rewarming methods

The baseline nasopharyngeal temperature did not differ significantly among the three groups ($P > .05$, Fig. 3). Compared with groups C and F1, the nasopharyngeal temperature in group F2 was significantly increased at T7, T8, T9, and T10 (T7: $35.87 \pm 0.55$ vs $36.07 \pm 0.43$ vs $36.38 \pm 0.417°C$, $P < .01$; T8: $36.08 \pm 0.37$ vs $36.25 \pm 0.48$ vs $36.59 \pm 0.34°C$, $P < .01$; T9: $36.21 \pm 0.24$ vs $36.45 \pm 0.52$ vs $36.68 \pm 0.59°C$, $P < .01$; T10: $36.42 \pm 0.14$ vs

**Table 1**

Demographic data of patients with postoperative hypothermia in the three groups.

|  | Group C (n = 78) | Group F1 (n = 82) | Group F2 (n = 83) | P-Values |
|---|---|---|---|---|
| Age (years) | $69.33 \pm 4.87$ | $69.55 \pm 3.64$ | $70.42 \pm 4.66$ | .252 |
| Body weight (kg) | $72.44 \pm 4.84$ | $73.45 \pm 4.89$ | $72.80 \pm 6.54$ | .499 |
| BMI (kg·m$^{-2}$) | $24.27 \pm 2.35$ | $24.32 \pm 2.91$ | $23.99 \pm 3.53$ | .746 |
| Sex (male/female) | 35/43 | 40/42 | 35/48 | .692 |
| ASA I or II (n) | 52/26 | 49/33 | 48/35 | .484 |
| Type of surgery, n (%) |  |  |  |  |
| Total knee arthroplasty | 57 (73.08%) | 55 (67.07%) | 60 (72.29%) | .659 |
| Total hip arthroplasty | 21 (26.92%) | 27 (32.93%) | 23 (27.71%) |  |

The variables are presented as mean ± SD or number of patients, n (%).
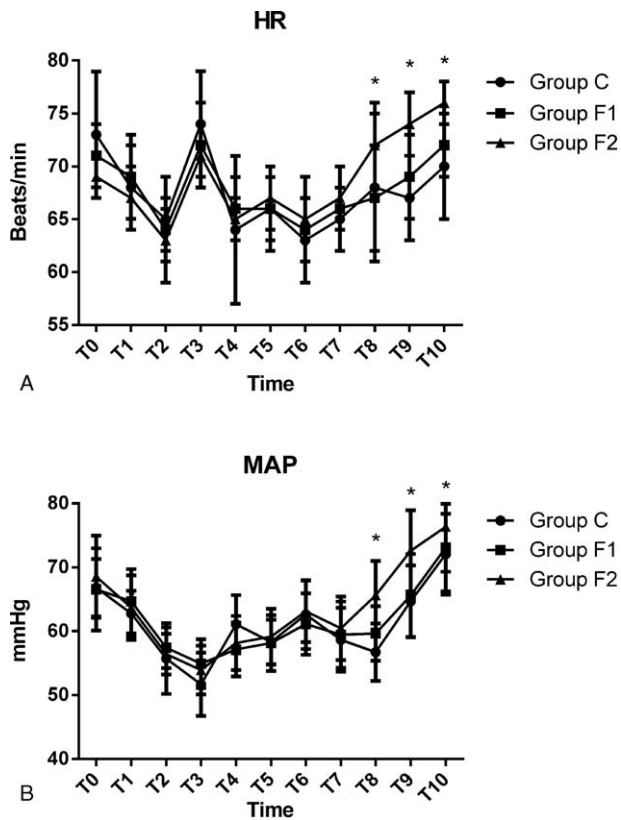ASA = American Society of Anesthesiologists, BMI = body mass index.

Figure 2. Hemodynamics were monitored in the three groups. T0, arrival in the operating room; T1, just before anesthesia induction; T2, 5 min after anesthesia induction; T3, at the start of the operation; T4, 10 min after the start of the operation; T5, 20 min after the start of the operation; T6, at the end of operation; T7 10 min after arriving in the PACU; T8, 20 min after arriving in the PACU; T9, 30 min after arriving in the PACU; T10, 45 min after arriving in the PACU. *$P < .05$ vs Group C.

F1, and F2, respectively; Table 3). There was also significant evidence of a difference in the increase in nasopharyngeal temperature among the three groups ($1.57 \pm 0.13$ vs $1.62 \pm 0.11$ vs $1.70 \pm 0.15$°C, $P < .001$, in group C, F1, and F2, respectively; Table 3).

### 3.4. Adverse events

The main adverse events are recorded in Table 4. Compared to the patients in groups C and F1, those in group F2 had a lower incidence of arrhythmia (15 vs 12 vs 5, $P = .041$, in group C, F1, and F2, respectively), shivering (30 vs 17 vs. 10, $P < .001$, in group C, F1, and F2, respectively). In contrast, no significant difference was found among the three groups in the incidence of hypoxemia (7 vs 6 vs 6, $P = .899$, in group C, F1, and F2, respectively), hypotension (14 vs 11 vs 9, $P = .423$, in group C, F1, and F2, respectively), and hypertension (18 vs 20 vs 15, $P = .585$, in group C, F1, and F2, respectively).

## 4. Discussion

We found the FAW system set at 42°C to be the most effective rewarming method for elderly patients with postoperative hypothermia. This method reduced the incidence of arrhythmia and shivering compared to that in the other two groups.

Mild hypothermia is particularly prominent in elderly patients undergoing general anesthesia. It can be caused by a number of factors, including impairment of thermoregulatory control on account of the anesthesia, the cool OR temperature and infusion fluids, internal redistribution of heat within the body, skin disinfection, and washing of wounds.[13–15] Previous studies have reported that more than 75% of the total heat loss is mainly the result of convection and radiation from the patient to the environment in elderly patients undergoing total knee or hip arthroplasty.[16,17] Previous studies have also shown that pre-warming before anesthesia for at least 1 h could reduce intraoperative hypothermia; however, such prolonged pre-warming is impractical for most patients, especially in our clinical centers (at least six hundred patients per year undergoing total knee or hip arthroplasty since 2015 and keep growing at 20% for everyyear).[18,19] As a result, we conducted this trial with the aim of evaluating the most effective temperature for postoperative rewarming of elderly patients undergoing total knee or hip arthroplasty.

In this study, we defined postoperative hypothermia as a core temperature (rectal temperature) <36°C, in accordance with the definition of the World Health Organization and American Society of PeriAnesthesia Nurses.[20,21] Both children and elderly

$36.69 \pm 0.55$ vs $36.85 \pm 0.36$°C, $P < .01$; in group C, F1, and F2, respectively). There was significant difference in the rewarming time in group C compared with groups F1 and F2 ($43.47 \pm 8.25$ vs $44.09 \pm 8.53$ vs $35.89 \pm 6.45$ min, $P < .001$; in group C, F1, and F2, respectively; Table 3).

Patients in groups C and F1 had a significantly lower rewarming rate than those in group F2 ($0.022 \pm 0.001$ vs $0.025 \pm 0.001$ vs $0.028 \pm 0.001$°C·min$^{-1}$, $P < .001$, in group C, F1,

### Table 2

Intraoperative data of patients with postoperative hypothermia in the three groups.

| | Group C (n = 78) | Group F1 (n = 82) | Group F2 (n = 83) | P-Values |
|---|---|---|---|---|
| Duration of surgery (min) | 81.28 ± 11.23 | 78.52 ± 10.45 | 79.03 ± 9.34 | .204 |
| Duration of anesthesia (min) | 92.31 ± 13.09 | 92.78 ± 11.91 | 89.36 ± 12.03 | .159 |
| Temperature in the operation room and PACU (°C) | 22.03 ± 0.74 | 22.31 ± 1.02 | 22.15 ± 0.97 | .148 |
| Estimated blood loss (mL) | 267.63 ± 34.64 | 265.04 ± 26.89 | 274.86 ± 38.23 | .153 |
| Fluid infusion (mL) | 982.72 ± 51.63 | 988.62 ± 42.62 | 972.93 ± 59.08 | .145 |
| Colloid fluid (mL) | 357.92 ± 45.58 | 350.09 ± 55.11 | 348.02 ± 44.19 | .363 |
| Crystalloid fluid (mL) | 638.23 ± 70.67 | 592.49 ± 60.81 | 602.78 ± 62.94 | .084 |

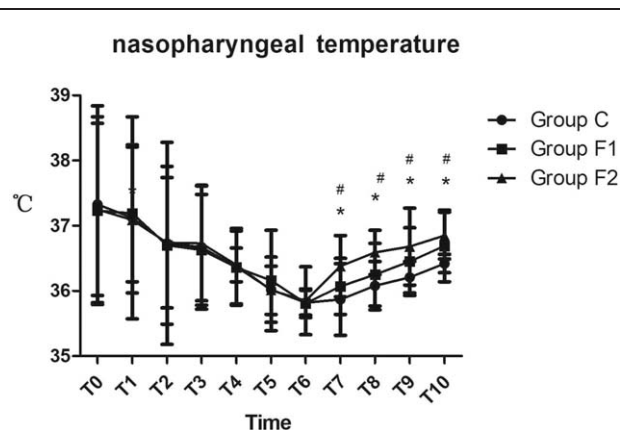The variables are presented as mean ± SD.

**Figure 3.** Nasopharyngeal temperature was monitored in the three groups. T0, arrival in the operating room; T1, just before anesthesia induction; T2, 5 min after anesthesia induction; T3, at the start of the operation; T4, 10 min after the start of the operation; T5, 20 min after the start of the operation; T6, at the end of operation; T7 10 min after arriving in the PACU; T8, 20 min after arriving in the PACU; T9, 30 min after arriving in the PACU; T10, 45 min after arriving in the PACU. *P < .05 vs Group C, #P < .05 vs Group F1.

patients are prone to the occurrence of hypothermia during surgery as they regulate their body temperature less efficiently than adults.[22,23] Unlike children, in most elderly patients, most instances of hypothermia occurring during the operation originate from a low basal metabolic rate and various endocrine disorders. Numerous studies have examined the validity of different rewarming methods for elderly patients during surgery.[2,3] However, there have been no guidelines for the management of postoperative hypothermia of such patients. Therefore, we conducted this randomized controlled trial to discuss the postoperative rewarming ways of elderly patients undergoing total knee or hip arthroplasty.

As mentioned in our previous studies, ways of preventing of hypothermia in the elderly include the use of external warming devices (covering with a blanket, treating with an electric blanket or a FAW system), increased the ambient room temperature, and administered warm intravenous or skin irrigation solutions.[24] Forced-air warming has been proven to be the most effective way to maintain normothermia during surgery.[25] Although FAW systems are expensive, such costs are worthwhile in shortening the patient's stay in the PACU and reducing the risk of the increased costs of treating complications associated with postoperative hypothermia.

Consistent with the findings of previous studies,[26,27] we found that the rewarming time, rewarming rate, and increase in nasopharyngeal temperature in group F2 (treated with a FAW system set at 42°C) were all significantly increased compared to the other two groups. Though several factors influence the rewarming effect of elderly patients, there were no significant differences found among the three groups in terms of baseline characteristics, duration of surgery and anesthesia, temperature in the OR and PACU, fluid infusion, colloid fluid, crystalloid fluid, and estimated blood loss. Compared with groups C and F1, HR and MAP in group F2 were significantly increased at T8, T9, and T10. Compared to the patients in groups C and F1, those in group F2 had a lower incidence of arrhythmia (15 vs 12 vs 5 incidences, P = .041, in group C, F1, and F2, respectively) and shivering (30 vs 17 vs 10, P < .001, in group C, F1, and F2, respectively). In contrast, no significant difference was found among the three groups in terms of the incidence of hypoxemia (7 vs 6 vs 6, P = .899, in group C, F1, and F2, respectively), hypotension (14 vs 11 vs 9, P = .423, in group C, F1, and F2, respectively), and hypertension (18 vs 20 vs 15, P = .585, in group C, F1, and F2, respectively). The reasons for this may include the short duration of the operations involved in this study and the different types of patients recruited, surgeries performed, and precise methods of rewarming selected.[28]

There are several limitations in the present study. First, the study is a randomized controlled trial. A large multi-center

**Table 3**

**Rewarming effects among patients with postoperative hypothermia in three groups.**

|  | Group C (n = 78) | Group F1 (n = 82) | Group F2 (n = 83) | P-Values |
|---|---|---|---|---|
| Rewarming time (min) | 43.47 ± 8.25 | 44.09 ± 8.53 | 35.89 ± 6.45*,# | <.001 |
| Rewarming rate (°C/min) | 0.022 ± 0.001 | 0.025 ± 0.001* | 0.028 ± 0.001*,# | <.001 |
| Increase in nasopharyngeal temperature (°C) | 1.57 ± 0.13 | 1.62 ± 0.11* | 1.70 ± 0.15*,# | <.001 |

The variables are presented as mean ± SD.
* P < .05 vs Group C.
# P < .05 vs Group F1.

**Table 4**

**Postoperative adverse events among patients with postoperative hypothermia in three groups.**

|  | Group C (n = 78) | Group F1 (n = 82) | Group F2 (n = 83) | P-Values |
|---|---|---|---|---|
| Arrhythmia | 15 (19.23%) | 12 (14.63%) | 5 (6.02%)*,# | .041 |
| Hypertension | 18 (23.08%) | 20 (24.39%) | 15 (18.07%) | .585 |
| Shivering | 30 (38.46%) | 17 (20.73%) | 10 (12.05%)*,# | <.001 |
| Hypotension | 14 (17.95%) | 11 (13.41%) | 9 (10.84%) | .423 |
| Hypoxemia | 7 (8.97%) | 6 (7.32%) | 6 (7.23%) | .899 |

The variables are presented as number of patients, n (%).
* P < .05 vs Group C.
# P < .05 vs Group F1.

prospective trial is necessary to verify the effect of a FAW system on rewarming elderly patients undergoing total knee or hip arthroplasty with postoperative hypothermia. Second, we only included elderly patients undergoing total knee or hip arthroplasty with operations of short duration (<2 h). Further research is required on elderly patients undergoing lengthy complex surgery. Third, we failed to consider hyperthermia as a complication during the postoperative period. Although none of the elderly patients in our study developed hyperthermia, this variable should be included in future study protocols. Finally, we did not compare the postoperative rewarming method with ways to keep the patient warm from the beginning or even 1 h before surgery.

In summary, of the use of a FAW system set at 42°C was shown to be an effective way of rewarming elderly patients with postoperative hypothermia. In addition, the incidences of arrhythmia and shivering were reduced. However, further multicenter prospective studies are needed to verify the effect of this composite technique with respect to treating postoperative hypothermia in elderly patients undergoing total knee or hip arthroplasty.

## Author contributions

Huiying Xu, Guangjun Xu, and Limin Wei conceived and designed the trial; Chunguang Ren, Liping Liu, collected the data; Chunguang Ren analyzed the data; Huiying Xu, Guangjun Xu, and Limin Wei wrote this paper.
**Conceptualization:** Guangjun Xu, Limin Wei.
**Data curation:** Huiying Xu, Liping Liu.
**Formal analysis:** Liping Liu.
**Investigation:** Limin Wei.
**Methodology:** Chunguang Ren.
**Software:** Chunguang Ren.
**Writing - original draft:** Huiying Xu, Guangjun Xu, Limin Wei.
**Writing - review & editing:** Huiying Xu, Guangjun Xu, Limin Wei.

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