J Anesth (2014) 28:880–885
DOI 10.1007/s00540-014-1820-z

ORIGINAL ARTICLE

Effect of pre-warmed intravenous fluids on perioperative hypothermia and shivering after ambulatory surgery under monitored anesthesia care

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Received: 23 October 2013 / Accepted: 11 March 2014 / Published online: 1 April 2014

Abstract
Purpose The aim of this study was to evaluate the effects of pre-warmed (approximately 41 °C) intravenous fluids (IV) on perioperative hypothermia and postoperative shivering in female patients undergoing short, ambulatory urological surgery under monitored anesthesia care (MAC).
Methods Patients between the ages of 35 and 80 years were randomly assigned to either the pre-warmed ($n = 27$) or the room temperature ($n = 26$) group. According to group allocation, either pre-warmed IV fluids that had been stored in a warming cabinet for at least 8 h or room temperature IV fluids were administered intraoperatively up to approximately 600–700 ml, including a bolus infusion of 10 ml/kg within 20 min. Perioperative core temperatures at the tympanic membrane, postoperative shivering, subjective thermal comfort, and the use of forced-air warming interventions in the post-anesthesia care unit (PACU) were recorded.
Results Mean core temperatures were significantly higher in the pre-warmed group than they were in the room temperature group after 10 ml/kg preload fluid was administered, at the end of the operation, and on admission to the PACU ($p = 0.004$, $p = 0.02$, and $p = 0.008$, respectively). The incidence of hypothermia (<36 °C) was significantly lower in the pre-warmed group ($n = 4$) than in the room temperature group ($n = 11$, $p = 0.035$) upon PACU admission. The postoperative shivering incidence was also significantly lower in the pre-warmed group ($n = 2$) than in the room temperature group ($n = 8$, $p = 0.039$).
Conclusions Infusion of pre-warmed IV fluid improved the postoperative recovery profile by decreasing hypothermia and shivering in female patients undergoing short, ambulatory urological surgery under MAC.

Keywords Ambulatory surgery · Core temperature · Monitored anesthesia care · Pre-warmed intravenous fluids · Shivering

Introduction

Perioperative hypothermia, defined as a core temperature less than 36 °C, and its related side effects, such as shivering, have been frequently observed after general anesthesia and neuraxial block [1–5]. Postoperative shivering increases O_2 consumption [6] and therefore can be detrimental to elderly patients, especially those with cardiac disease. Infusion of preoperatively or intraoperatively warmed fluid has had mixed results but was effective in reducing perioperative hypothermia and related shivering in some reports [7–10].

Although monitored anesthesia care (MAC), as a fast-track anesthetic protocol, accounts for one-third of ambulatory anesthesia cases [11], perioperative measurement of core temperature and postoperative shivering associated with MAC have not been concerns for anesthesiologists in busy outpatient centers. Core temperature monitoring has been neglected in most MAC settings because of the short operation times and the difficulty in obtaining invasive core temperature measurements as a result of the sedation level of MAC anesthesia. In this tertiary university hospital,

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many cases of short-duration urological surgery for female patients are performed on an outpatient basis. Because female urological surgery is frequently carried out in relatively older patients, perioperative hypothermia and shivering should be carefully monitored.

There is no previous report regarding the beneficial effect of a small amount of pre-warmed intravenous (IV) fluids on the recovery profile after short-duration ambulatory surgery under MAC. Therefore, in the current study, we aimed to evaluate the impact of the administration of a small amount of pre-warmed fluid stored in a warming cabinet on the incidence of hypothermia, shivering, thermal comfort, and the use of a forced-air warming intervention after ambulatory surgery under MAC.

Materials and methods

This single-blinded, prospective, randomized, controlled study was performed following approval by the local Institutional Review Board (2012-05-093-002), and written informed consent was obtained from all enrolled patients before the study began. A total of 53 female patients with American Society of Anesthesiologists (ASA) physical status I and II and age between 35 and 80 years, who were scheduled for ambulatory urological surgery by one surgeon under MAC, were studied. Exclusion criteria were a preoperative baseline tympanic membrane temperature >38 °C or <36 °C, conditions requiring restrictive IV fluid administration, such as end-stage renal failure and heart failure, and otitis media.

Patients were instructed via telephone to remain nulla per os (NPO) 8 h before the planned operation time. They were admitted to the hospital on the morning of the day of surgery, and peripheral venous access was secured using an 18- or 20-gauge angiocatheter and maintained with an IV lock by 2 ml sterile normal saline. Premedication was not administered to any patient.

A random number generated by an Internet-based computer program (http://www.randomizer.org) and the sealed envelope technique were used to assign patients into two groups to receive either room temperature or pre-warmed IV fluids.

Upon arrival at the operating room, Hartman's solution and a 150-cm-long infusion set were delivered by the attending anesthesiologist, according to group assignment, and connected to the patient after an IV flush with 2 ml sterile normal saline. Before the administration of any anesthetics, basic monitoring, including electrocardiogram (EKG), noninvasive blood pressure, peripheral oxygen saturation, and bispectral index, was applied. A circulating warm water blanket was used for all patients. MAC was achieved with a target-controlled infusion (Orchestra® Module DPS; Fresenius Kabi, France) of 1 % propofol and remifentanil to maintain the bispectral index value at 60–80 following the administration of 1 or 2 mg IV midazolam. Local anesthetic infiltration at the operation site was also conducted by a surgeon. A simple facial mask was applied to provide 5 l/min oxygen, and adequacy of ventilation was assessed by monitoring the presence of exhaled carbon dioxide during the MAC. As a preloading of fluid, both groups of patients were hydrated with 10 ml/kg Hartman's solution during surgical positioning and draping, which usually took 15–20 min. Then, estimated maintenance fluid requirements [12] were infused until the end of surgery. In the room temperature group, IV fluids and infusion sets were prepared in the operating room where the ambient temperature was maintained at a constant 22–24 °C. In the pre-warmed group, a warming cabinet (KRS-205; Karis, Gyeonggi-do, Korea) set to 41 °C was used to store IV fluids and infusion sets for at least 8 h. A forced-air warming system (Model 505, Bair Hugger; Augustine Medical, Eden Prairie, MN, USA) was applied to patients in the post-anesthesia care unit (PACU) when their core temperature fell below 36 °C and they complained of a chilling sensation or shivering.

The core temperature at the tympanic membrane was taken in the same ear, and the highest reading from three consecutive measurements was recorded. Tympanic temperatures were checked at the following times: immediately after arrival at the operating room (T1), after the preload fluid administration (T2), at the end of the operation (T3), and upon admission to the PACU (T4). During the PACU stay, patients were questioned about dizziness, drowsiness, fatigue, thirst, nausea, and vomiting. The pain score was measured using the visual analogue scale. A numerical rating scale was adopted for evaluating chilling sensation, with 0 as the worst imaginable cold, 5 as comfortable, and 10 as insufferably hot. Patients were regarded as feeling cold if they scored <4 and feeling warm if they scored >6 for chilling sensation. Shivering was graded into none (0), mild and intermittent (1), and intense and continuous shivering (2) by the blinded investigator in the PACU.

In this study, a sample size of 25 participants in each group was obtained from a power analysis with reference to previous studies [8, 9], and set a mean difference in core temperature at least one time point of 0.4 °C. For that calculation, we used a standard deviation (0.5) of the core temperature with a desired power of 80 % and an α-level of 0.05 (two-tailed). To allow for 10 % loss during the study period, we intended to recruit a total of 60 patients. The Statistical Package for the Social Sciences (SPSS) software (SPSS 18.0; SPSS, Chicago, IL, USA) was used to perform the statistical analyses. Comparisons of the core temperature at four study points between the groups were made

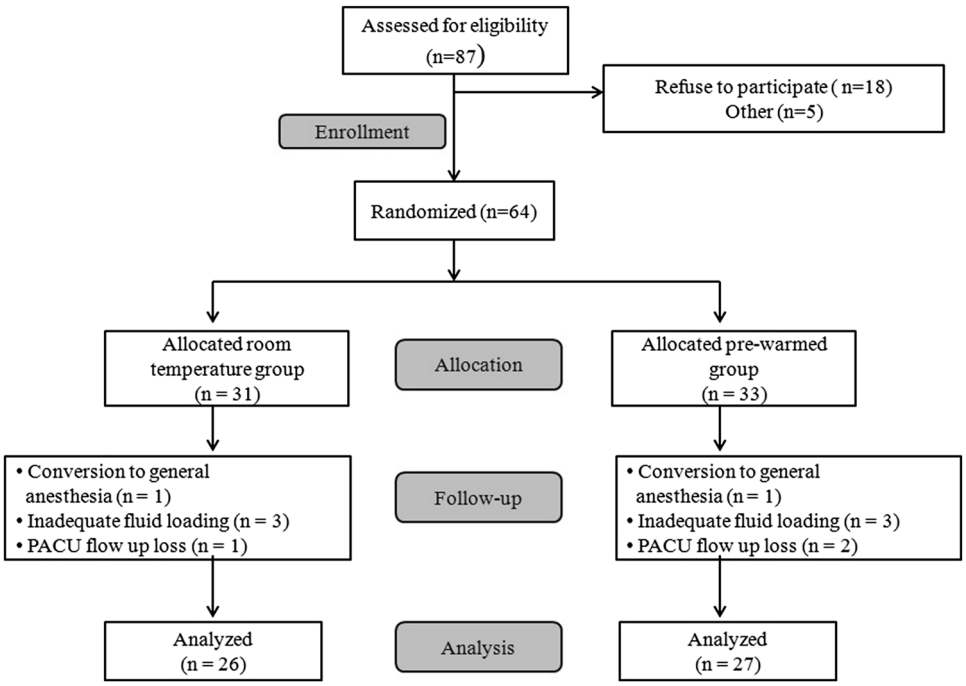

Fig. 1 Consort diagram of the study. *PACU* post-operative care unit

using an independent *t* test or a Mann–Whitney *U* test with a Bonferroni correction according to the normality of the variables. The comparisons of core temperatures between the baseline value (T1) and other study points (T2–T4) within each group were carried out using paired *t* tests. The number of patients with a core temperature <36 °C on PACU admission and the number of those requiring post-operative interventions for shivering or hypothermia between groups were compared using a chi-square test or Fisher's exact test. To compare other categorical variables between groups, a chi-square test or Fisher's exact test was used. Data are presented as mean (standard deviation, SD), median (interquartile range), and number (%). A p value < 0.05 was considered statistically significant.

Results

A total of 87 female patients undergoing ambulatory urological surgery under MAC were assessed for eligibility from September 1, 2012 to May 30, 2013. Among these patients, 64 were approved to participate in this study and were randomly allocated into two groups. Eleven were excluded from the data analyses after enrollment because of a change in the anesthetic method (conversion to general anesthesia resulting from severe pain) in 2 patients, an inadequate amount of preload fluid infusion in 6 patients, and improper PACU data in 3 patients. Finally, 27 patients received pre-warmed fluid, and 26 patients were given ambient temperature fluid (Fig. 1).

Table 1 Demographic and perioperative clinical characteristics in patients undergoing ambulatory urological surgery under monitored anesthesia care

	Room temperature ($n = 26$)	Pre-warmed ($n = 27$)	p
Patient			
Age (years)	57 ± 10	60 ± 9	0.163
Body weight (kg)	56.5 ± 1.1	57.6 ± 1.3	0.565
BMI (k/m^2)	23.3 ± 3.1	23.4 ± 2.4	0.972
Duration of			
Anesthesia (min)	64 ± 13	60 ± 11	0.227
Operation (min)	23 (16–26)	21 (17–25)	0.407
PACU stay (min)	72 (45–78)	80 (50–85)	0.262
Intraoperative			
Crystalloid (ml)	751 ± 179	670 ± 192	0.117
Estimated blood loss (ml)	40 (10–50)	40 (10–50)	0.589
Total dose of			
Propofol (mg)	175 (150–250)	180 (150–250)	0.367
Remifentanil (mg)	0.22 (0.2–0.25)	0.2 (0.2–0.25)	0.356
Bispectral index	71 ± 4	70 ± 3	0.276
Environmental temperature			
Waiting room (°C)	24.6 (24.2–25.5)	24.7 (24.8–25.1)	0.210
Operating room (°C)	25 (23–25.1)	23.4 (23–24)	0.270

Data are shown as mean ± SD or median (interquartile range)

BMI body mass index, *PACU* post-anesthesia care unit

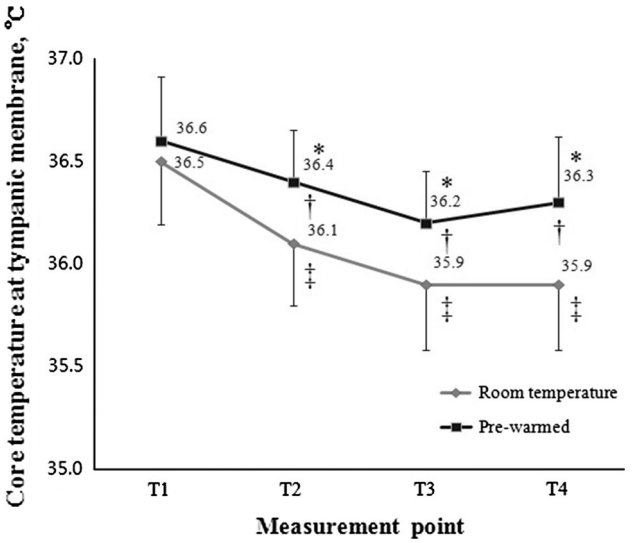

Fig. 2 A serial change in core temperature at the tympanic membrane in patients receiving room temperature and pre-warmed intravenous fluids. Measurement points were as follows: T1 = immediately upon arrival at the operating room, T2 = after the preloading of fluid, T3 = at the end of the operation, T4 = upon admission to the PACU. *Asterisk* indicates statistically significant difference between the groups at each point. *Dagger* indicates statistically significant difference between T1 and other points in the pre-warmed group. *Double dagger* indicates statistically significant difference between T1 and other points in the room temperature group. *Vertical bars* represent standard deviations (but only in one direction) for clarification of the figure. *PACU* post-anesthesia care unit

Table 2 Comparison of postoperative data between the room temperature group and the pre-warmed group

	Room temperature ($n = 26$)	Pre-warmed ($n = 27$)	p
Hypothermia in the PACU	11 (42.3)	4 (14.8)	0.035
Chilling sense (point)	3.6 (3–5)	4.2 (4–5)	0.075
Shivering	8 (30.8)	2 (7.4)	0.039
VAS for pain	1.4 ± 1.5	1.9 ± 2.0	0.321
Forced-air warming	17 (65.4)	9 (33.3)	0.056

Data are presented as number of patients (%), median (interquartile range), or mean ± SD. Hypothermia in the PACU is represented as a core temperature <36 °C just after admission to the PACU

VAS visual analogue scale, *n* number of patients, *PACU* post-anesthesia care unit

Table 1 presents patient characteristics, anesthetics, and operative variables between the groups. In the room temperature group, the amount of administered fluid was identified as approximately 10 % more on average, and temperature in the operation room was higher. However, there were no statistically significant parameters between the two groups.

As shown in Fig. 2, core temperatures in the pre-warmed group were significantly higher than those of the room temperature group at T2, T3, and T4 ($p = 0.004$, $p = 0.02$, and $p = 0.008$, respectively). The mean core temperatures in the pre-warmed group were maintained above 36 °C for all measurement points. The highest difference in core temperature between the groups was identified as 0.4 °C at T4. Compared to T1, core temperatures at T2, T3, and T4 were all significantly lower ($p = 0.001$, $p < 0.001$, and $p < 0.001$, respectively) in both the room temperature and the pre-warmed groups. The incidence of hypothermia <36 °C was significantly lower in the pre-warmed group ($n = 4$) than the room temperature group ($n = 11$) at T4 ($p = 0.035$) (Table 2).

The occurrence of shivering in the PACU was significantly higher in the room temperature group ($n = 8$, 30.8 %) than in the pre-warmed group ($n = 2$, 7.4 %) ($p = 0.039$). However, the incidence of grade 2 shivering was not significantly different between the room temperature group ($n = 2$) and the pre-warmed group ($n = 1$). The two groups also did not report a statistically significant degree of subjective feeling of thermal comfort. Chilling sensations <4 were observed more frequently in the room temperature group than in the pre-warmed group (11 patients vs. 6 patients), but this difference was not significant. Other side effects, such as dizziness, drowsiness, fatigue, thirst, nausea, and vomiting, and pain score, were not different between the groups.

Discussion

In the current study, we found that the infusion of approximately 600–700 ml pre-warmed crystalloid significantly alleviated perioperative core temperature reduction and postoperative shivering in female patients undergoing ambulatory urological surgery under MAC.

Ambulatory surgery has been on the increase in accordance with dramatic trends toward minimally invasive surgery [13–15]. Therefore, the role of anesthesiologists has expanded to cost-effective perioperative care for fast-track recovery of outpatients [13]. MAC has been considered as a fast-track anesthetic protocol because it uses intravenous drugs characterized by a rapid onset and a short duration of action [16, 17]. The most widely used intravenous drug for MAC, propofol, tends to reduce vasoconstriction in direct proportion to its blood concentration even at the sedation dose [18]. Moreover, inadvertent hypothermia can be caused by a cool operating room temperature, body exposure, evaporation of disinfectant solutions, and the administration of room temperature IV fluids in patients receiving MAC. In this regard, perioperative hypothermia can disturb the fast-track recovery process as a result of postoperative shivering, cardiac adverse events, and coagulopathy [2–4, 6, 15]. Warming of the IV

fluids has the advantage of preventing perioperative hypothermia [3, 8, 10, 19], but using fluid-warming devices may be an inconvenient intervention in terms of the time-consuming work and installation costs involved, especially for very short ambulatory surgeries using MAC. It has been estimated that a steady-state temperature of pre-warmed fluid can be achieved after 8 h of storage in a 40 °C warming cabinet [20]. The temperature of the pre-warmed fluid was checked to be above 34 °C at the distal end of a 120-cm fluid infusion set over a 30-min infusion period with 30–35 ml/min flow rate [21]. Storage of IV fluids in the warming cabinet for at least 8 h before the operation can be considered both a simple and cost-saving method to prevent perioperative hypothermia in patients undergoing MAC during ambulatory surgery.

Administration of 1 l room temperature crystalloid has been calculated to decrease the mean core temperature by 0.25 °C [22]. Accordingly, there is no doubt that a large amount of room temperature fluids aggravates the decrease in core temperature during surgery, and thus, warming of IV fluids is necessary to prevent hypothermia [3]. Although the National Institute for Health and Clinical Excellence (NICE) guidelines recommend that even low volumes of IV fluids (500 ml or more) should be warmed to 37 °C using a fluid-warming device [23], a direct comparison of core temperatures between a small volume of room temperature fluids and warmed fluids has not been performed. In previous studies, the minimum amount of pre-warmed administered IV crystalloids was approximately 1 l [7, 9, 10]. Accordingly, we administered 10 ml/kg crystalloid for fluid loading within 20 min and then delivered the estimated maintenance fluid requirements [12].

It has been reported that sufficient compensatory administration of up to 20–30 ml/kg crystalloid fluids can reduce dizziness, drowsiness, pain, nausea, and vomiting in low-risk ambulatory patients [24, 25]. However, we speculated that such an amount of fluid might not be required for short, ambulatory surgery under MAC because vasodilation would not be as severe as that of general or regional anesthesia, and a rapid recovery (including bowel function) would enable the patient to start an oral diet soon after surgery. Significant postoperative nausea and vomiting or pain would also be less than that observed with general anesthesia. In addition, postoperative urinary retention sometimes interrupts early discharge [16] after MAC in ambulatory surgery, and the incidence of urinary retention might be increased if more than 750 ml intraoperative fluids is used [26]. Therefore, the current study result seems specific by showing maximal 0.4 °C in core temperature difference with <1 l fluid administration. Significant core temperature differences were also observed at all the study points after fluid infusion (Fig. 2), and the incidence of hypothermia with a temperature <36 °C at PACU admission was lower in the pre-warmed group (Table 2).

An interesting finding in our study was that the incidence of postoperative shivering was significantly lower in the pre-warmed group than it was in the room temperature group (Table 2). This result is different from those of previous research studies, which investigated the effect of pre-warmed fluid on core temperature under general or regional anesthesia [8, 10]. They suggested that the small power in their studies might explain the insignificance of the shivering incidence between the groups, although there were significant impacts on core temperature and hypothermia. Nevertheless, a fourfold increase in postoperative shivering was observed in the present study.

Postoperative shivering is generally derived from core hypothermia and vasoconstriction [27], which are defined as thermoregulatory mechanisms. However, in some cases, shivering has not been explained by thermoregulatory mechanisms alone [28]. The exact mechanism for a different outcome is still unknown, but pain has been suggested as a triggering factor [29]. Surgical stress in this study was managed with local infiltration at the operative site in addition to MAC. The average visual analogue scale in the PACU indicated that the level of pain was not severe enough to require additional pain control. Although high-dose remifentanil has been associated with postoperative shivering [30], the low-dose remifentanil used in this study would not have influenced postoperative shivering. Another possibility might be related to the shivering threshold. Thermoregulatory impairment and a decrease in the shivering threshold might be lesser in MAC than for general or regional anesthesia because of the lighter depth of anesthesia in MAC. In addition, postoperative shivering after MAC would be observed early in the PACU because of the rapid recovery from anesthesia. Therefore, we speculate that shivering in our patients was principally affected by a decreased core temperature.

Although the tympanic membrane temperature has been regarded as inaccurate because of discrepancies in the measured values [31, 32], the core temperature measurement at the tympanic membrane has demonstrated high degrees of reliability with esophageal measurements [33, 34]. Furthermore, invasive core temperature monitoring, such as with an esophageal probe, is difficult to perform under MAC. An infrared tympanic thermometer can be used as a practical means to monitor core temperature in patients under MAC. Therefore, we recorded the highest value from three consecutive measurements from the same ear to decrease the measurement error.

One limitation of this study was that core temperature reduction with MAC was not prominent in the room temperature group; the mean lowest core temperature was only 35.9 °C. The degree of vasodilatation caused by MAC with

propofol and remifentanil may be lower than that caused by general or neuraxial anesthesia. In addition, the use of a circulating warm water blanket in all patients of both groups might also mitigate core temperature reduction in the room temperature group. Accordingly, the thermal comfort scale score between the two groups was not significantly different in this study, even though the incidences of hypothermia (<36 °C) and shivering were significantly lower in the pre-warmed fluid group.

In conclusion, the administration of approximately 600–700 ml fluids pre-warmed to 41 °C may play an important role in fast-track anesthetic techniques by maintaining perioperative normothermia and decreasing the incidence of postoperative shivering in female patients undergoing ambulatory urological surgeries under MAC.

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