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ORIGINAL ARTICLE

The effects of anesthetic technique and ambient temperature on thermoregulation in lower extremity surgery

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Abstract
Purpose The purpose of our study was to determine the effects of anesthetic technique and ambient temperature on thermoregulation for patients undergoing lower extremity surgery.
Methods Our study included 90 male patients aged 18–60 years in American Society of Anesthesiologists Physical Status groups I or II who were scheduled for lower extremity surgery. Patients were randomly divided into three groups according to anesthetic technique: general anesthesia (GA), epidural anesthesia (EA), and femoral-sciatic block (FS). These groups were divided into subgroups according to room temperature: the temperature for group I was 20–22 °C and that for group II was 23–25 °C. Therefore, we labeled the groups as follows: GA I, GA II, EA I, EA II, FS I, and FS II. Probes for measuring tympanic membrane and peripheral temperature were placed in and on the patients, and mean skin temperature (MST) and mean body temperature (MBT) were assessed. Postoperative shivering scores were recorded.
Results During anesthesia, tympanic temperature and MBT decreased whereas MST increased for all patients. There was no significant difference between tympanic temperatures in either the room temperature or anesthetic method groups. MST was lower in group GA I than in group GA II after 5, 10, 15, 20, 60 and 90 min whereas MBT was significantly lower at the basal level ($p < 0.05$). MST after 5 min was significantly lower in group GA I than in group FS I ($p < 0.05$). Shivering score was significantly higher in group GA I ($p < 0.05$).
Conclusions There were no significant differences in thermoregulation among anesthetic techniques. Room temperature affected thermoregulation in Group GA.

Keywords Thermoregulation · General anesthesia · Epidural anesthesia · Femoral sciatic block and ambient temperature

Introduction

Hypothermia is often observed during intraoperative and postoperative periods unless steps are taken to prevent it. Moderate hypothermia has been shown to have a protective effect against injury during voluntary tissue ischemia. However, wound infection, myocardial damage, morbid cardiac events, increased adrenergic activity, prolonged recovery and hospital stay, shivering, and increased mortality after major trauma are among the negative effects of hypothermia [1].

General anesthetics can inhibit the hypothalamic thermoregulatory center. Although regional anesthesia does not have any effect on the thermoregulatory center, it can block thermal afferent sensory perception distal to the block level. In both methods of anesthesia, hypothermia occurs by redistribution of body temperature from the central to the colder peripheral regions [1, 2]. In the following period, hypothermia increases when the loss of temperature because of the redistribution is greater than the heat produced by metabolism [1, 3]. However, studies of the effects of peripheral nerve blocks on thermoregulation have not been reported in the literature.

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The purpose of this study was to investigate the effects of three commonly used anesthetic techniques (general anesthesia, epidural anesthesia, and femoral-sciatic block) and two different ambient temperatures on thermoregulation for patients undergoing lower extremity surgery.

Materials and methods

A prospective randomized clinical trial (ACT-RN12612000812897) was started after approval from the Faculty Ethics Committee. The study was included 90 male patients aged between 18 and 90 years whose physical status was in American Society of Anesthesiologists Physical Status (ASA) groups I or II and were scheduled for lower extremity surgery. In all cases, to avoid errors in body temperature measurement arising from diurnal rhythm, body temperature measurements were taken in the morning between 0830 and 1300 hours.

Patients with inflammatory diseases, diabetes mellitus, muscle disease, hypo/hyperthyroidism, cardiac, hepatic, and renal diseases, Parkinson disease, Reynold syndrome, a history of using drugs that are known to affect body temperature, regional anesthesia contraindications, drug and alcohol addiction, obesity, and those with allergies to local anesthetics were excluded from the study. Because body temperatures are affected by the menstrual cycle, female patients were not included in the study. In addition, patients whose surgery was shorter than 60 min and longer than 180 min and those surgery required use of a tourniquet were also excluded from the study. Patients having a greater than 30 % change in hemodynamic data during surgery, those who needed use of a vasopressor or vasodilator, and those who required a blood transfusion were also excluded from the study.

Randomization of patients was achieved by use of opaque envelopes. After giving oral and written consent, patients were divided into three groups according to their applied anesthesia technique: Group GA (general anesthesia, $n = 30$), Group EA (epidural anesthesia, $n = 30$), and Group FS (femoral sciatic block, $n = 30$). Each of these groups was then divided into two on the basis of the ambient temperature of the operating theater, which was either 20–22 or 23–25 °C. Thus the final distribution of the patients was into six subgroups is as follows: Group GA I, patients undergoing general anesthesia (GA) ($n = 15$) with an operating theater temperature (RT) of 20–22 °C; Group GA II, patients undergoing GA ($n = 15$) with an operating theater temperature of 23–25 °C; Group EA I, patients undergoing epidural anesthesia (EA) ($n = 15$) with an operating theater temperature of 20–22 °C; Group EA II, patients undergoing EA ($n = 15$) with an operating theater temperature of 23–25 °C; Group FS I, patients undergoing femoral sciatic block (FS) ($n = 15$) with an operating theater temperature of 20–22 °C; and Group FS II, patients undergoing FS ($n = 15$) with an operating theater temperature of 23–25 °C.

None of the patients received premedication. When the patients were on the operating table their heart rate (HR), noninvasive blood pressure (NIBP), and pulse oximeter (SpO_2) were monitored, and probes for the measurement of peripheral temperature were placed in the axilla, and on the chest, arms, ½ medium inner face of the forearm, the middle finger, thigh, and calf. Tympanic temperature was measured by use of a Genius 2 Tm Accusystem device (Kendall, Mansfield, Massachusetts, USA) whereas peripheral temperature was measured by use of a Draeger monitor (Draeger Cato Edition, Germany). Blood pressure measurement and fluid infusion were not performed on the arm used to measure temperature.

Vascular access was achieved via a 20 G cannula, and isotonic saline (NaCl 5 ml/kg/h 0.9 %) held at room temperature was infused. After GA group patients received preoxygenation with 100 % O_2, induction of anesthesia was achieved with sodium thiopental (3–6 mg/kg), vecuronium bromide (0.1 mg/kg), and fentanyl (2 μg/kg). After endotracheal intubation, anesthesia was maintained with desflurane (5–6 %) in 50 % N_2O–50 % O_2. Respiration was continued mechanically and was adjusted to 30–40 mmHg $ETCO_2$. In addition, to partially humidify and heat inhaled gases, a disposable humidifier was added to the breathing circuit. To remove the residual muscle relaxant effects during recovery from anesthesia, neostigmine (0.04 mg/kg), and when required, intravenous atropine (0.01 mg/kg) were used. When laryngeal reflexes and adequate spontaneous breathing returned, the patients were extubated.

Epidural anesthesia was performed at the L4–5 level in accordance with the loss of resistance technique. Lidocaine (2 %, 3 ml) was given as a test dose before waiting for 5 min. After receiving a negative response to the test dose, levobupivacaine (0.5 %, 10–20 ml) and fentanyl (50 μg) were administered. Oxygen (3 l/min) was given to patients with a facemask. The level of sensory block was checked at 5-min intervals by the pinprick test, and additional doses were administered as needed. Patients with a degree of sensory block up to T10 were included in the study, but patients who developed higher levels of sensory block were excluded.

In Group FS, the sciatic nerve block was performed in accordance with Labat's technique, with a nerve stimulator (Stimuplex HNS 11; Braun Freiburg, Germany). The initial current of the nerve stimulator was set to 1.5–2 mA, and after plantar or dorsal flexion was obtained, the current was reduced to 0.3–0.5 mA. After a negative aspiration test, levobupivacaine (0.375 %, 25 ml) was injected. Femoral block also was guided by use of a nerve stimulator. When quadriceps femoris muscle contractions and patella movements were seen at 0.3–0.5 mA, levobupivacaine solution (0.375 %, 20 ml) was injected.

After administration of regional anesthesia, patients were wrapped with a single layer cloth and oxygen (3 l/min) was given via a mask until adequate anesthesia was achieved. The level of anesthesia was checked every 5 min in the perioperative period.

When patients were on the operating table, their heart rate (HR), mean arterial pressure (MAP), and tympanic and peripheral temperatures were measured immediately before the induction of anesthesia (baseline), and 5, 10, 15, 20, 30, 45, 60, 90, and 120 min after induction of anesthesia. After the operation, patients were transferred to the postanesthesia care unit and their tympanic membrane and axillary temperature, visual analog scale (VAS) pain score, shivering (0: no shivering, 1: presence of one or more of the following findings: piloerection without muscle movement, peripheral vasoconstriction, peripheral cyanosis, 2: presence of muscle activity observed in only one muscle group, 3: muscle activity present in more than one muscle group, 4: significant muscle activity covering the whole body) [4], and nausea and vomiting scores (0: no nausea or vomiting, 1: mild nausea, 2 : nausea and retching, 3: single vomiting, 4: multiple vomiting) were recorded.

Mean skin temperature (MST) was calculated by use of the formula (0.3 (Tarm + Tchest) + 0.2 (Tthigh + Tleg)) [4], and mean body temperature (MBT) was calculated by use of the formula (0.85 × Tcentral + 0.15 × Tskin) [5]. At the end of 1-h follow-up in the postanesthesia care unit, patients with a modified Aldrete score of nine and above were discharged to services.

Statistical analysis was performed using SPSS 15.0 (Statistical Package for Social Sciences for Windows 15.0) software. Results were expressed as mean ± standard deviation (SD). To evaluate age, operation duration, surgical and recovery room temperature, HR, MAP, tympanic and other temperatures between groups, a distribution of variance of analysis was used. Furthermore, comparison between groups was performed by means of the post-hoc Tukey HSD test. Nonparametric data (ASA PS, VAS, shivering, and PONV score) were evaluated by use of the Mann–Whitney *U* test. A paired sample *t* test was used for evaluation of intra-group repeated measurements; $p < 0.05$ was considered significant.

Results

In GA group, two patients who required a blood transfusion and operation duration exceeding 3 h were excluded. In the EA group, two patients developed inadequate block were excluded. The study included new patients instead of the excluded patients.

No significant differences were observed among groups when patients were compared for age, ASA physical status, surgery duration, and recovery room temperature ($p > 0.05$). When we compared groups for surgical room temperature, the room temperatures of groups GA I, EA I, and FS I were significantly lower than for groups GA II, EA II, and FS II ($p < 0.001$) (Table 1).

In all groups, administration of anesthesia led to a decrease of tympanic temperature (Fig. 1) and MBT (Fig. 2), whereas MST increased (Fig. 3) during all periods compared with the baseline period ($p < 0.05$).

Different operating theater temperatures did not significantly affect tympanic temperature, MST, or MBT for patients from groups given epidural anesthesia and femoral sciatic block. Tympanic temperature was not significantly different among patients undergoing general anesthesia. However, MST was significantly lower in group GA I than in group GA II after 5, 10, 15, 20, 60, and 90 minutes. Moreover, MBT was also significantly lower in the baseline period in group GA I than in group GA II ($p < 0.05$).

At different operating theater temperatures, when we evaluated the effect of anesthetic technique on tympanic temperature, MST, and MBT, we determined that the choice of anesthetic technique at either room temperature did not significantly affect tympanic temperature and MBT. However, when the effects of anesthetic technique on MST at a operating theater temperature of 20–22 °C were compared, MST after 5 minutes was significantly lower in group GA I than in group FS I ($p < 0.05$).

Intraoperative heart rate was not significantly different among groups. Intraoperative MAP in the EA groups was significantly lower than that in the GA groups after 45 and 90 minutes and that in the FS groups after 120 minutes. When MAP in the GA groups was compared with that in the FS groups, the GA groups had significantly lower MAP after 15, 30, and 45 minutes than the FS groups. In addition, MAP in the EA groups was significantly lower after 30 and 45 minutes than in the FS group ($p < 0.05$).

In the recovery period, tympanic and axillary temperatures were not significantly different among groups. Postoperative shivering score was higher in group GA I than in groups EA I or EA II. Moreover, shivering score for group FS I was higher than that for group EA I ($p < 0.05$) (Fig. 4).

Postoperative nausea and vomiting scores were not significantly different among groups (Fig. 5). Furthermore, VAS scores for groups GA I and GA II were significantly higher than for the other groups ($p < 0.01$). The VAS scores in groups EA II and FS I were higher than in group EA I. Moreover, the VAS scores in group EA II were higher than those in group FS II (Fig. 6).

Table 1 Demographic data of groups (mean ± SD)

Group	Age (year)	ASA	Duration of anesthesia (min)	Operation room temperature (°C)	PACU temperature (°C)
GA I	31.13 ± 11.49	1.33 ± 0.48	90.33 ± 31.47	21.66 ± 0.48*	25.93 ± 1.57
GA II	34.40 ± 14.19	1.47 ± 0.51	89.00 ± 27.72	24.20 ± 0.67	26.8 ± 1.52
EA I	39.67 ± 14.76	1.60 ± 0.50	75.00 ± 29.21	21.66 ± 0.48*	26.66 ± 0.97
EA II	36.40 ± 17.11	1.60 ± 0.50	90.00 ± 31.67	23.86 ± 0.51	27.00 ± 1.00
FS I	37.07 ± 16.93	1.33 ± 0.48	79.33 ± 32.17	21.66 ± 0.48*	26.13 ± 1.45
FS II	44.93 ± 18.70	1.53 ± 0.51	62.00 ± 11.46	24.46 ± 0.63	26.40 ± 1.54

* $p < 0.001$

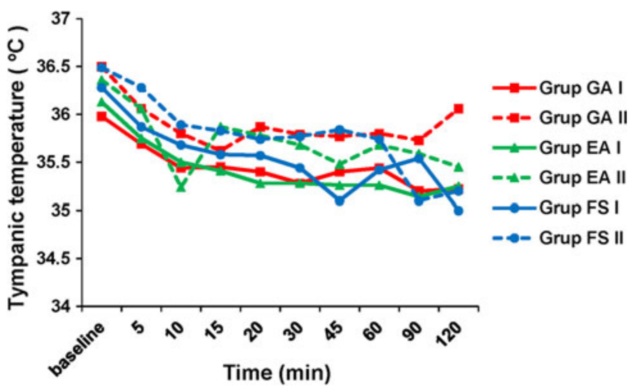

Fig. 1 Tympanic temperature of groups

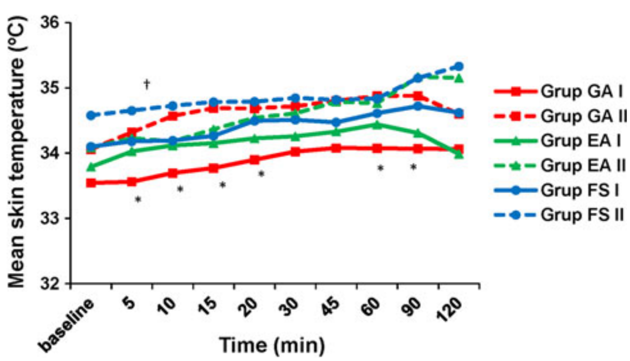

Fig. 2 Mean skin temperature of groups

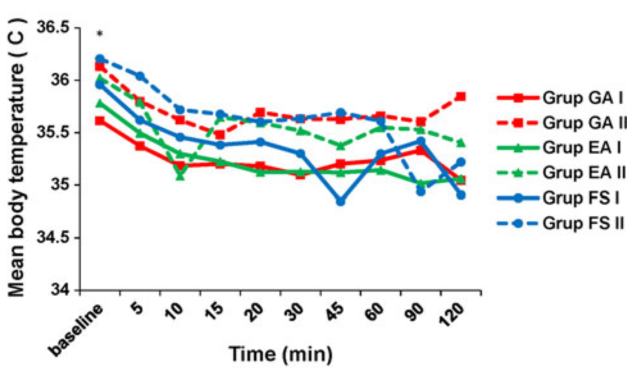

Fig. 3 Mean body temperature of groups

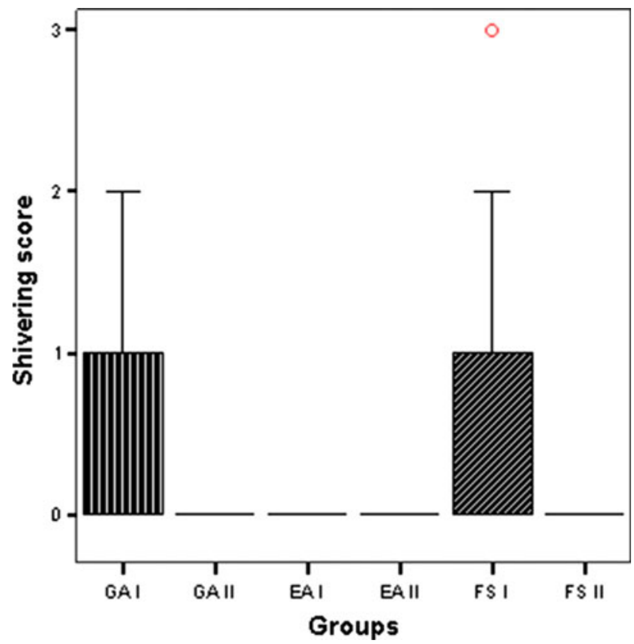

Fig. 4 Shivering scores of the groups

Discussion

Perioperative hypothermia is one of the most common thermal disorders in the practice of anesthesia today. Because of its complications, it is crucial to prevent or treat hypothermia to reduce the risks of anesthesia and surgery. The normal thermoregulatory mechanism of the human body, and changes to this mechanism which occur because of anesthesia have been extensively studied. In this study, our purpose was to investigate the effects of anesthetic technique and ambient temperature on thermoregulation in patients undergoing lower extremity surgery.

In a study in which the development of factors affecting hypothermia during anesthesia for infants and newborn patients was examined, patients were divided into groups according to room temperature (<23 and >23 °C). Mean central temperature decreased significantly, and the central temperature of patients in the room at the lower temperature decreased until the end of the operation. Reduction in

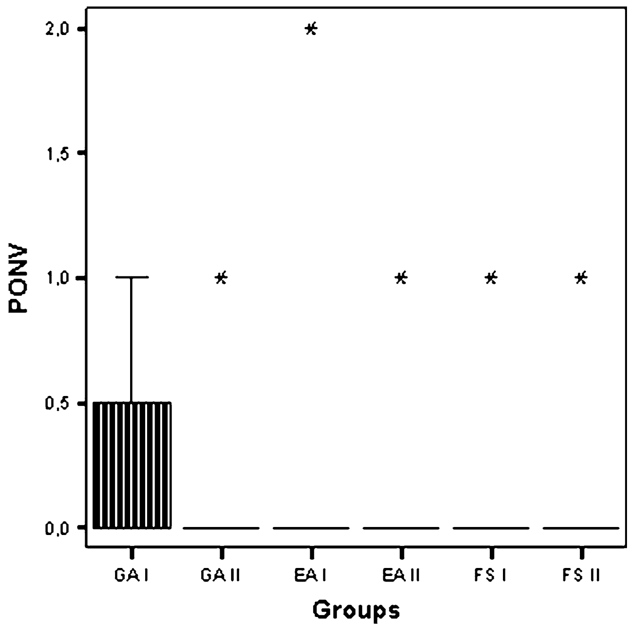

Fig. 5 PONV scores of the groups

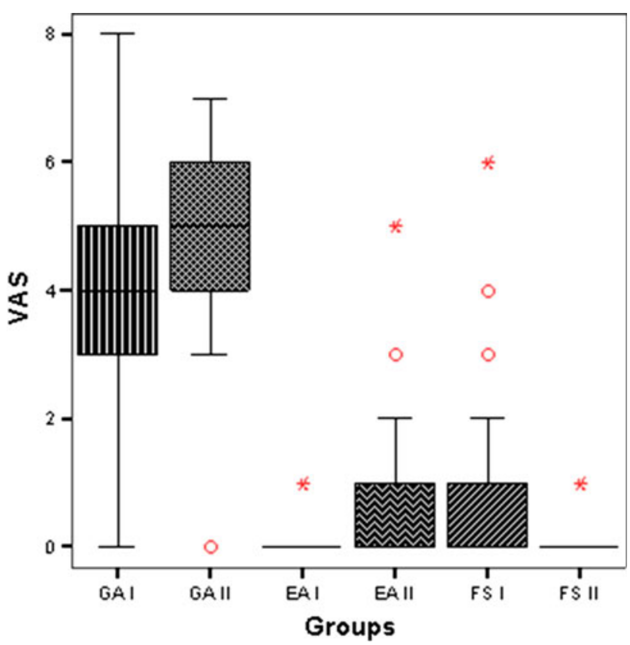

Fig. 6 VAS scores of the groups

central temperature was greatest for newborn patients undergoing major surgery at low room temperature. This ambient temperature alone reduced the patient's central temperature by a factor of 1.96 [6].

In another study investigating the effects of room temperature on body temperature, it was determined that a room temperature of 21 °C reduces inadvertent hypothermia during epidural anesthesia. However, a warmer environment is needed to maintain the body temperature when general anesthesia is used [7].

In our study, which was performed at room temperatures from 21 to 22 and from 23 to 25 °C, there was no significant difference between tympanic temperatures for all methods of anesthesia. This can be explained by the fact that both room temperatures were within the accepted range for anesthetic applications, and that our study did not include pediatric and geriatric patients, for which hypothermia tendency is high. Moreover, similar to literature reports, patients undergoing general anesthesia had significantly higher MST and MBT when the room temperature was 21–22 °C than when the room temperature was 23–25 °C. As a result, it can be suggested that the room temperature is an important factor affecting thermoregulation for patients undergoing general anesthesia compared with other anesthetic techniques.

In their study with caesarean section patients undergoing epidural and general anesthesia, Yentur et al. [8] measured core temperature rectally. Core temperatures were not significantly different in any of the periods between epidural and general anesthesia. Jenkins, et al. [9] evaluated the effects of general and epidural anesthesia on changes in body temperature during transvesical prostatectomy. In patients undergoing epidural anesthesia, total body temperature and MBT decrease more quickly, but a net temperature loss was observed for both groups 6 hours after surgery. Another study comparing the effects of general and epidural anesthesia in patients undergoing radical prostatectomy showed that tympanic temperature was similar for both groups [10].

In our study, we observed a decrease in tympanic temperature for all methods of anesthesia, but there was no significant difference between groups. As Frank et al. [11] suggested the extent of block in spinal anesthesia is an important factor in the development of hypothermia. In our study, patients received epidural anesthesia with a sensory block level up to T10, and patients who developed higher levels of sensory block were excluded. Therefore, tympanic temperature, MBT, and MST were not significantly different for patients undergoing either general anesthesia or epidural anesthesia.

Distal extremities have low resistance to arteriovenous anastomosis with excessive innervated sympathetic vasoconstrictor nerves. Therefore, there is an increase in skin temperature after peripheral nerve blocks of the distal extremities [12]. Stevens et al. [13] investigated the possibility of using skin temperature as an initial predictor of success of the block in epidural anesthesia and femoral sciatic block. Increase in skin temperature because of the sensory block in patients undergoing femoral sciatic block was observed, but was shown to be slower than the increase resulting from epidural anesthesia.

There are no studies in the literature investigating core temperature variation for patients undergoing peripheral nerve block. We did not detect significantly different tympanic temperature and MBT among patients undergoing femoral sciatic block, general anesthesia, or epidural anesthesia. However, MST was significantly lower for patients undergoing general anesthesia than for those with femoral sciatic block at an operating theater temperature between 20 and 22 °C.

Shivering that occurs during the early postanesthesia period is a major postoperative problem. The incidence of shivering in the postoperative period has been reported to be between 5 and 65 % after general anesthesia and up to 33 % after epidural anesthesia [14, 15]. Shivering impairs the patient's comfort, and can affect release of catecholamines and cause an increase in oxygen consumption, which may cause serious morbidity [16, 17]. Therefore, it is important to prevent shivering.

In our study, evaluation of postoperative shivering between groups showed that Group GA I had more shivering than the EA I and EA II groups. Lislie et al. [18] showed that the decrease of the shivering threshold value was proportional to the number of blocked spinal segments. Because the epidural anesthesia groups in our study only included patients with a sensory block level up to T10, the group with the lowest shivering score was the epidural anesthesia group. In addition, shivering scores for group FS I were higher than for group EA I. We did not evaluate the shivering threshold in our study. But, in previous studies, it has been demonstrated that general and epidural anesthesia reduced the shivering threshold [18–21]. With regard to the causes of shivering in group FS I we believe:

1 Although shivering threshold decreased in group EA I, shivering threshold did not decrease in group FS I. Therefore, shivering occurred at higher body temperature in group FS I.
2 Shivering may also have been caused by a reason other than hypothermia.

Similar to the literature, VAS scores in our study for patients undergoing general anesthesia were higher than those who received regional anesthesia [22, 23]. Although VAS scores among groups receiving regional anesthesia were statistically significantly different, the difference was not clinically significant. Because VAS scores for all patients were less than 3, analgesia was considered to be close to ideal.

In our study, we investigated the effects of different anesthetic techniques—general anesthesia, epidural anesthesia, and femoral sciatic block—and the effect of ambient temperature on thermoregulation in patients undergoing lower extremity surgery without the use of a tourniquet. We observed that tympanic temperature and MBT decreased, whereas MST increased with induction of anesthesia in all groups. However, tympanic temperature and MBT were not significantly different among the different anesthetic techniques. When room temperature was 20–22 °C, MST was significantly lower for patients undergoing general anesthesia than for those administered femoral sciatic block. When the effect of room temperature on thermoregulation was evaluated, tympanic temperature was not significantly different among the groups. We found a significant difference in MST and MBT between room temperatures (20–22 and 23–25 °C) only for patients undergoing general anesthesia. However, one of the limitations of our study is that we did not investigate the shivering threshold.

In conclusion, core temperature decrease for patients undergoing lower extremity surgery may develop for all methods of anesthesia including peripheral nerve block. This decrease was most important for patients undergoing general anesthesia. Thermoregulation was not significantly different among anesthetic methods but room temperature changed thermoregulation in general anesthesia. Therefore, we conclude that hypothermia may develop in all methods of anesthesia, with that in general anesthesia being more significant.

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