Epidural versus General Anesthesia, Ambient Operating Room Temperature, and Patient Age as Predictors of Inadvertent Hypothermia

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To elucidate the multifactorial nature of perioperative changes in body temperature, the influence of several clinical variables, including anesthetic technique, ambient operating room temperature, and age, were evaluated. Perioperative oral sublingual temperatures were measured in 97 patients undergoing lower extremity vascular surgery randomized to receive either general (GA) or epidural (EA) anesthesia. Surgery and anesthesia were performed in operating rooms (OR) with a relatively warm mean ambient temperature (24.5 ± 0.4°C) (GA, n = 30; EA, n = 33) or relatively cold mean ambient temperature (21.3 ± 0.3°C) (GA, n = 21; EA, n = 13). Patients were 35-94 yr old, with a mean age of 64.5 ± 1.1 yr. A regression analysis was performed to determine the variables that correlated with intraoperative decrease in temperature and postoperative rewarming rate. The major correlates of greater intraoperative decrease in temperature were 1) GA (P = 0.003); 2) cold ambient OR temperature (P = 0.07); and 3) advancing patient age (P = 0.03). There was significant interaction between ambient OR temperature and type of anesthesia (P = 0.03): there was a greater intraoperative decrease in temperature with GA compared to EA in a cold OR but a smaller decrease with GA and EA in a warm OR. The data also suggest an interaction between type of anesthesia and patient age (P = 0.06), showing a greater decrease in temperature with GA compared to EA in the younger patients, but a similar decrease between GA and EA in older patients. Age was the only significant determinant of postoperative rewarming rate, with the older patients taking longer to rewarm (P = 0.0003). The results suggest that temperature is reduced by GA to a greater degree than by EA when ambient OR temperature is cold, but this difference between GA and EA is not significant when ambient OR temperature is relatively warm. Also, the ability to maintain temperature during anesthesia decreases with advancing age. (Key words: Age; hypothermia. Anesthetic techniques: epidural; general. Operating room; ambient temperature. Temperature: regulation.)

REGULATION OF BODY TEMPERATURE IN THE SURGICAL PATIENT HAS IMPORTANT IMPLICATIONS. HYPOTHERMIA IS COMMON IN THE PERIOPERATIVE PERIOD AND CAN HAVE ADVERSE PHYSIOLOGIC EFFECTS, INCLUDING CARDIAC ARRHYTHMIAS, COAGULOPATHIES, ALTERED LEVELS OF CONSCIOUSNESS, DECREASED DRUG METABOLISM, IMPAIRED RENAL FUNCTION, AND A LEFTWARD SHIFT IN THE HEMOGLOBIN OXYGEN SATURATION CURVE, RESULTING IN DECREASED OXYGEN DELIVERY TO THE TISSUES. POSTOPERATIVE SHIVERING HAS BEEN SHOWN TO INCREASE TOTAL BODY OXYGEN CONSUMPTION BY AS MUCH AS 400%, WHICH, ALONG WITH THE ASSOCIATED INCREASE IN CARDIAC OUTPUT, CAN INCREASE MORBIDITY IN PATIENTS WITH CARDIOPULMONARY DISEASE. GENERAL ANESTHETICS HAVE BEEN SHOWN IN SEVERAL STUDIES TO INDUCE HYPOTHERMIA VIA INHIBITION OF THERMOREGULATION.5-8 THERE IS SOME EVIDENCE TO SUGGEST THAT THERMOREGULATION IS MAINTAINED WITH EPIDURAL ANESTHESIA (EA)5,9 DESPITE VASODILATION FROM SYMPATHETIC NERVOUS SYSTEM BLOCKADE. FEW STUDIES HAVE COMPARED GENERAL ANESTHESIA (GA) AND EA WITH RESPECT TO PERIOPERATIVE CHANGES IN BODY TEMPERATURE, AND THESE STUDIES HAVE INCLUDED SMALL NUMBERS OF PATIENTS WITH INCONSISTENT RESULTS. ONE INVESTIGATOR SHOWED A GREATER INCIDENCE OF HYPOTHERMIA WITH GA2; OTHERS HAVE SHOWN A GREATER INCIDENCE WITH EA.10,11

It has been demonstrated that ambient temperature can influence body temperature in anesthetized patients5,4,12,13 but the interaction between ambient temperature and anesthetic technique has not been investigated. This issue is relevant because the operating room (OR) staff is more comfortable in a cooler environment, whereas the maintenance of the patient's body temperature may require a warm environment.

Elderly patients are considered to have a decreased ability to maintain normal body temperature, even in the unanesthetized state.14,15 During anesthesia, it is not clear how age influences body temperature control. Studies that address this issue provide conflicting evidence that advancing age either does16,17 or does not18 interfere with thermoregulation. These investigations are misleading, however, because they include patients with a wide variety of surgical procedures; the one study that compared regional anesthesia with GA did not do so in a randomized fashion.16

Thermoregulatory research has demonstrated that assessment of alteration of body heat conservation is a complex matter, requiring the determination of "core" tem-

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perature as well as mean body temperature. Routine clinical care in awake patients, however, continues to employ oral, sublingual temperature measurements with modern, low-time-constant, digital instruments. The present investigation reports on changes in body temperature measured orally in a group of patients undergoing lower extremity vascular bypass grafting; patients were randomized to receive either EA or GA. We hypothesized that multiple factors may interfere with maintenance of temperature in the perioperative period. Several clinical variables, including anesthetic technique, ambient temperature, and age, were analyzed in a multivariate fashion not only to identify the effects of these factors alone, but to identify possible interactions among these factors.

Materials and Methods

After approval was received from the Committee of Clinical Investigations and written informed consent was obtained, 97 patients scheduled for lower extremity vascular reconstruction were randomized to receive either GA (n = 51) or EA (n = 46). Three patients initially randomized to receive EA actually received GA because of failed epidural block. Data analysis was performed according to the anesthetic the patients received: GA (n = 54), EA (n = 43).

Surgery was performed in either 1) a group of ORs with a relatively warm mean ambient temperature maintained at 24.5 ± 0.4°C or 2) a single OR with a relatively cold mean ambient temperature of 21.3 ± 0.3°C. The ambient temperatures were measured with an electronic temperature monitor (model 43TA, Yellow Springs Instrument Co., Yellow Springs, OH). The thermistor probe was placed near the patient, but not in proximity to the heat-generating monitoring equipment. The "cold" OR was maintained as such because this room was also used for cardiac surgery with hypothermic cardiopulmonary bypass. The airflow system in all rooms was nonrecirculating, and no rooms had a laminar flow system. Assignment to rooms was not controlled or formally randomized but was based on scheduling rules and OR availability. Patients were 35–94 yr old, with a mean age of 64.5 ± 1.1 yr. Patient assignment by type of anesthesia received, and ambient OR temperature is summarized in table 1.

Anesthetic management was dictated by protocol. All patients were premedicated with intramuscular midazolam (0.05 mg/kg). A lumbar approach with a 17-G needle was used to perform EA. A 3-mL test dose of 0.75% bupivacaine with 5 μg/ml epinephrine, followed by a 7-mL dose of 0.75% bupivacaine, was given through the needle. Supplemental doses were given via an epidural catheter as needed to maintain a sensory block at the T6–T8 level, as assessed by loss of sharp sensation to pinprick. Injectate was at room temperature. Patients receiving EA were sedated during surgery with midazolam in 0.5-mg increments and fentanyl in 25-μg increments given intravenously as needed to maintain sedation. All patients receiving EA were arousable and able to respond to verbal commands.

General anesthesia was induced with thiopental (2–6 mg/kg), fentanyl (5–10 μg/kg), and succinylcholine (1 mg/kg) administered intravenously. The trachea was intubated in all patients, and anesthesia was maintained with 0.5%–1.0% enflurane and 50% nitrous oxide in oxygen delivered through a mixed gas system at a fresh gas flow rate of 4 L/min. Pancuronium (0.05 mg/kg) was given intravenously immediately after induction. Mechanical ventilation was adjusted to maintain end-tidal P\textsubscript{CO\textsubscript{2}} at 35–40 mmHg. All patients receiving GA were given incremental doses of morphine sulfate (0.05–0.2 mg/kg) intravenously during emergence to maintain a respiratory rate of 10–15 breaths/min and an end-tidal P\textsubscript{CO\textsubscript{2}} of 35–50 mmHg. All patients were breathing spontaneously and had the endotracheal tube removed at the end of the surgical procedure before leaving the OR.

Postoperative analgesia was controlled by protocol. Patients in the EA group were given epidural fentanyl (100 μg) in 10 mL saline during skin closure, followed by an epidural fentanyl infusion of 50 μg/h with a concentration of 5 μg/mL. The infusion was increased up to 200 μg/h as needed to ensure adequate analgesia. Patients in the GA group were given intravenous morphine sulfate delivered by patient-controlled analgesia, with a baseline rate

<table>
<thead>
<tr>
<th>Type of Anesthesia, Ambient Operating Room Temperature</th>
<th>n</th>
<th>Preoperative Temperature (°C)</th>
<th>Crystallloid (L)</th>
<th>Units of Blood Transfused</th>
<th>Operating Room Time (hours)</th>
<th>Age (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General, warm</td>
<td>33</td>
<td>36.5 ± 0.1</td>
<td>3.4 ± 0.2</td>
<td>0.7 ± 0.2</td>
<td>6.6 ± 0.5</td>
<td>65.2 ± 2.0</td>
</tr>
<tr>
<td>General, cold</td>
<td>21</td>
<td>36.6 ± 0.1</td>
<td>3.4 ± 0.3</td>
<td>0.8 ± 0.4</td>
<td>4.4 ± 0.3*</td>
<td>68.2 ± 2.1</td>
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<tr>
<td>Epidural, warm</td>
<td>30</td>
<td>36.6 ± 0.1</td>
<td>2.9 ± 0.2</td>
<td>0.7 ± 0.2</td>
<td>5.1 ± 0.3*</td>
<td>62.9 ± 2.0</td>
</tr>
<tr>
<td>Epidural, cold</td>
<td>13</td>
<td>36.4 ± 0.1</td>
<td>3.8 ± 0.6</td>
<td>1.2 ± 0.5</td>
<td>5.5 ± 0.4</td>
<td>60.2 ± 3.2</td>
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* P ≤ 0.05 versus general, warm.

† P ≤ 0.05 versus general, cold.
of 0.5 mg/h and a bolus dose of 1 mg with a lockout interval of 10 min.

All intraoperative body-heat-conserving measures were performed in accordance with protocol and were the same for all patients, regardless of the ambient temperature in the OR. All intravenous fluids and blood were given through a warming device with an approximate infusion temperature of 30–35° C (Fenwal model BW-5, Deerfield, IL). During GA, inspired gases were humidified and warmed to approximately 38–39° C (Conchatherm III, Arlington Heights, IL). Heating blankets or pads were not used in the OR or during the postoperative period. A single cotton hospital blanket covered with sterile paper drapes was used to cover the abdomen, chest, and arms of all patients during the surgical procedure. Cotton blankets were used to cover all patients in the postoperative period.

Intravenous fluid and blood was administered in accordance with routine clinical practice. All patients received approximately 10 ml/kg of warmed isotonic crystalloid solution before either epidural dosing or induction of GA. Urine output was monitored continuously as a guide to intravenous volume and fluid requirements. The hematocrit was maintained near 30% with transfusion of packed red blood cells when necessary.

Oral temperatures were measured with an electronic digital thermometer (IVAC Temp-plus II, San Diego, CA) placed sublingually. This instrument was maintained and calibrated in accordance with the manufacturer’s guidelines. Preoperative temperatures were measured just before transport to the OR. Postoperative temperatures were measured immediately after surgery on arrival at the intensive care unit and every hour for 24 h. Temperatures were obtained by experienced nurses who insured sublingual placement and mouth closure during measurement. In the postoperative period, all patients were without oral intake and were breathing nonhumidified, nonhumidified oxygen by face mask at approximately 4 l/min. The intraoperative change in temperature was defined as the first postoperative temperature minus the preoperative temperature. The time from admission to the intensive care unit until warming to 36° C was used to assess postoperative rewarming rate. Presence or absence of shivering was determined by visual examination of the patient 1 h after admission to the intensive care unit.

**Statistical Analysis**

Demographic data were analyzed with a one-factor analysis of variance. Discrete variables were analyzed with chi-square analysis and Fisher’s exact tests. Continuous variables were analyzed with an unpaired, two-tailed Student’s t test. Analysis of the effect of several variables on changes in body temperature was done with a multiple linear regression analysis with backward elimination.10 P ≤ 0.12 was used as the criterion for retaining variables in the regression. All values are given as mean plus or minus standard error of the mean. For all statistical comparisons, P ≤ 0.05 was considered significant. All analyses were performed with the StatView 512+© computer program (BrainPower Inc., Calabasas, CA).

**Results**

There were no significant differences among the four patient groups (GA/warm OR, GA/cold OR, EA/warm OR, EA/cold OR) regarding preoperative oral temperatures or intraoperative crystalloid and blood administration (table 1). Patients receiving GA in a cold OR and patients receiving EA in a warm OR had less OR time compared to those receiving GA in a warm OR. Also, patients receiving EA in a cold OR had a lower mean age than those receiving GA in a cold OR.

Correlates of intraoperative decrease in temperature are shown in table 2. Variables significantly related to a greater decrease in intraoperative temperature were GA (P = 0.003) and advancing patient age (P = 0.03). The relationship between patient age and intraoperative decrease in temperature is illustrated in figure 1. Although not statistically significant at P ≤ 0.05, the analysis suggests that a cold ambient OR temperature is associated with a greater decrease in temperature (P = 0.07). There was significant interaction (P = 0.03), however, between ambient OR temperature and type of anesthesia: there was a greater intraoperative decrease in temperature with GA (1.8 ± 0.2° C) compared to EA (0.8 ± 0.2° C) in a cold OR, but a similar decrease between GA (1.0 ± 0.2° C) and EA (1.0 ± 0.2° C) in a warm OR (fig. 2). The data also suggests an interaction (P = 0.06) between type of

<table>
<thead>
<tr>
<th>Correlate</th>
<th>Coefficient</th>
<th>P</th>
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<tbody>
<tr>
<td>Time spent in the operating room</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Crystalloid administration</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Units of blood transfused</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Ambient operating room temperature–age interaction</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Ambient operating room temperature*</td>
<td>−2.11</td>
<td>0.07</td>
</tr>
<tr>
<td>Epidural or general anesthesia†</td>
<td>−5.22</td>
<td>0.003</td>
</tr>
<tr>
<td>Patient age</td>
<td>−0.11</td>
<td>0.09</td>
</tr>
<tr>
<td>Epidural or general anesthesia–age interaction</td>
<td>0.036</td>
<td>0.06</td>
</tr>
<tr>
<td>Epidural or general anesthesia–ambient operating room temperature interaction</td>
<td>0.98</td>
<td>0.03</td>
</tr>
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</table>

NS = not significant; these variables were eliminated in backward elimination regression analysis.
* Coded 0 = warm; 1 = cold.
† Coded 0 = epidural; 1 = general.
Anesthesia and patient age, showing a greater decrease in temperature with GA (1.3 ± 0.2°C) compared to EA (0.6 ± 0.2°C) in the younger patients, but a similar decrease between GA (1.4 ± 0.2°C) and EA (1.3 ± 0.3°C) in the older patients (fig. 3).

Variables that did not influence intraoperative decrease in temperature include duration of time in the OR, intraoperative volume of intravenous crystalloid and units of blood transfused, and interaction between ambient OR temperature and patient age. These variables were eliminated from the regression analysis with \( P \geq 0.12 \).

The time required to rewarmin 36°C was used to assess rewarming rate in the postoperative period. Of all variables entered into the regression analysis, age was the only one that significantly influenced rewarming rate (\( P = 0.0003 \)) (fig. 4). The older the patient, the longer it took to rewarmin the postoperative period. Variables that were entered into the regression but did not influence rewarming were duration of time in the OR, intraoperative volume of intravenous crystalloid, units of blood transfused, ambient temperature in the OR, and type of anesthesia.

There was a greater incidence of shivering assessed 1 h into the postoperative period in patients receiving EA (10/42 [24%]) compared to those receiving GA (5/53 [9%]) \( P \leq 0.05 \). The time required to rewarmin 36°C during the postoperative period for patients with and without shivering 1 h after surgery is shown in figure 5. Shivering patients required significantly less time to rewarmin compared to nonshivering patients \( P = 0.04 \).

**Discussion**

These results show that not only GA, but also a cold ambient OR temperature and advanced patient age can significantly interfere with the maintenance of temperature during anesthesia and surgery. Prior investigations have examined these issues, but this study is unique because we have identified interactions among these variables by using multivariate analysis on a large number of
patients having similar surgical procedures that were randomized to anesthetic technique.

Our data show that GA is associated with greater intraoperative decrease in temperature compared to EA when the ambient OR temperature is relatively cold, but there is little difference between GA and EA when the ambient temperature is warm. Insofar as changes in oral sublingual temperature in our study may be considered to reflect central temperature, one can speculate on the physiologic mechanisms that would explain these results. Both GA and EA are known to alter function of the autonomic nervous system, which plays a significant role in the body temperature regulation. General inhalational anesthetics are thought to inhibit central thermoregulatory responses by suppressing the preoptic and hypothalamic nuclei, which are intimately involved in the integration of thermal information in the brain. In the doses used in the present study, GA has a less pronounced effect on the peripheral responses (vasoconstriction) that regulate body temperature. Unlike GA, EA spares the central nervous system and primarily interferes with peripheral vasoconstriction below the level of sympathetic blockade. The relative inhibition of the central versus peripheral regulatory responses with the two anesthetics may explain the better maintenance of temperature in the EA group.

The effects of ambient temperature on body temperature during anesthesia have not been clearly defined. Goldberg and Roe found no appreciable effect of ambient temperature in 101 patients receiving general inhalational anesthesia. They stated that 90% of the ORs were maintained at 20–23°C. Morris et al. defined 21°C as the critical ambient OR temperature at or above which body temperature is maintained during GA. Our results show that an ambient temperature of 21°C (mean temperature in our cold room) is adequate for the maintenance of temperature during EA, but a warmer environment is required for similar maintenance during GA.

The significant differences we have demonstrated between younger and older patients may reflect differences between GA and EA regarding body temperature control. It has been shown that unanesthetized elderly people have a somewhat impaired ability to maintain a constant body temperature. Our data suggest that EA does not alter the normal relationship between age and temperature maintenance, whereas GA appears to induce a poikilo-thermic state whereby the old and the young have a similar intraoperative decrease in temperature. In the postoperative period, the time required to rewarm to 36°C was longer in the elderly, regardless of type of anesthesia or ambient temperature in the OR. Thus, it appears that the time it takes patients receiving either GA or EA to return to baseline temperature maintenance after emergence from anesthesia is positively and directly related to patient age.

At 1 h into the postoperative period, fewer patients in the GA group were noted to be shivering. Although some patients may have stopped shivering by the time of observation, this finding is consistent with other studies comparing the two anesthetic techniques. In our study, the reduced incidence of shivering with GA may be related to the opioid administered during emergence from anesthesia. The reduced time that was required to rewarm the shivering patients suggests that postoperative shivering is an effective mechanism in temperature homeostasis.

The patient groups in our study were demographically comparable. There were differences, however, between the GA and EA groups in terms of duration in the OR and mean patient age. Duration in the OR, which has been shown to be related to change in body temperature, was not found to correlate with changes in oral temperature in our study. The relatively long duration of the surgical procedures in our study may explain this lack of correlation. Age was a significant correlate of oral temperature, and although the four groups of patients were not identical with regard to age, the difference in age should not influence the final results and conclusions because age was adjusted for by the regression analysis.

All patients enrolled in our study were undergoing peripheral vascular surgery specifically for atherosclerotic vascular disease distal to the inguinal ligament. Because no patients underwent intraabdominal or retroperitoneal procedures, the results of this study may not apply to patients undergoing these or other types of surgery. Also, the level of EA was maintained at the T6–T8 level, which is not associated with a large sympathetic blockade. For this reason, the findings in this study may not be applicable to patients with higher levels of EA. We are unable to comment on the effects of EA and GA combined because
no patient in this study received an anesthetic combination.

Oral temperatures may not be a reliable indicator of central temperature, and thus quantitative statements about thermoregulatory alterations are not possible from our data. It is unlikely, however, that our findings regarding the influence of age, ambient OR temperature, and type of anesthesia on oral sublingual temperature would vary systematically because of our methods. The use of this route for temperature measurement can be influenced by recent oral intake and temperature of the inspired gases. We reduced the potential for this artifact by requiring all patients to be without oral intake during the entire perioperative period. Also, all patients were breathing room air before surgery, and nonheated, nonhumidified oxygen was given by face mask at approximately 4 l/min during the postoperative period. To ensure proper technique, we obtained measurements with the mouth closed.

From this study, we conclude that, in a relatively warm environment, both GA and EA are associated with equal and minimal changes in body temperature. In a cold environment, GA is more likely to result in postoperative hypothermia compared to EA. Our findings also indicate that elderly patients require specific attention to prevent perioperative hypothermia, which may include additional measures not used in this study. The results presented here suggest that, depending on the type of surgery and associated patient disease, either EA or GA can be used and that the risk of hypothermia is similar between these anesthetic techniques as long as the ambient temperature in the OR is relatively warm.

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References