Intraoperative Phenylephrine Infusion Decreases the Magnitude of Redistribution Hypothermia

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Core hypothermia during the first hour after induction of general anesthesia results largely from an internal core-to-peripheral redistribution of body heat. This redistribution results from both central inhibition of tonic thermoregulatory vasoconstriction in the arteriovenous shunt and anesthetic-induced vasodilation. We therefore tested the hypothesis that acute administration of phenylephrine, a pure α-adrenergic agonist, reduces the magnitude of anesthetic-induced core-to-peripheral redistribution of body heat. Patients undergoing minor oral surgery were randomly assigned to an infusion of 0.5 μg·kg⁻¹·min⁻¹ phenylephrine IV or no treatment (control). The phenylephrine infusion was started immediately before anesthesia was induced with 2.5 mg/kg propofol IV. Subsequently, anesthesia was maintained with sevoflurane and 60% nitrous oxide in oxygen. Calf minus toe, skin-temperature gradients, 0°C were considered indicative of significant arteriovenous shunt vasodilation. Ambient temperature and end-tidal concentrations of maintenance sevoflurane were comparable in each group. Although there were no significant differences in skin-temperature gradients, core temperatures in the untreated patients decreased significantly more (1.2 ± 0.4°C) than in those given phenylephrine (0.5 ± 0.2°C, P < 0.001). These data suggest that maintaining precapillary vasoconstriction of blood vessels, not in the arteriovenous shunt reduces the magnitude of redistribution hypothermia. Implications: Core hypothermia immediately after induction of general anesthesia results largely from core-to-peripheral redistribution of body heat. Core temperature reduction during the first hour of anesthesia decreased less in patients given phenylephrine than in untreated controls. These data suggest that maintaining precapillary vasoconstriction possibly reduces the magnitude of redistribution hypothermia.

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Methods

With approval of the Ethics Committee at the Hamamatsu University School of Medicine and written informed consent, we studied 18 ASA physical status I-II patients undergoing minor oral surgery. None was obese, was taking medication, or had a history of thyroid disease, dysautonomia, or Raynaud’s syndrome.

Patients fasted for 10 h before arriving at the operating room. They were premedicated IM with 0.5 mg atropine and 20 mg famotidine 30 min before induction of anesthesia. A 20-gauge catheter was inserted into a left forearm vein for fluid and drug administration. The patients were randomly assigned, based on computer-generated codes, to an IV infusion of phenylephrine (0.5 μg·kg⁻¹·min⁻¹) or no treatment (control). The patients were blinded to group assignment and treatment, but the investigator was not. The phenylephrine infusion was started immediately before induction of anesthesia.

Anesthesia in both groups was induced with 2.5 mg/kg propofol IV. Endotracheal intubation was facilitated by IV administration of 0.1 mg/kg vecuronium bromide. Anesthesia was subsequently maintained with 0.2% end-tidal sevoflurane and 60% nitrous oxide in oxygen at a 6-L/min fresh-gas flow. Ventilation was controlled to maintain end-tidal carbon dioxide partial pressure near 35 mm Hg. Heat-and moisture-exchanging filters were positioned between the endotracheal tube and breathing circuit. IV fluids were warmed to 37°C and ambient temperature was maintained near 25–26°C. Patients were covered with a single cotton blanket and one layer of surgical drape.

Ambient temperature was measured by a thermocouple positioned at the level of the patient, well away from any heat-producing equipment. Mean skin temperature was calculated from four sites: 0.3 (Tchest + Tarm) + 0.2 (Tthigh + Tcall) (13). Calf minus toe skin-surface temperature gradients were used as an index of foot arteriovenous shunt perfusion. As in previous studies, we considered a leg gradient <0°C to indicate vasodilation (14).

Core temperature was measured at the tympanic membrane before induction of anesthesia using thermocouples. The aural probes were inserted by patients until they felt the thermocouple touch the tympanic membrane; appropriate placement was confirmed when patients easily detected a gentle rubbing of the attached wire. The aural canal was occluded with cotton, the probe securely taped in place, and a gauze bandage positioned over the external ear. All skin and tympanic membrane temperature probes were positioned on the patients’ right sides. After induction of anesthesia, core temperature was measured from the distal esophagus. All temperatures were measured using Mon-a-Therm® thermocouples (Mallinckrodt Anesthesiology Products, Inc., St. Louis, MO).

Heart rate was measured from a three-lead electrocardiogram. Blood pressure was determined oscillometrically at the left ankle. End-tidal sevoflurane and carbon dioxide concentrations were recorded from an Ultima monitor (Datex, Helsinki, Finland). Oxyhemoglobin saturation (SpO₂) was monitored by pulse oximetry. All values were recorded at 15-min intervals, starting immediately before induction of anesthesia (elapsed time zero).

Hemodynamic responses, end-tidal sevoflurane and carbon dioxide concentrations, ambient temperature, and mean skin temperatures were first averaged within each patient, the resulting values were then averaged among patients. Differences between two groups were compared using two-tailed, unpaired t tests. All results are presented as means ± SDs, P < 0.05 was considered statistically significant.

Results

Morphometric characteristics were comparable in the two groups. Duration of surgery, fluid replacement, ambient temperature, end-tidal sevoflurane and carbon dioxide partial pressure, and mean skin temperature were also similar in the two groups. Heart rate was somewhat less in the patients given phenylephrine (although not significantly so) whereas mean blood pressure was significantly greater (Table 1).

Initial core temperatures were virtually identical in the two groups. However, core temperatures in the patients given phenylephrine subsequently remained significantly higher than those in the patients without phenylephrine (Fig. 1). Core temperature during the first hour of anesthesia decreased 1.2 ± 0.4°C in the control patients, but only 0.5 ± 0.2°C in those given phenylephrine. (P < 0.01).

The patients in both groups were intensely vasoconstricted in the arteriovenous shunt before induction of anesthesia, with calf minus toe, skin-temperature gradients near 7°C. Induction of anesthesia in both groups produced arteriovenous shunt vasodilation, as indicated by negative skin-temperature gradients. There were, however, no statistically significant differences in calf minus toe skin-surface temperature gradients between the two groups (Fig. 2).

Discussion

Hypothermia during general anesthesia develops with a characteristic pattern consisting of three distinct phases: 1) an initial rapid decrease in core temperature, resulting largely from an internal core-to-peripheral redistribution of body heat (5); 2) a slower, linear decrease in core temperature that results from...
Our major finding is that core temperature during the first hour of anesthesia decreased significantly less in the patients given phenylephrine. Hypothermia during this period is known to result from central anesthetic-induced inhibition of tonic thermoregulatory vasoconstriction in the arteriovenous shunt combined with anesthetic-induced arterial and venous vasodilation.

Interestingly, though, calf minus toe skin-temperature gradients were similar in both the phenylephrine and placebo groups. Gradients are relatively specific for shunt flow of the skin. These data thus indicate that arteriovenous shunts in both groups were constricted before induction of anesthesia, but subsequently dilated. Dilation is consistent with the central thermoregulatory inhibition caused by propofol (6), sevoflurane (19,20), and nitrous oxide (21,22).

Because arteriovenous shunt flow seems to have been virtually identical in the two groups, differing core temperatures suggest that phenylephrine modulated heat balance and/or distribution by producing vasoconstriction at another site (23). The most likely site is precapillary arterioles. This location is consistent with the drug’s known mechanism of action and the fact that it increases systemic vascular resistance. It is also consistent with the observed increase in mean arterial pressure. We did not, however, directly measure extremity perfusion or flow or core-to-peripheral flow of heat. Methods exist to evaluate both (5,17,24), but none is easy to implement during surgery.

Precapillary vasoconstriction induced by phenylephrine administration will, to some extent, counter the vasodilating effects of general anesthetics. This will not prevent the core-to-peripheral redistribution associated with arteriovenous shunt dilation, but will reduce the effect of anesthetic-induced precapillary dilation (11), because core temperature decreased after induction of anesthesia even during phenylephrine infusion. The net effect then, as in our patients, is to reduce the overall magnitude of redistribution hypothermia. It is likely that the difference in core temperatures during the first hour of anesthesia is almost entirely due to reduced redistribution of heat in the phenylephrine-treated patients.

An additional potential effect of phenylephrine is reduced cutaneous perfusion which would decrease flow of metabolic heat to the environment (23). There is some support for this possibility, in that core temperature continued to decrease after the first hour of anesthesia in the control patients, whereas it reached a core-temperature plateau in the others. However, redistribution is hardly complete after just one hour of anesthesia. Instead, it continues for up to three hours and contributes significantly to core hypothermia.

Table 1. Morphometric and Anesthetic Data

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Phenylephrine</th>
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<tbody>
<tr>
<td>Sex (M/F)</td>
<td>4/5</td>
<td>4/5</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>32 ± 14</td>
<td>32 ± 15</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>53 ± 8</td>
<td>59 ± 8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161 ± 10</td>
<td>167 ± 5</td>
</tr>
<tr>
<td>Duration of surgery (min)</td>
<td>125 ± 92</td>
<td>143 ± 42</td>
</tr>
<tr>
<td>Fluid replacement (L)</td>
<td>1.1 ± 0.6</td>
<td>0.8 ± 0.3</td>
</tr>
<tr>
<td>Ambient temperature (°C)</td>
<td>25.4 ± 0.9</td>
<td>25.2 ± 0.7</td>
</tr>
<tr>
<td>End-tidal sevoflurane (%)</td>
<td>1.9 ± 0.2</td>
<td>2.0 ± 0.3</td>
</tr>
<tr>
<td>End-tidal CO₂ (mm Hg)</td>
<td>38 ± 3</td>
<td>38 ± 3</td>
</tr>
<tr>
<td>Mean skin temperature (°C)</td>
<td>33.9 ± 0.7</td>
<td>34.0 ± 0.6</td>
</tr>
<tr>
<td>Heart rate (bpm)</td>
<td>79 ± 9</td>
<td>71 ± 11</td>
</tr>
<tr>
<td>Mean blood pressure (mm Hg)</td>
<td>72 ± 8</td>
<td>83 ± 9*</td>
</tr>
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Values are means ± SD.
* P < 0.05.
throughout this period (17). It is thus impossible to determine from our data alone the extent to which continued hypothermia in the control patients resulted from additional redistribution or whether the core-temperature plateau in the treated patients resulted in part from reduced cutaneous heat loss.

Phenylephrine decreases cardiac output by increasing afterload and reducing heart rate (25). This may be important because Shitara et al. (26) have demonstrated that dobutamine infusion aggravates intraoperative hypothermia after induction of anesthesia. The mechanism, apparently, is an increase in cardiac output which in turn augments convective transfer of heat from core to peripheral tissues. To the extent that phenylephrine reduces cardiac output, it may restrict transfer of heat to the periphery.

In summary, core hypothermia immediately after induction of general anesthesia results largely from core-to-peripheral redistribution of body heat. Core temperature reduction during the first hour of anesthesia decreases less in patients given phenylephrine than in untreated controls. These data suggest that maintaining precapillary vasoconstriction possibly reduces the magnitude of redistribution hypothermia.

References