Mild Hypothermia Does Not Impair Postanesthetic Recovery in Infants and Children

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We tested the hypothesis that mild perioperative hypothermia (e.g., central temperature 34-36°C) does not impair postanesthetic recovery in infants and children. The postoperative course was evaluated in 84 ASA Physical Status 1 or 2 patients, weighing 5-50 kg, who were recovering from peripheral surgery lasting less than 3 h. Postoperative monitoring initiated in the Post Anesthesia Care Unit (PACU) included: 1) rectal (central) temperature; 2) oxyhemoglobin saturation (SpO₂) while breathing 21% oxygen; 3) apnea (using impedance pneumography); and, 4) duration of recovery determined by an anesthesiologist not involved with the study and unaware of the patients' central temperatures. Data were stratified according to patients' weights and central temperatures on admission to PACU. Recovery was rapid in all patients, with no statistically significant differences in duration of recovery among the groups. Only three patients had SpO₂ values less than 90%, and in each case desaturation was observed during only one 15-min epoch and resolved without specific treatment. The lowest observed SpO₂ was 82%. These three patients weighed between 10 and 20 kg and had initial temperatures exceeding 36°C. No patient had an apneic episode exceeding 15 s. We conclude that mild hypothermia per se neither impairs respiratory function, nor prolongs postanesthetic recovery generally in infants and children undergoing peripheral surgery.

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Mild postoperative hypothermia (i.e., central temperature 34-36°C) is a common complication of anesthesia and surgery (1). It results from radiation, convection, and conduction in cold operating environments (2,3), surgical skin preparation (4), inhibition of protective thermoregulatory responses (5,6), and evaporation from tissues within surgical incisions (7). Hypothermia can be prevented (8) or treated (9-11) relatively easily in vasodilated, anesthetized patients. During recovery, however, thermoregulatory vasoconstriction (12) in patients who are hypothermic but no longer anesthetized substantially slows transfer of cutaneously applied heat to the core (13).

Some anesthetists actively warm surgical patients (e.g., using airway heating and humidification (14,15), circulating-water blankets (9,10,16), or forced-air (10,16)) to minimize perianesthetic hypothermia. The latter is purported to prolong postanesthetic recovery duration and impair respiratory drive (17-20). Respiratory complications of hypothermia are considered especially severe in infants, causing apnea and acidosis (21). Other anesthesiologists rarely actively warm patients because postoperative complications attributable to hypothermia are not obvious (14,22). Accordingly, we tested the hypothesis that mild perianesthetic hypothermia does not impair postanesthetic recovery in infants and children.

Methods

With approval from the Ethical Committee of the Hospital for Sick Children, we prospectively studied 84 ASA Physical Status 1 or 2 pediatric patients during recovery from peripheral surgery lasting less than 3 h. The patients weighed 5-50 kg and none was obese, took medication, or had a history of thyroid disease, dysautonomia, Raynaud's syndrome, malignant hyperthermia, or recent fever.

General anesthesia was induced and maintained in a manner routine for the Hospital for Sick Children. In nearly all cases, sodium thiopental and 20 μg/kg atropine were used for induction of anesthesia. Succinylcholine was administered for muscle relaxation and anesthesia maintained with nitrous oxide/halothane. When nondepolarizing muscle relaxants were administered, relaxation was antagonized using atropine/neostigmine (if necessary) and reversal doc-
uumed by a sustained response to tetanic peripheral nerve stimulation.

Perioperative thermal management also was conducted in a routine fashion. Fluids and respiratory gases were rarely warmed, but a circulating warming blanket set to 37°C was placed under the patients. Operating rooms were maintained at normal temperature, near 20°C. Specific anesthetic and thermal managements were determined by the attending anesthesiologist and not controlled.

At the end of surgery, anesthesia was discontinued and the patients’ tracheas extubated. Patients were transported rapidly to the Post Anesthesia Care Unit (PACU) where they were covered by a single warmed cotton blanket. The blanket was not replaced during recovery, and no active warming was applied. The ambient temperature in the PACU was maintained near 21°C. Postoperative pain was treated as necessary with intravenous morphine sulfate.

Measurements during postanesthetic recovery included central temperature, Spo2, respiration, and shivering. Central temperature was monitored continuously using a rectal thermocouple inserted 10 cm, connected to an electronic thermometer (Mon-a-Therm®, St. Louis, MO). Oxygen saturation was measured continuously using a Nellcor N200 pulse oximeter (Hayward, CA) with the probe positioned on one finger. Supplemental oxygen was not administered. Respiration was evaluated continuously using a Model 78834C neonatal impedance pneumograph (Hewlett-Packard, Inc., Waltham, MA), and apnea was defined by lack of respiration for 15 s. Shivering was evaluated using a previously described three-point scale: 0 = none, 1 = mild, and 2 = severe (12).

Heart rate and blood pressure were measured oscil-
lometrically (Dinamap™ 1846 SX, Critikon Inc., Tampa, FL). State of consciousness during postanesthetic recovery was evaluated by the same investigator recording central temperature and oxygen saturation, and was rated using a four-point scale: 1 = asleep, 2 = barely arousable, 3 = drowsy, and 4 = awake.

All measurements were initiated in the PACU and recorded at 15-min intervals until patients were deemed fit for discharge. To increase our sensitivity for detecting adverse events, the lowest value for arterial oxygen saturation and the highest score for shivering during each 15-min epoch were considered the respective values for that epoch.

Fitness for discharge was determined by patients obtaining a score of 10 on Aldrete and Kroulik’s scale (23). Scores were determined by attending anesthesiologists who did not participate in the study and were unaware of the patients’ intraoperative and postoperative central temperatures. Discharge criteria included: 1) voluntary movement of all extremities; 2) spontaneous deep breathing or competent coughing; 3) arterial blood pressure values within 20% of preanesthetic values; 4) fully awake state of consciousness; and 5) pink mucus membranes. Central temperature was not a discharge criterion.

The time elapsed between tracheal extubation and the determination that patients were fit for discharge defined the duration of recovery. Actual discharge time was not used because transportation delays and bed availability occasionally prevented patients from immediately leaving the PACU.

Data were stratified according to patient weight (5–10 kg, 10–20 kg, and 20–40 kg) and PACU initial central temperature (34–35°C, 35–36°C, 36–37°C, and 37–38°C). Differences among these groups were analyzed using two-way ANOVA; P < 0.05 identified statistically significant differences. Results are presented as means ± standard deviations.

### Results

The number of patients and duration of recovery in each data group are reported in Tables 1 and 2. Recovery was rapid in all patients, and recovery time did not differ significantly among groups. Sixty-four of the 84 patients (76%) remained in the study at 60 elapsed min, but only 24 patients (28%) remained at 90 elapsed min.

Statistical analysis revealed no significant interaction between weight and initial PACU temperature (P = 0.2). When patients were stratified by weight, there were no significant differences in central temperature, Spo2, or state of consciousness (Figure 1). When the same patients were stratified by initial PACU temperatures, there were no significant differences in Spo2 or state of consciousness (Figure 2). No patient shivered at any time.

Only three patients had Spo2 values less than 90%. In each case, such desaturation was observed only during one 15-min epoch and resolved without specific treatment. Each of these three patients weighed between 10 and 20 kg and had an initial temperature exceeding 36°C. The lowest Spo2 value recorded in any patient at any time was 82%.

Heart rate, blood pressure, and respiratory status did not differ significantly among temperature groups. No apneic episode exceeded 15 s.

### Table 1. Duration of Recovery in Patients Stratified by Weight

<table>
<thead>
<tr>
<th>Weight Range (kg)</th>
<th>5–10 kg</th>
<th>10–20 kg</th>
<th>20–40 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>24</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Duration (min)</td>
<td>60 ± 35</td>
<td>54 ± 25</td>
<td>52 ± 2</td>
</tr>
</tbody>
</table>

There were no statistically significant differences in duration of recovery among the groups. More than half the patients in the 5–10 kg group weighed less than 8 kg.
Table 2. Duration of Recovery in Patients Stratified by Temperature

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Number</th>
<th>Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>34-35°C</td>
<td>14</td>
<td>64 ± 28</td>
</tr>
<tr>
<td>35-36°C</td>
<td>32</td>
<td>58 ± 25</td>
</tr>
<tr>
<td>36-37°C</td>
<td>30</td>
<td>46 ± 27</td>
</tr>
<tr>
<td>37-38°C</td>
<td>8</td>
<td>66 ± 35</td>
</tr>
</tbody>
</table>

Discussion

Hypothermia did not prolong duration of recovery in our patients, a result differing markedly from that of previous reports (17-19). Our study differs from previous ones in that we studied infants and children rather than adults. Although unlikely, pediatric patients possibly tolerate postoperative hypothermia better than adults. Perhaps a more important difference is that duration of recovery in our patients was determined using definite criteria, by an independent anesthesiologist blinded to the temperature data.

A "normal" central temperature is not a discharge criterion specified by the American Society of Postanesthesia Nurses (24), nor is it one of the items in Aldrete and Kroulik's (23) or Steward's (25) recovery scales. Absence of a specific temperature requirement probably is appropriate because there is little, if any, evidence that mild hypothermia per se does deleterious in an otherwise recovered patient. Nonetheless, many hospitals have established arbitrary central temperature requirements for discharge (e.g., >36°C). Although central temperatures rapidly returned to nearly normal values in all of our patients, recovery duration in those with the lowest initial temperatures would have been slightly prolonged had a central temperature exceeding 36°C been one of our discharge criteria.

Clinically important desaturation was rare in our patients, even though they were maintained on room air. (Administration of supplemental oxygen is routine during postanesthetic recovery (21), but was not used in this study, to increase our ability to detect hypoxemia using pulse oximetry.) These data suggest that mild hypothermia per se does not produce hypoxemia in postoperative infants and children.

Apnea exceeding 15 s was not detected in any of our patients. Although possible that ventilation was marginally inadequate in some patients, severe ventilatory deficits would have been observed as apnea or desaturation. Because arterial catheters were rarely required in these patients, we did not directly measure PCO₂ which may have been elevated in some patients. However, hypercarbia unaccompanied by metabolic acidosis or hypoxia probably is not harmful (26). In preliminary studies, we attempted to measure transcutaneous PCO₂, but abandoned the attempt because our recovering patients were insufficiently cooperative.

Although infants are believed especially susceptible
to postoperative complications (21), we observed mild desaturation in only three of our patients. Furthermore, the smallest infants (5-10 kg) reached discharge criteria as quickly as larger children (11-40 kg). It remains possible that statistically significant differences among the groups would have been detected had we studied more patients. Nonetheless, variability within groups was relatively small and there were no trends suggesting that lack of difference resulted simply from an inadequate sample size. Consequently, it seems unlikely that clinically significant differences would be identified simply by studying more patients.

None of our patients shivered in the postanesthetic period. Shivering occurs rarely, if at all, in infants (27). Even in hypothermic adults recovering from anesthesia, shivering frequently does not occur despite hypothermia (28,29). Inhibition of shivering most likely results from residual anesthetic adjuvants, particularly opioids (30-32). (Although the reported incidence of postanesthetic shivering in adults is ~40% (1,33), it is probably less common because current practice is to administer opioids more often, and in larger amounts, than previously.) Thus, although shivering might have been expected in the older hypothermic children, its absence is not atypical.

Our findings indicate that neither duration of recovery nor respiratory function are impaired by postoperative hypothermia. Nonetheless, hypothermia is known to cause other complications including prolonged drug effect (34), hampered blood coagulation (35), and thermal discomfort (12). Furthermore, preliminary (unpublished) evidence suggests that mild hypothermia also may impede immune responses to perioperative wound infections. In contrast, 1-3°C central hypothermia provides significant protection against global and regional ischemia (36-38), hypoxemia (39), and malignant hyperthermia (40). Our results should thus not be considered a blanket endorsement of perioperative hypothermia. Instead, we suggest that thermal management, like other therapies, be given a thoughtful risk-benefit analysis in each patient.

Central temperatures in our patients exceeded 34°C; lower temperatures may cause complications not observed in this study. However, central temperatures less than 34°C are rare, even when no precautions are taken, because further hypothermia usually is limited by thermoregulatory vasoconstriction (41,42) and non-shivering thermogenesis (in infants) (43,44).

Our results may have differed had we studied patients with severe preexisting disease or those undergoing intraabdominal, neurological, or cardiac surgery. Hypothermia clearly impairs respiration in premature infants, and formerly premature infants within 50 gestational weeks are particularly susceptible to postoperative apnea (21); it is likely that hypothermia combined with the stress of surgery and residual anesthetic drugs is especially harmful in these patients. Similarly, hypothermia combined with some treatments for postoperative pain may cause problems not detected in this study. It is not possible in a study of this size to eliminate the possibility of rare adverse events. Hypothermia thus may cause prolonged recovery or respiratory complications in some patients.

In summary, we evaluated respiratory function and duration of postanesthetic recovery in 84 pediatric patients recovering from peripheral surgery with general anesthesia. Data were stratified according to patient weight and central temperatures on admission to the PACU. Recovery was rapid in all patients, and there were no statistically significant differences among the groups. Only three patients had Spo2 values less than 90%, and, in each case, such desaturation was observed only during one 15-min epoch and resolved without specific treatment. Each of these three patients weighed between 10 and 20 kg and had an initial PACU temperature exceeding 36°C. No patient had an apneic episode exceeding 15 s. We conclude that mild hypothermia per se does not impair respiratory function, nor prolong postanesthetic recovery in generally healthy infants and children undergoing peripheral surgery lasting less than 3 h.

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References