Do Passive Heat and Moisture Exchangers Keep the Patient Warm?

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The inner structures of the human nose and pharynx capture heat and moisture during exhalation and retain them during inhalation. In principle, a heat and moisture exchanger (HME) operates in much the same way, capturing the patient’s exhaled water vapor and returning it in the next breath. The natural humidification process is impaired during anesthesia when the trachea is intubated with an oral or nasal endotracheal tube. Inadequate humidification can cause many problems. One of the most significant is airway obstruction by retained, dried secretions.

We have employed a heat and moisture exchanger, Siemens-Elema Servo Humidifier 150® (fig. 1) to decrease the effects of dry, cool inspired gases on the respiratory tract. We noted that the HME, especially with low fresh gas flow rates (FGFR), helped to maintain body temperature during surgery. A review of the literature revealed laboratory and clinical trials1-9; but none of the clinical studies were controlled, nor did they determine whether use of HME would help maintain body temperature. We undertook a study, therefore, to determine the effects of HME and FGFR on body temperature.

METHODS

All patients studied were adult men who were scheduled for operations on extremities and not invading body cavities, lasting more than 2 h. All were ASA physical status I–III. There was no significant difference in age between the groups. All patients arrived in the operating room with a normal temperature. Premedication was not controlled, but most received oral diazepam. The trachea was intubated following administration of iv thiopental and succinylcholine. Anesthesia was maintained by N₂O, enflurane, and pancuronium using a semiclosed circle system with a CO₂ absorber. All patients were mechanically ventilated with a volume-controlled ventilator delivering 10 ml/kg at a rate of 10 breaths per min. The room temperature was maintained between 20° and 21° C (68°–69.8° F). No warming blankets were used. Routine surgical draping was used in all cases. IV crystalloid solutions were not warmed, but any blood given was heated using a blood warmer. No patient needed a transfusion in excess of 1000 ml, and the mean estimated blood loss was not significantly different between the groups. Core body temperature to the nearest 0.1° C was measured in all cases with the same Yellow Springs® temperature monitor and probe. We calibrated the temperature monitor and the probe before each study with a mercury thermometer designated only for this study. The flexible probe was inserted into the lumen of an esophageal stethoscope to provide stiffness. The probe was inserted into the esophagus to a depth of 40 cm from the teeth immediately after endotracheal intubation. We waited 5 min before making the first reading; thereafter, the temperature was recorded every 15 min. Room temperatures were recorded every 15 min.

Forty-one patients were randomly assigned to one of our study groups. Group 1 consisted of ten patients receiving 3 l FGFR and an HME was inserted. Group 2 consisted of ten patients receiving 6 l FGFR and an HME was used. Group 3 consisted of 11 patients receiving 3 l FGFR and no HME was used. Group 4 consisted of ten patients receiving 6 l FGFR and no HME was used.

The Siemens-Elema Servo Humidifier 150® (fig. 1) was placed between the endotracheal tube connector and the "Y" piece of the anesthetic breathing system.

The temperature data were analyzed using an analysis of variance and covariance including repeated measures that yield temperature change per unit of time equivalent to slope in a regression analysis.10 Individual comparisons of the multiple means were done using Newman/Keuls statistics11,§ as described by Winer.12

RESULTS

The body core temperature decrease in Group 1 with 3 l/min FGFR and an HME was 0.34 ± 0.12° C/h (mean ± SD), and the lowest observed body-core temperature

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The temperature decrease in all the groups was compared. Temperature decrease was not significantly different between pooled groups with 6 and 3 l FGFR and an HME had a temperature decrease of 0.44 ± 0.12°C/h, and the lowest observed body-core temperature was 35.1°C. Group 3 with a 3 l/min FGFR without an HME had a temperature decrease of 0.62 ± 0.24°C/h, and lowest observed body-core temperature was 34.0°C. Group 4 with a 6 l/min FGFR without an HME had a 0.62 ± 0.12°C/h. Temperature decrease and lowest observed body core temperature was 34.2°C (fig. 2 and table 1).

**DISCUSSION**

The effectiveness of passive HME, including the Siemens-Elema Servo Humidifier®, in maintaining higher humidity levels and increased temperatures in inspired gases has been previously well documented.1-3,5,6 A comparison of technical characteristics and performance of commercial HME is available.7 The HME (fig. 1) is the essence of simplicity. As the patient exhales heated and humidified air, the device captures some of the heat and some of the humidity. When the patient inhales, the device gives off both heat and humidity to the inspired gases. Heat and humidity are closely related because heat must be supplied to vaporize water.

The heat of vaporization of water is high, 580 calories per g, and the specific heat of gas is low (for air, it is 0.0003 calories per g). Hence, vaporization of water requires considerably more heat than warming of gas. Conversely, condensation of water produces more heat than cooling of gas.

Gas is normally exhaled from the lungs at 37°C and 100% relative humidity (RH) (44 mg water per l gas). When cooled, the absolute humidity (AH) of the gas will decrease, and the RH will remain at 100%. By the time

**FIG. 1.** Schematic drawing of the Siemens-Elema Servo Humidifier 150.

**FIG. 2.** Average body-core temperature fall observed at time after start of surgery for the four study groups.
the exhaled gas reaches the end of the endotracheal tube, it has cooled to approximately 30°C, with an AH 30 mg water per l gas.

Further cooling takes place in the HME; as water condenses on the HME surfaces, the latent heat that kept the water in a vaporized state is released. It is this latent heat that warms HME, as the specific heat of the exhaled gas is too low to contribute substantially to the warming of the HME.

If the exhaled gas leaves the HME at 20°C, AH 17 mg water per l gas, then 13 mg water per l gas has been deposited in the HME along with its associated latent heat. The greater the temperature difference between the two sides of the HME, the more heat and moisture will have been deposited.

During the following inhalation, the HME can deliver maximally what was deposited during exhalation, namely 13 mg water per l gas. The patient must provide the additional water vapor to achieve body temperature pressure saturated with water vapor (BTPS) and at 37°C this would be (44 – 13 = 31) mg of water per liter gas provided the fresh gas is dry.

The clinical use of this device in maintaining body temperature has not been studied previously. While this investigation was underway, a clinical study of the effects of the Siemens-Elema HME 150® on gas temperature in the endotracheal tube appeared. It showed that the temperature of inspired gas after passing through the HME was 8°C warmer than the gas in the inspiratory limb of the anesthesia circuit. Thus, the findings of a slower decline of body-core temperature in this study was to be expected.

We were unable to demonstrate any decrease in temperature fall with 3 l/min FGFR of anesthetic gases when the HME was not used. Although the differences between the 3 and 6 l/min FGFR were not significant, the data suggest that using a low flow along with the HME is slightly more effective in conserving heat.

The lowest patient body core temperature was 35.1°C with the HME, and without the HME it was 34.0°C. We did not expect the HME to be able to maintain normal body-core temperature because no other reason for heat loss was changed or eliminated.

Hypothermia is generally regarded as body-core temperature below 35°C. At a temperature of 32–35°C, the human body experiences shivering, vasoconstriction of peripheral vessels, diuresis, and the hormonal stress response. The oxygen demand is increased and can, below 35°C, stay sustained at 300% of the basal metabolic rate.13

### Table 1. Body-core Temperature Fall (mean ± SD) and Lowest Observed Body-core Temperature Observed in the Group

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Body-core Temperature Fall (°C/l)</th>
<th>Lowest Observed Body-core Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0.34 ± 0.07</td>
<td>35.3</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>0.44 ± 0.07</td>
<td>35.1</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>0.62 ± 0.21</td>
<td>34.0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>0.62 ± 0.07</td>
<td>34.2</td>
</tr>
</tbody>
</table>

Group 1, heat and moisture exchanger (HME) + 3 l/min fresh gas flow rate (FGFR); Group 2, HME + 6 l/min; Group 3, 3 l/min FGFR; and Group 4, 6 l/min FGFR.

General anesthesia will delay these effects until the patient starts recovering postoperatively. We observed a reduced temperature decrease of approximately 1°C with the use of the HME, which will result in less postoperative increase in the systemic oxygen uptake and less strain on the cardiovascular system. We suggest this is clinically significant.

In summary, use of the Siemens-Elema Servo Humidifier 150® in adult men having general anesthesia for superficial or extremity operations significantly decreased the rate of fall in core body temperature.

### References