Effects of Surgical Site and Inspired Gas Warming Devices on Body Temperature during Lower Abdominal and Thoracic Surgery

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To evaluate the effects of surgical site and inspired gas warming and humidifying devices on body temperature, we studied rectal, tympanic membrane, and esophageal temperature changes in 48 patients. The patients were divided into 4 groups (n=12), according to surgical site, lower abdominal surgery and thoracic surgery, and according to the warming device used, heat and moisture exchanger (ThermoVent 600) and heated humidifier (Cascade 1). The heated humidifier was controlled to warm inspired gases to about 35°C. All body temperatures fell significantly during surgery. There was no difference in the tympanic membrane and esophageal temperature declines between the two surgical sites, but the decline in rectal temperature was larger in the lower abdominal surgery than in the thoracic surgery. At the end of surgery, all temperatures returned to the value before surgery, and the rectal and tympanic membrane temperatures even exceeded them. There was no difference between the effects of the ThermoVent 600 and Cascade 1. These results suggest that rectal temperature is influenced by the ambient temperature during lower abdominal surgery and that warming and humidifying devices for inspired gases do not prevent, but can restore the decline in body temperature during lower abdominal and thoracic surgery. The heated humidifier showed no advantage over the heat and moisture exchanger in our study. (Key words: anesthesia, surgery, inspired gases humidification, body temperature)

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Hypothermia during surgery can cause many problems, such as prolonged effects of non-depolarizing muscle relaxants, delayed recovery from general anesthesia, and postoperative shivering which may result in hypoxemia or hypoventilation[1,2]. Various methods are used to prevent heat loss during surgery, but the effects of warming and humidifying inspiratory gases remain controversial in adults[1–3]. Differences in the sites of surgery and of temperature monitoring in previous

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studies may be responsible for this controversy.

During anesthesia and surgery, the measured body temperature depends on the site of monitoring[1–3]. Rectal and esophageal temperatures may be influenced by feces and inspired gas temperature, respectively. In addition, they may also be influenced by the body cavity exposed. Tympanic membrane temperature, which is measured by a probe in the external auditory canal with a commercially available system, may be influenced by ambient temperature or blood flow to the canal.

The purpose of this study was to evaluate the influence of the surgical site and the effects of warming and humidifying inspired gases on body temperature. To alleviate the bias by the site of temperature monitoring, we measured rectal, esophageal, and tympanic membrane temperatures simultaneously.

Methods

Forty-eight ASA physical status 1 or 2 patients undergoing lower abdominal or thoracic surgery lasting more than 3 hours were studied after informed consent was obtained. The patients undergoing lower abdominal surgery were randomly assigned to one of two groups: group AHM (n=12) was ventilated with passively heated and humidified gases using a heat and moisture exchanger (HME), ThermoVent 600 (Portex Inc.), and group AHH (n=12) was ventilated with actively heated and humidified gases using a heated humidifier, Cascade 1 (Bennett, Inc.). Similarly, the patients undergoing thoracic surgery were randomly assigned to one of two groups: group THM (n=12) was ventilated with passively heated and humidified gases, while group THH (n=12) received actively heated and humidified gases. In groups AHH and THH, we controlled the Cascade 1 to warm the inspired gases to approximately 35°C measured at the connector between the anesthesia circuit and the endotracheal tube.

Anesthesia was induced by fentanyl, diazepam, and thiamylal, and maintained by 66% nitrous oxide in oxygen with intermittent injection of fentanyl and pancuronium. Patients were mechanically ventilated with a non-rebreathing system (Servo Ventilator 900C, Siemens, Inc.), and minute ventilation was adjusted to maintain Pa_{CO_2} near 35 mmHg. Operating room temperature was kept at approximately 23°C. A warming mattress with circulating heated water at 38°C was used, but intravenous fluid, except for banked blood, was not warmed.

We monitored tympanic membrane, rectal, and esophageal temperatures with a model 6500 thermometer (Mon-a-therm, Inc.), placing the esophageal temperature probe where the cardiac sounds were loudest[4]. We recorded these temperatures just before surgery, when they reached the lowest values during surgery, and at the end of surgery. We also calculated their decline during surgery and the difference between the value at the end of surgery and the value before surgery. We recorded the operating room and inspired gases temperatures every 20 min during the surgery. Temperature of the inspired gases in groups AHM and THM were measured at the connector between the inspiratory limb of the anesthesia circuit and the ThermoVent 600.

Data are presented as mean ± SD. The lowest temperature and the temperature at the end of surgery were compared with the value before surgery by paired t-test. Temperatures were compared among the four groups by two-way analysis of variance (ANOVA) for repeated measures, using the surgical site and the device for warming and humidifying gases as the two factors. A P-value less than 0.05

Table 1. Demographic Data

	Group AHM	Group AHH	Group THM	Group THH
Number	12	12	12	12
Sex (M/F)	6/6	4/8	7/5	8/4
Age (yr)	63 ± 12	59 ± 11	62 ± 9	60 ± 10
Weight (kg)	52 ± 8	52 ± 9	53 ± 10	57 ± 7
Height (cm)	155 ± 6	155 ± 8	158 ± 9	160 ± 8
Surgical time (min)	303 ± 121	385 ± 183	302 ± 66	298 ± 82
Fluid infused at room temperature (ml)*	3520 ± 1460	4710 ± 2180	2690 ± 610	2850 ± 160
Inspired gas temp. (°C)*+	24.7 ± 0.4	35.3 ± 0.8	24.4 ± 0.5	35.0 ± 1.1
Room temp. (°C)+	23.9 ± 0.9	23.8 ± 1.1	23.2 ± 0.7	23.3 ± 0.8

Values are mean ± SD.
*$P < 0.05$ between the patients undergoing lower abdominal surgery (groups AHM and AHH) and the patients undergoing thoracic surgery (groups THM and THH).
+Inspired gas and operating room temperatures were measured every 20 min thoughout the surgery.

Table 2. Rectal, Tympanic Membrane, and Esophageal Temperatures (°C)

		Before Surgery	Lowest Value during Surgery	At the End of Surgery
Group AHM	Rectal	36.7 ± 0.4	35.9 ± 0.4**	36.7 ± 0.3
	Tympanic	36.3 ± 0.4	35.9 ± 0.4**	36.6 ± 0.3
	Esophageal	36.4 ± 0.5	36.0 ± 0.5**	36.8 ± 0.4*
Group AHH	Rectal	36.6 ± 0.5	35.9 ± 0.5**	36.5 ± 0.5
	Tympanic	36.3 ± 0.4	35.9 ± 0.5*	36.5 ± 0.6
	Esophageal	36.3 ± 0.4	36.1 ± 0.5**	36.7 ± 0.7
Group THM	Rectal	36.6 ± 0.4	36.1 ± 0.6**	37.0 ± 0.7*
	Tympanic	36.3 ± 0.4	35.9 ± 0.6**	36.9 ± 0.8*
	Esophageal	36.3 ± 0.4	35.9 ± 0.7*	37.0 ± 0.7**
Group THH	Rectal	36.6 ± 0.4	36.3 ± 0.4**	37.1 ± 0.5**
	Tympanic	36.2 ± 0.3	36.0 ± 0.4**	36.9 ± 0.4**
	Esophageal	36.3 ± 0.4	36.1 ± 0.4*	37.0 ± 0.4**

Values are mean ± SD.
*$P < 0.05$ compared with the value before surgery.
**$P < 0.01$ compared with the value before surgery.

was considered significant.

Results

Table 1 shows patients' characteristics. There was no difference among the four groups except for the temperature of the inspired gases and the volume of fluid infusion at room temperature, although the actual temperature of the inspired gases in groups AHM and THM may have been 2–3°C higher than the measured value[5,6]. The types of lower abdominal surgeries were similar between groups AHM and AHH; gynecological surgeries were 6 and 7, and urological surgeries were 6 and 5, respectively. The types of thoracic surgeries were also similar between groups THM and THH; segmental or total pneumonectomy were 10

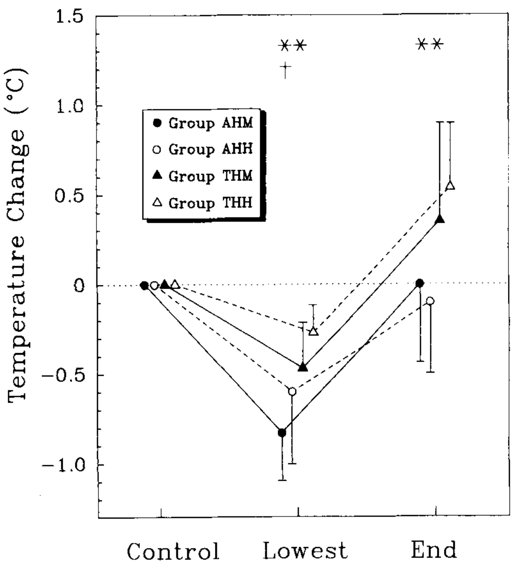

Fig. 1. Effects of surgical site and the devices for warming and humidifying inspired gases on changes in rectal temperature. The maximum decline during surgery (Lowest) and the change at the end of surgery (End) from the value before surgery (Control) were compared among the four groups. Values are means ± SD. **Significant difference between the effects of lower abdominal surgery and of thoracic surgery ($P < 0.01$). $^{+}$Significant difference between the effects of the HME and of the heated humidifier ($P < 0.01$). See text for further explanations.

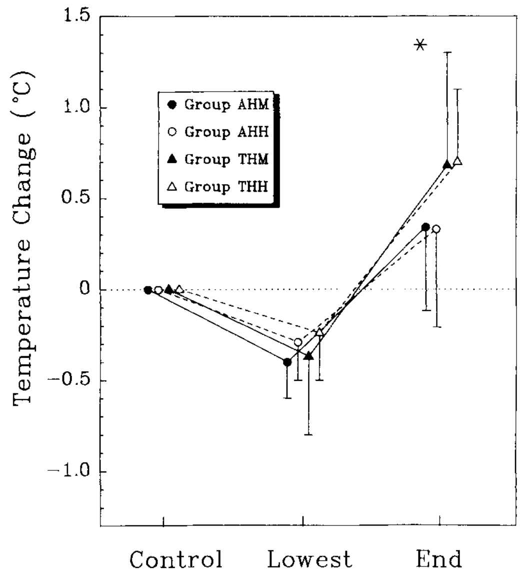

Fig. 2. Effects of surgical site and the devices for warming and humidifying inspired gases on changes in tympanic membrane temperature. The maximum decline during surgery (Lowest) and the change at the end of surgery (End) from the value before surgery (Control) were compared among the four groups. Values are means ± SD. **Significant difference between the effects of lower abdominal surgery and of thoracic surgery ($P < 0.01$). See text for further explanations.

and 9, and decortication of the lung were 2 and 3, respectively.

The lowest body temperature during surgery was significantly lower than the body temperature before surgery in all groups and at all sites of measurement (table 2). However, after surgery, the body temperature was equal to or even higher than the value before surgery.

The body temperature before surgery did not differ among the four groups. There was no interaction on the body temperature between the effects of surgical site and the device for warming inspired gases. Figure 1 shows the change in rectal temperature during surgery. The decline in rectal temperature during lower abdominal surgery (groups AHM and AHH) was larger than that during thoracic surgery (groups THM and THH). The rectal temperature at the end of thoracic surgery was higher than that at the end of lower abdominal surgery. Figures 2 and 3 show the change in tympanic membrane temperature and esophageal temperature. Their decline during surgery did not differ between the two surgical sites, but at the end of surgery, were higher in the patients who underwent thoracic surgery (groups THM and THH) than in those who underwent lower abdominal surgery (groups AHM and AHH). There was no difference between the

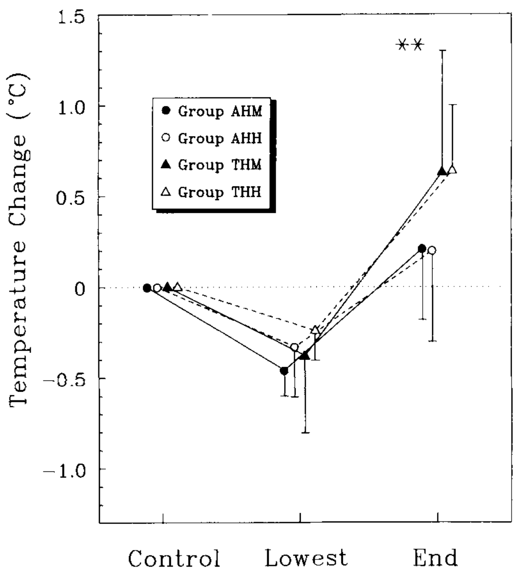

Fig. 3. Effects of surgical site and the devices for warming and humidifying inspired gases on changes in esophageal temperature. The maximum decline during surgery (Lowest) and the change at the end of surgery (End) from the value before surgery (Control) were compared among the four groups. Values are means ± SD. *Significant difference between the effects of lower abdominal surgery and of thoracic surgery ($P < 0.05$). See text for further explanations.

effects of the ThermoVent 600 and the Cascade 1 on the body temperature at all monitoring sites, except for the decline in rectal temperature.

Discussion

1. *Influence of the surgical site.*

The decline in rectal temperature during abdominal surgery is larger than that during surgery at other sites[7]. Crocker et al. measured rectal and esophageal temperatures in 2,139 cases of general anesthesia, about one half of them underwent abdominal surgery, and they found that the rectal temperature continued to fall until 150 min after the induction of anesthesia[8]. The esophageal temperature started to rise after 60 min from the induction of anesthesia. Esophageal temperature has been shown not to be influenced even during upper abdominal surgery[9].

The effects of an opened thoracic cavity on body temperature are less known. Rectal and nasopharyngeal temperatures were reported to decline during thoracic surgery as during other surgery, but that study was preliminary and included esophageal surgery which requires the abdominal cavity to also be opened[10]. Our results indicated that the decline in body temperature during thoracic surgery is equivalent to that during lower abdominal surgery.

Heat loss is greatest during the first hour of anesthesia, mainly due to redistribution of blood flow[3,4,11,12]. Therefore, the fall in body temperature during this period might not differ so much with the type of surgery. After that time, an equilibrium is gradually obtained between heat loss and heat production, and heat loss becomes less. Our results indicated that the heat balance turned positive during surgery, and the net heat loss was smaller in thoracic surgery than in lower abdominal surgery. This smaller heat loss may be explained by the smaller amount of fluid infused at room temperature[2,3] and the nature of the thoracic surgery in the present study; the thoracic cavity was opened on only one side, and patients were thickly covered by drapes to prevent infection.

2. *Influence of devices for warming and humidifying inspired gases*

The body temperature returned to its previous value during the surgery in all groups, although its decline was not prevented. Heat loss by inspiration of dry gases at room temperature with a semi-closed circuit is calculated to be 10–13 $kcal \cdot h^{-1}$ [13,14]. This loss consists of only 20% of heat production[3], and heat loss through an opened abdominal or thoracic cavity may be as high as 400 $kcal \cdot h^{-1}$ [14]. Therefore, the effect of warmed and humidified inspiratory gases on body temperature is relatively small during surgery. Warming and humidifying the inspiratory gases to a temperature of 45°C has been reported to be effective[15–17]. However, such a high temperature should be avoided in order to prevent tracheal mucous membrane injury, and be restricted to less than 41°C[1,2].

Once an equilibrium is established between heat loss and heat production, heat loss becomes smaller, as previously mentioned, and can be compensated for by warming and humidifying the inspired gases[12,18]. About 1 hour after the induction of anesthesia, body temperature ceases to fall, while it continues to fall with the use of dry and cool inspired gases[19]. Thus, by use of a warming blanket, warmed infusion fluid, and higher room temperature, together with warmed and humidified inspiratory gases, the decline in body temperature can be prevented even in major abdominal surgery[19].

The HME, ThermoVent 600, can add about 70% relative humidity and increase the temperature of inspiratory gases by only 2.0–5.0°C[5,6,20–22]. In a non-rebreathing system, such as in our study, it is less effective[5,6]. The effect of HME in saving heat loss is calculated as only 5 $kcal \cdot h^{-1}$ [2], and has been reported to not prevent the fall in body temperature in adults undergoing even peripheral surgery[23–27], unlike in infants[28]. However, it has been reported that using a cotton-covering of the body surface and warmed infusion fluid, together with HME shift the net heat loss to negative during spinal and abdominal surgery[18,29]. In our study, we did not find any difference between the effects of the ThermoVent 600 and the Cascade 1 on the change in body temperature. This results suggested that HME is equally effective as heated humidifier in reducing heat loss during surgery, when it is used together with other means such as higher operating room temperature and warming mattress in our study.

In summary, we studied the influence of surgical sites on body temperature and compared the effects of HME, ThermoVent 600, with that of a heated humidifier, Cascade 1. During thoracic surgery, the decline in body temperature was equal to the fall during lower abdominal surgery. The decline in body temperature reversed after that, and after thoracic surgery the body temperature became even higher than the value before surgery. The effect of the HME on body temperature did not differ from the effect of the heated humidifier.

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