We have observed an elevation of body temperature during surgical repair of pectus excavatum. To document this phenomenon and attempt to prevent it, we undertook a combination retrospective-prospective study. The retrospective arm included an analysis of the anesthetic records of patients undergoing repair of pectus excavatum during the past 5 years and included 22 boys and 3 girls. Body temperature increased in all 25 patients, from a starting temperature of $36.1^\circ C \pm 0.5^\circ C$ to $38.0^\circ C \pm 0.6^\circ C$. The maximum temperature exceeded $38^\circ C$ in 12 patients and $39^\circ C$ in 3 patients.

An additional retrospective review of the anesthetic records of 15 children undergoing another type of thoracic procedure (thoracotomy) for noninfectious problems revealed only a modest, statistically nonsignificant rise in temperature from a starting point of $35.9^\circ C \pm 0.7^\circ C$ to a maximum of $36.3^\circ C \pm 1.2^\circ C$. The maximum temperature was greater than $38^\circ C$ in one of these 15 patients.

The prospective arm of the study included a standardized anesthetic technique in 10 patients. Neither a heated humidifier nor a warming blanket were used, and the ambient temperature of the room was maintained at $70^\circ F$. Core body temperature increased from a starting temperature of $36.1^\circ C \pm 0.6^\circ C$ to $36.8^\circ C \pm 0.8^\circ C$.

A significant elevation of body temperature occurs in children during repair of pectus excavatum that may be avoided by eliminating the use of exogenous methods to prevent hypothermia (e.g., heated humidifier, warming blanket).

Key words: Hyperthermia, pectus excavatum, pediatric anesthesia.

Introduction

Core body temperature generally decreases following the induction of anesthesia because of inhibition of peripheral vasoconstrictor tone with a redistribution of blood flow and body heat from the core to the periphery. The drop in core body temperature may be even more dramatic in the pediatric population. As a result, aggressive measures, which include raising the room temperature and use of a heated humidifier and a warming blanket, are frequently taken in children to prevent hypothermia.

Contrary to these findings, it has been our clinical experience that children undergoing repair of pectus excavatum frequently develop significant increases in their core body temperature. To further document this phenomenon and to attempt to prevent its occurrence, we undertook a combination retrospective-prospective study. The retrospective part of the study involved a chart
review to document the occurrence of intraoperative hyperthermia during repair of pectus excavatum and compare the intraoperative change in temperature with a similar group of patients undergoing thoracotomy. The prospective arm of the study included an evaluation of certain measures to limit intraoperative hyperthermia.

Methods

The study was approved by the institutional review board and the committee for the protection of human subjects. Because the anesthetic care did not vary from our usual clinical practice, the need for written consent was waived. The retrospective part of the study included an analysis of the anesthetic records of patients undergoing repair of pectus excavatum and a group of patients of similar age and weight who were undergoing thoracotomy for noninfectious problems. Demographic data collected included the patient’s age, weight, gender, underlying medical problems, and medications. Patients with a history of malignant hyperthermia (MH), family history of MH, or an underlying medical condition known to be associated with MH were excluded from analysis. The anesthetic record was examined for the agents used for induction and maintenance of general anesthesia. The site of temperature monitoring was noted. Each patient’s intraoperative temperature was recorded every 15 to 30 minutes throughout the procedure.

The patients in the prospective arm of the study were ASA I or II physical status undergoing repair of pectus excavatum. Patients with a history of MH, family history of MH, or an underlying medical condition known to be associated with MH were excluded from analysis. The prospective arm of the study included a protocol anesthetic. All children were fasted for at least 6 hours. Premedication consisted of oral midazolam (0.7 mg/kg) or intravenous midazolam (0.15 mg/kg). This was followed by either inhalation induction with halothane in 70% nitrous oxide and oxygen or intravenous induction with sodium pentothal (4-6 mg/kg). Glycopyrrolate (5 μg/kg) was administered following the induction of anesthesia. Neuromuscular blockade was achieved using intermittent doses of vecuronium. Maintenance anesthesia consisted of isoflurane in 50% nitrous oxide and fentanyl (2 to 5 μg/kg). Esophageal temperature was monitored and recorded every 15 minutes.

Intravenous fluids were not warmed prior to administration. Intravenous fluid therapy included lactated Ringer’s solution at maintenance plus third space losses (3 to 4 mL/kg per hour) plus blood loss replacement (3 mL for each 1 mL of estimated blood loss). External measures to maintain body temperature, such as a heated humidifier and warming blanket, were not used. The room temperature was set and maintained at 70°F throughout the surgical procedure.

The highest body temperature recorded during the operative procedure was compared with the starting temperature using a paired t test with $P < 0.05$ considered significant. All data are expressed as the mean ± SD.

Results

Retrospective data. Complete records were available from 25 patients who underwent repair of pectus excavatum defects. There were 22 boys and 3 girls ranging in age from 2.5 to 19 years (mean ± SD, 10.7 ± 5.9 years) and in weight from 12.7 to 78 kg (mean ± SD, 41.0 ± 23.6 kg). The anesthetic data are summarized in Table I. Ten patients received no premedication, 7 received intravenous midazolam, and 8 received oral midazolam. The induction technique included intravenous thiopental in 14 patients and mask halothane in the remaining 11. Thirteen patients received anticholinergic agents, including atropine in 10 and glycopyrrolate in 3. Tracheal intubation was facilitated with succinylcholine in 7 patients. In the remaining 18 children, nondepolarizing agents were used for tracheal intubation. This included vecuronium in 12, atracurium in 5, and curare in 1. Nondepolarizing agents were used throughout the procedure in all 25 patients and included vecuronium in 18, atracurium in 5, pancuronium in 1, and curare in 1. Maintenance anesthesia consisted of isoflurane in 23 patients and halothane in the remaining 2. Nitrous oxide was administrated to 15 patients. Narcotic agents were administered to 21 patients and included fentanyl in 13 patients, sufentanil in 5 patients, and morphine, alfentanil, and butorphanol in 1 patient each.

Surgical time varied from 3 to 5.25 hours (mean ± SD, 4.4 ± 0.8 hours). Core body temperature was measured using an esophageal temperature probe. External measures to maintain body temperature included a circulating water blanket and a heated humidifier. From the retrospective review, determination of the ambient room temperature was not possible.

Core body temperature increased in all 25 patients, from a starting temperature of 36.1°C ± 0.5°C to 38.0°C ± 0.6°C ($P < 0.001$). The maximum temperature was greater than 38°C in 12 patients and greater than 39°C in 3 patients.

In addition, the charts were reviewed of 15 patients who underwent thoracotomy during the same period. Patients with an infectious disease...
requiring surgical intervention (e.g., empyema or interstitial pneumonitis) were excluded from consideration. There were 10 boys and 5 girls ranging in age from 4.5 to 15 years (mean ± SD, 9.4 ± 4.4 years) and in weight from 14.5 to 61 kg (mean ± SD, 37.5 ± 19.8 kg). Premedication, intraoperative anesthetic technique, use of anticholinergic agents, and choice of muscle relaxant and narcotic agents varied among these patients but did not differ from the agents used in the patients undergoing repair of pectus excavatum.

Surgical time varied from 2.5 to 5 hours (mean ± SD, 3.7 ± 1.2 hours). Core body temperature was measured using an esophageal temperature probe. External measures to maintain body temperature included a circulating water blanket and a heated humidifier. Patients in whom the external measures used to control body temperature could not be determined were not included in the study. It was not possible to determine the ambient room temperature.

The core body temperature increase in the 15 patients from a starting temperature of 35.9°C ± 0.7°C to a maximum of 36.3°C ± 1.2°C (P, not significant) during the surgical procedure. The maximum temperature was greater than 39°C in 1 patient.

**Prospective data.** The prospective arm of the study included 10 patients (8 boys and 2 girls) ranging in age from 6.5 to 18 years (mean ± SD, 11.3 ± 5.5 years) and in weight from 22.6 to 77 kg (mean ± SD, 46.6 ± 21.6 kg). Surgical time varied from 3 to 5.25 hours (mean ± SD, 4.4 ± 0.8 hours).

Core body temperature increased in all patients, from a starting temperature of 36.1°C ± 0.6°C to 36.8°C ± 0.8°C (P<.05). None of the 10 patients had a core body temperature greater than 38°C.

## Discussion

Exogenous means to maintain body temperature are commonly required to prevent hypothermia in children. Such measures include overhead radiant warmers, raising the ambient temperature of the operating room, heated humidifiers, warming blankets, and the warming of intravenous fluids. With such aggressive measures, it has been suggested that hyperthermia may now be more common than hypothermia. It was our clinical impression that a consistent rise in body temperature occurred during repair of pectus excavatum. The retrospective chart review documented a rise in body temperature from 36.1°C ± 0.5°C to 38.0°C ± 0.6°C, with 12 of 25 patients having a temperature in excess of 38°C. This was not the case in patients undergoing a different thoracic procedure (lateral thoracotomy). Although there was a modest increase in core body temperature during the procedure (35.9°C ± 0.7°C to a maximum of 36.3°C ± 1.2°C), only 1 of the 15 patients had a temperature greater than 38°C.

The detrimental physiologic effects of hyperthermia are limited in children with normal cardiopulmonary function. Effects on cardiovascular function include increases in cardiac output and heart rate, while respiratory effects include increased oxygen consumption and carbon dioxide production. Although these physiologic alterations are generally well tolerated in children, the rise in body temperature may be difficult to distinguish from true MH. This may be particularly relevant in our current patient population as it has been suggested that the incidence of MH is not only higher in children, but perhaps also in patients with musculoskeletal deformities. In addition, although evidence is lacking in humans, animal studies suggest that hyperthermia itself may trigger MH.

We are uncertain about the cause for the hyperthermia in patients undergoing repair of pect-

| Table I |
| Summary of the anesthetic management of 25 patients in the retrospective arm of the study who underwent repair of pectus excavatum |

<table>
<thead>
<tr>
<th>Premedication</th>
<th>None</th>
<th>Oral midazolam</th>
<th>Intravenous midazolam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of anticholinergic agents</td>
<td>None</td>
<td>Atropine</td>
<td>Glycopyrrolate</td>
</tr>
<tr>
<td>Induction technique</td>
<td>Inhalation (halothane in nitrous oxide)</td>
<td>Intravenous (thiopental)</td>
<td></td>
</tr>
<tr>
<td>Neuromuscular blocking agent</td>
<td>Succinylcholine</td>
<td>Atracurium</td>
<td>Vecuronium</td>
</tr>
<tr>
<td>Maintenance anesthesia</td>
<td>Isoflurane</td>
<td>Halothane</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>Intraoperative narcotic agent</td>
<td>None</td>
<td>Fentanyl</td>
<td>Sufentanil</td>
</tr>
</tbody>
</table>
tus excavatum. Even without the use of exogenous means (prospective patients), there was a statistically significant rise in body temperature from a starting temperature of 36.1°C ± 0.6°C to 36.8°C ± 0.8°C. However, none of the patients had a temperature in excess of 37.5°C.

Bloch et al have described the occurrence of hyperthermia during limb tourniquet application in anesthetized children. They noted an increase in core body temperature from 36.45°C ± 0.52°C to 37.16°C ± 0.49°C (P = .01) at 120 minutes into the surgical procedure with the use of a single limb tourniquet and from 36.46°C ± 0.58°C to 37.79°C ± 0.85°C (P = .01) when a tourniquet was applied to both limbs. They suggested that the application of the tourniquet prevented heat loss from the extremity that would normally occur following the induction of general anesthesia with peripheral vasodilation. Further evidence for their theory is supplied by adult studies demonstrating a decrease in core body temperature following tourniquet release. In addition, the rise in body temperature was greater following bilateral as opposed to unilateral tourniquet application. Such an effect on the redistribution of heat is not a likely explanation in our patient population.

It is also unlikely that the anesthetic technique contributed to the rise in body temperature. Crocker et al found no effect on core body temperature using nondepolarizing neuromuscular blocking agents or anticholinergic drugs. Engelman and Lockhart demonstrated a fall in temperature of 0.68°C over 30 to 75 minutes in children anesthetized with nitrous oxide and halothane. In addition, our retrospective review demonstrated a consistent rise in body temperature regardless of the anesthetic agents used and no such rise in patients undergoing a different thoracic procedure. As such, it would seem that there may be some causal relationship between the type of procedure and the rise in body temperature.

Core temperature is controlled by the balance of heat production, heat loss to the environment, and the internal distribution of body heat. Because neither the anesthetic technique nor the surgical procedure would be expected to interfere with the latter two factors, we speculate that an alteration in heat production is the only plausible explanation for our findings. Increases in heat production may be the result of endogenous pyrogens, excessive muscular activity, or hypermetabolic states such as hyperthyroidism. Because the latter two are unlikely to explain hyperthermia in our patient population, we remain unsure about the exact cause of the rise in core body temperature that occurs during surgical repair of pectus excavatum.

Although we were not able to identify the agents responsible for hyperthermia in our patient population, the purpose of our review was first to document its occurrence and then to determine a method of preventing it. We have demonstrated that significant elevations in body temperature occur in children during repair of pectus excavatum when exogenous means of heating are used. We currently do not use such measures during this surgical procedure. By avoiding the need for a heated humidifier and a warming blanket, some modest cost savings may be offered to the patient.

In addition, by avoiding the need to raise the ambient temperature of the room, the environment is made more comfortable for our surgical colleagues. More important, excessive intraoperative hyperthermia can be avoided. Although we have come to expect hyperthermia during repair of pectus excavatum, the occurrence of intraoperative temperatures in excess of 38.5°C may suggest the diagnosis of MH. The thought of MH may lead to an unnecessary escalation of care and increase patient charges and the cost of medical care.

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