Evaluation of two warming systems after cardiopulmonary bypass

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Summary
We have compared the Thermodex electric undermattress (JMW Systems, Edinburgh, UK) and the Bair Hugger (Augustine Medical, Courteley, Switzerland) forced-air warming blanket in 30 adult patients after cardiac surgery. All patients were warmed to an oesophageal temperature of 38°C before termination of cardiopulmonary bypass (CPB); those with oesophageal temperatures <35.5°C at skin closure were allocated randomly to be rewarmed in the intensive care unit either on the Thermodex (n = 15) or under the Bair Hugger blanket (n = 15), at their highest settings. Oesophageal and lateral thigh skin temperatures were recorded every 15 min for 4 h. There was a significantly faster increase in core temperature (0.5 vs 0.75°C h⁻¹; P < 0.0002) and skin temperature (0.86 vs 1.3°C h⁻¹; P < 0.001) in the Bair Hugger group. However, there was no difference in the number of patients who reached a core temperature of 36°C at their highest settings. Oesophageal and lateral thigh skin temperatures were recorded every 15 min for 4 h. There was a significantly faster increase in core temperature (0.5 vs 0.75°C h⁻¹; P < 0.0002) and skin temperature (0.86 vs 1.3°C h⁻¹; P < 0.001) in the Bair Hugger group. However, there was no difference in the number of patients who reached a core temperature of 36°C at skin closure were allocated randomly to be rewarmed in the intensive care unit either on the Thermodex (n = 15) or under the Bair Hugger blanket (n = 15), at their highest settings. Oesophageal and lateral thigh skin temperatures were recorded every 15 min for 4 h. There was a significantly faster increase in core temperature (0.5 vs 0.75°C h⁻¹; P < 0.0002) and skin temperature (0.86 vs 1.3°C h⁻¹; P < 0.001) in the Bair Hugger group. However, there was no difference in the number of patients who reached a core temperature of 36°C at skin closure were allocated randomly to be rewarmed in the intensive care unit either on the Thermodex (n = 15) or under the Bair Hugger blanket (n = 15), at their highest settings.

Methods and results
After obtaining approval from the hospital Ethics Committee, we studied 30 adult patients with normal to moderately impaired left ventricular function undergoing hypothermic CPB for elective cardiac surgery. Premedication comprised a benzodiazepine and opioid; anaesthesia was induced with fentanyl 20–30 μg kg⁻¹, and midazolam 1–10 mg or thiopentone 25–100 mg, or both, and pancuronium was administered to provide neuromuscular block. Patients’ lungs were ventilated with oxygen-enriched air (+ isoflurane before bypass) with a heat-moisture exchanging filter; propofol 1–2 mg kg⁻¹ was infused during CPB to maintain anaesthesia. Oesophageal (heart) and nasopharyngeal (brain) temperatures (Mon-a-therm General Purpose Critical Care Temperature Probes, Mallinckrodt Medical, Inc., Northampton, UK) were measured continually during operation. All patients were warmed actively to both oesophageal and nasopharyngeal temperatures of at least 38°C before termination of bypass, using warm perfusion and a heated water mattress. Oesophageal temperature was used thereafter to measure core temperature, consistent with routine practice in our ICU. Patients with oesophageal temperatures <35.5°C at skin closure were allocated randomly to be rewarmed in the ICU either covered with a sheet and a cotton blanket, lying on the Thermodex mattress set at 41°C (its highest setting) or using the Bair Hugger set on “high” (43°C), placed directly on the patient and covered with a sheet and cotton blanket. Core and peripheral (skin, lateral aspect of thigh; Mon-a-therm, Mallinckrodt Medical, as above) temperatures were recorded every 15 min for 4 h or until normothermia (oesophageal temperature 37°C) was achieved. The presence or absence of gross shivering, blood loss in the first 4 h and time to extubation were recorded. Sample size was determined by power analysis; 30 patients were required to detect a clinically relevant difference (one method warming patients to 36°C core temperature 1 h faster than the other) with an 80% power of achieving a statistically significant result at the 5% level. The two sample t test was used to compare

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Key words

A decrease in temperature after cardiopulmonary bypass (CPB) is common; adequate rewarming may be difficult to achieve despite active intraoperative warming [1–3]. Residual hypothermia may delay drug clearance, impair coagulation and cause haemodynamic instability [4, 5]. We hypothesized that a forced-air convective system, such as the Bair Hugger, is a better means of warming adult patients after CPB in the intensive care unit (ICU) than a heated electric undermattress such as the Thermodex, which warms by conduction. This study was designed to determine if the Bair Hugger warming blanket is more effective than the Thermodex warming mattress in rendering adult patients normothermic who are hypothermic on arrival to the ICU after CPB.
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There were no differences between the two groups in patient characteristics, treatment with inotropes or vasodilators, or incidence of postoperative shivering (two of 15; 13%). There was no difference in mean oesophageal temperature (34.8 °C for the Thermomat group, 34.4 °C for the Bair Hugger group; P = 0.051) or mean skin temperature (31.6 °C for the Thermomat group, 31.9 °C for the Bair Hugger group; P = 0.5) on arrival in the ITU, or a difference in core-to-skin temperature gap (3.2 °C for the Thermomat group, 2.5 °C for the Bair Hugger group; P = 0.1).

The number of patients reaching core temperatures of 36 °C (15 in the Bair Hugger group, 14 in the Thermomat group; 0.2 > P > 0.1) and 37 °C (11 in the Bair Hugger group, seven in the Thermomat group; 0.1 > P > 0.05), was not significantly different. Only two patients in the Thermomat group reached a skin temperature of 36 °C compared with 12 patients in the Bair Hugger group (P < 0.001). There was no difference in the number of patients who reached a peripheral temperature of 37 °C within 4 h (one patient in the Thermomat group, four patients in the Bair Hugger group; 0.2 > P > 0.1). The mean rate of core temperature increase was 0.5 °C/h for patients in the Thermomat group and 0.75 °C/h in the Bair Hugger group (P < 0.0002). The mean rate of increase in skin temperature was 0.86 °C/h for the Thermomat group and 1.3 °C/h for the Bair Hugger group (P < 0.001). A comparison of mean temperatures for each group over time is shown in figure 1.

Comment

Patients undergoing CPB are unique in that intentional systemic hypothermia occurs with an open chest cavity; for part of this time the lungs are not ventilated and the heart is actively cooled separately. Even with aggressive central and peripheral warming, there is ongoing heat loss after bypass, during wound closure and transport to the ITU. Subsequent temperature equilibration between the core and periphery may result in a decrease in core temperature, sometimes rapidly. Behavioural and physiological responses to hypothermia are often undesirable in cardiac patients and may be ablated in the ITU by residual anaesthetic agents, vasodilators, sedation and neuromuscular block. Shivering may be intentionally abolished because it increases the body’s oxygen demand by 400–500% [6]; it may also promote respiratory acidosis from increased carbon dioxide production. Ordinarily, spontaneous arrhythmias are not seen until core temperature has decreased to approximately 33 °C. In patients who have had open heart surgery, ischaemia, acid–base or electrolyte abnormalities, or other co-existing factors, may contribute to myocardial irritability. Other physiological changes associated with hypothermia such as altered blood-gas transport, increased blood viscosity and mental status changes, do not occur until reductions in body temperature are extreme [4].

Conductive heat transfer occurs by direct contact between objects; in the intraoperative period, heat is lost in this way to the operating table and underlying wet sheets, cool i.v. fluids and irrigating solutions. The heat supply of a warming mattress (a conducting surface) is limited by skin conductance, temperature gradient and contact area. To prevent burns, a sheet is usually interposed between the mattress and the patient, interfering with heat transfer. Additionally, peripheral vasoconstriction may further reduce the effectiveness of a warming mattress as a heat exchanger. A warming mattress can be warmed on the bed before the patient is transferred to it, but removal of the warming mattress from under the patient can be cumbersome. However, the mattress may stay in place during most routine postoperative care in the ICU. Convective heat exchange involves the direct transfer of energy by collisions between

Figure 1 Comparison of changes in mean core temperature (left) and mean skin temperature (right) between the Bair Hugger group (○) and Thermomat (●) groups (mean, se).
body surface molecules and moving air molecules. Air velocity, ambient temperature and surface area are its main determinants. The forced-air warming mattresses currently available are lightweight and easy to use, although they are often partially removed or displaced in the ICU for certain aspects of care, potentially decreasing their effectiveness as a means of warming.

Although our study showed a faster rate of both core and peripheral warming by the Bair Hugger, there was no difference in the time to tracheal extubation or in the overall nature of the post-operative course between the two groups. This suggests that both a heated electric undermattress and a forced-air warming blanket are appropriate methods of warming hypothermic patients after bypass in the ICU.

References