HUMIDIFICATION AND LOSS OF BODY HEAT DURING ANAESTHESIA II: EFFECTS IN SURGICAL PATIENTS

C. A. SHANKS

SUMMARY

Changes in temperature and body heat were measured in 30 patients. Despite the warming of most fluids given intravenously, all the patients ventilated with dry anaesthetic gases became cooler, with an average heat loss of 12.4 kilocalories per hour. In a group to whom the gases were delivered saturated at body temperature, the average hourly loss was 1.5 kilocalories. This difference is in agreement with the effects calculated from respiratory heat exchange, and indicates that heated humidification can help to limit or prevent the development of hypothermia in anaesthetized adults.

The anaesthetized patient has a reduced metabolic rate, and his thermoregulation is impaired. Body temperatures decrease more rapidly when skin and visceral surfaces are extensively exposed to cool air (Lunn, 1969; Morris, 1971). Cold intravenous infusions, irrigating solutions and wet packs further enhance the tendency to body cooling. The combination of these effects can cause the deep body temperature to become less than 32°C (Newman, 1971). This can happen even with blood-warming and a heated water-mattress (Searle, 1971).

The role of respiratory heat exchange has been discounted in anaesthesia for adults (Sato, 1961), yet many of the studies in which temperature reductions were reported appear to involve ventilation with dry gases (Lunn, 1969; Lewis and Mackenzie, 1972). In infants and children, Rashad and Benson (1967) showed that heated humidification was able to limit or prevent temperature reductions. Moreover, the humidifier has been used effectively in “core” rewarming of adults with accidental hypothermia (Ledingham and Mone, 1972; Lloyd, 1973).

In order to assess the role which the humidifier might have, this study compares two groups of adult patients undergoing elective surgery, and attempts to separate the effects of respiratory heat exchange from the other factors which influence heat balance.

METHOD

Thirty adult patients were studied before and during anaesthesia; in 27 of the patients the operation involved the abdominal cavity. The patients were divided into two groups of 15, matched as evenly as possible for age, weight and sex. Gases were delivered to the control group from a fully dried non-rebreathing system. In the other 15 patients, a heated water-bath humidifier was in the inspiratory line of a circle absorber system, and adjustments were made to deliver saturated gases at body temperature. After premedication with a narcotic and an antialagogue drug, anaesthesia was induced with thiopentone. Pancuronium was administered to maintain muscle relaxation, and the patients were ventilated, via an orotracheal tube, with a mixture of nitrous oxide, oxygen and halothane at a minute volume of 10–11 litres.

Temperatures were measured with thermocouples (Ellab, Copenhagen). Deep body temperatures were measured in at least two of four sites: auditory canal, lower oesophagus, rectum and nasopharynx. Skin temperatures were measured at four sites; mean skin temperatures were obtained according to Ramanathan (1964). The Appendix shows how these were used in the calculation of mean body temperature and stored body heat (Burton, 1935; Colin et al., 1971). Measurements were made before and after induction of anaesthesia, and at 10-min intervals thereafter.

The only particular effort to restrict heat losses was the use of an immersion coil to warm the intravenous fluids, so that patients in both groups received less than 300 ml of solutions at room temperature during any hour of anaesthesia. Patients who became hypotensive were excluded from the study.

One of the control group required a second laparotomy, when humidification was used (fig. 1).
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TABLE I. The effects of humidification on the operative heat losses of 30 patients. The mean values (and SEM) are given.

<table>
<thead>
<tr>
<th></th>
<th>Dry gases</th>
<th>Humidified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>15 (9M, 6F)</td>
<td>15 (8M, 7F)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>51.1 (4.2)</td>
<td>53.9 (5.4)</td>
</tr>
<tr>
<td>Number aged more than 60 years</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.2 (2.1)</td>
<td>60.1 (2.3)</td>
</tr>
<tr>
<td>Theatre air temperature (°C)</td>
<td>21.7 (0.3)</td>
<td>21.7 (0.3)</td>
</tr>
<tr>
<td>Number of patients in theatres below 21°C</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Change in core temperatures (°C) Before induction</td>
<td>to 30 min: -0.40 (0.09)</td>
<td>-0.45 (0.11)</td>
</tr>
<tr>
<td></td>
<td>to 60 min: -0.66 (0.09)</td>
<td>-0.61 (0.12)</td>
</tr>
<tr>
<td></td>
<td>60-120 min (hour 2): -0.09 (0.05)</td>
<td>+0.11 (0.08)</td>
</tr>
<tr>
<td></td>
<td>120-180 min (hour 3): -0.20 (0.08)</td>
<td>-0.01 (0.09)</td>
</tr>
<tr>
<td>Hourly change for whole anaesthetic: -0.29 (0.04)</td>
<td>-0.12 (0.05)</td>
<td></td>
</tr>
<tr>
<td>Change in body heat (kcals) Before induction</td>
<td>to 30 min: -14.5 (3.4)</td>
<td>-12.8 (5.8)</td>
</tr>
<tr>
<td></td>
<td>to 60 min: -19.7 (3.4)</td>
<td>-9.8 (6.7)</td>
</tr>
<tr>
<td></td>
<td>Hour 2: -7.0 (2.8)</td>
<td>+5.9 (2.9)</td>
</tr>
<tr>
<td></td>
<td>Hour 3: -12.6 (1.8)</td>
<td>+0.5 (4.5)</td>
</tr>
<tr>
<td>Average hourly change: -12.4 (2.3)</td>
<td>-1.5 (2.2)</td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION

Temperature changes.

The control (dry gas) group showed an average reduction of core temperature of 0.29°C per hour (table I). Similar reductions have been reported by Goldberg and Roe (1966), Roe et al. (1966), Vale and Lunn (1969), Lunn (1969), and Lewis and Mackenzie (1972); most of these patients were undergoing surgery which involved a body cavity and/or the vascular system. Goldberg and Roe found that those of their patients who were over 60 years of age cooled more readily. Newman (1971) demonstrated that cold fluids, administered in cool rooms, could produce larger temperature reductions during anaesthesia (e.g. 2°C decrease in 3 hours). In patients who had been anaesthetized for more than 45 min Morris and Wilkey (1970) observed that deep body temperatures decreased by 0.3°C per hour when air temperatures were below 21°C, but became stable in warmer rooms. The control group (table I) did not show this plateau, despite warming of the bulk of intravenous fluids.

Prevention of inadvertent hypothermia has been attempted by various means, including application of heat to the body surface. Newman (1971) used warmed intravenous fluids in conjunction with an electric blanket, and reductions in oesophageal temperature did not exceed 0.5°C.

RESULTS

Following induction of anaesthesia, skin temperatures increased rapidly and core temperatures decreased slightly, without loss of body heat; 10 to 20 min after induction of anaesthesia, while the patient lay exposed on the operating table, heat was lost rapidly. Shortly after the surgical drapes were in position skin temperatures increased again, but most core temperatures continued to decrease. By the end of the first half-hour of anaesthesia the two groups lost similar amounts of heat (table I). Heat loss after the first hour of anaesthesia, and for the average hourly total were examined, and the difference between the means was significant at the 98% confidence level.

During the second hour of anaesthesia, 10 of the humidified group showed a gain in heat, as compared with 2 of the control group. This was significant at the 99% confidence level (chi-square test). All 15 patients who were ventilated with dry gases showed a net heat loss for the whole period of anaesthesia, whereas this occurred in less than half of the humidified group (P<0.01). The average heat loss in the control group was found to be 12.4 kcal per hour, and only 1.5 in the humidified group (table I); 14 of the 15 humidified patients lost less than 10 kcal per hour.

Fig. 1. Two records of the same patient, No. 3 in the control group. He required a second exploration of his biliary tract two weeks later, and a humidifier was used during this anaesthetic. Once the first hour of anaesthesia had elapsed, the net heat balance was different on the two occasions. During the first operation, respiratory heat loss contributed to the reduction in temperature. In the second procedure it would appear that metabolic heat production was able to cope with the reduced total of heat losses.
HUMIDIFICATION AND BODY HEAT—II

Because skin damage has been associated with the use of heating blankets (Scott, 1967; Crino and Nagel, 1968), a heat-retaining mattress has been advocated (Shanks and Lunn, 1969; Vale, 1972). Despite these measures, inadvertent hypothermia may still occur (Searle, 1971; Morris and Kumar, 1972; Lewis and Mackenzie, 1972).

Changes in stored body heat.

If heat is redistributed from the body “core” to cooler peripheral tissues, then the central temperature decreases while the total body heat remains unaltered. Vasodilatation occurs with the induction of anaesthesia, and this reduction may be as much as 1°C in 15 min (Cohen, 1967). None of the patients in this series showed this large response. However, comparisons of heat loss must include an estimate of mean skin temperature as heat redistribution has produced the fall in core temperature (Vale, 1972). The four-point system of Ramanathan (1964) has been shown to give surprisingly good agreement with the “optimal” system utilizing 15 skin sites (Mitchell and Wyndham, 1969).

Large heat losses during operation have been reported (Lunn, 1969; Vale and Lunn, 1969; Dyde and Lunn, 1970), where control groups had mean losses of some 21 kcal per hour during thoracotomy. In those series, it would appear that the fluids administered intravenously were not warmed. This might account for the smaller deficit shown in table I where the dry gas group had an average hourly loss of 12.4 kcal.

Ventilation with dry gases at 10 litre/min produces a loss from the respiratory tract of approximately 10 kcal per hour (Caldwell, Gomez and Fritts, 1969; Shanks, 1974). When the humidifier is adjusted to supply gases at body temperature, respiratory heat exchange becomes zero (Dery, 1973). This humidification, associated with the warming of intravenous fluids was able to limit or prevent the development of hypothermia. Avoidance of these loss factors resulted in 14 of the 15 humidiﬁed patients losing less than 10 kcal per hour. Heated humidification has a deﬁnable role in reducing the amount of heat lost by the anesthetized adult.

APPENDIX

If \( Q_a = \) stored body heat \\
\( T_b = \) mean body temperature \\
\( T_{db} = \) deep body temperature \\
\( T_{sk} = \) mean skin temperature \\
\( M_b = \) body mass \\
0.83 = specific heat of the body

\[
\text{Then} \quad \Delta Q_a = \Delta T_b \cdot M_b \cdot 0.83
\]

\[
\bar{T}_{sk} = X \cdot T_{db} + (1 - X) \bar{T}_{sk}
\]

Where

(i) \( X \) was given as 0.66 (Burton, 1935, Colin et al., 1971).

(ii) \( \bar{T}_{sk} \) was calculated by the method of Ramanathan (1964):

\[
T_{sk} = 0.3(T_{chest} + T_{arms}) + 0.2(T_{thigh} + T_{me})
\]

REFERENCES


