HEAT LOSSES IN INFANTS UNDERGOING SURGERY IN AIR-CONDITIONED THEATRES

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SUMMARY

An association is described between hypothermia occurring in anaesthetized babies and early postoperative morbidity and death. Sixty-seven children under one year old had operations in 1960, of whom twelve died; seven of these cases (which are described) were associated with hypothermia. While other factors were undoubtedly involved it seems that hypothermia was the principal factor responsible for the deaths.

Hypothermia is most likely to occur during long operations, in air-conditioned theatres and when respiration is controlled. Ways of preventing inadvertent hypothermia are discussed and the importance of temperature monitoring and of rigid maintenance of normal temperatures is emphasized.

Ibadan in Western Nigeria is in the tropical forest belt 180 m (600 ft.) above sea level, 7° north of the equator. The average midday temperature is above 27°C (80°F) and the average relative humidity above 65 per cent (wet bulb temperature 24°C (75°F)). The temperatures of patients who undergo operations in these theatres tend to remain steady except in the cases of small children in whom temperature drops are common.

At first this was not thought to be harmful but in August 1959 the following event occurred.

CASE 1. A 7-day-old baby underwent a resection of gangrenous bowel following a volvulus of the small intestine. Anaesthesia was maintained with nitrous oxide and oxygen using intermittent suxamethonium (total dose 70 mg) and controlled respiration. The operation lasted 105 minutes, during which time the temperature fell from 38.7°C (98°F) to 35°C (95°F). After operation the respiration was inadequate and was not improved by atropine 0.25 mg and neostigmine 0.025 mg nor by intramuscular nikethamide. The baby felt cold to the touch and was therefore wrapped up and placed in the warm recovery room. Artificial respiration with oxygen was given, but 1½ hours after operation the circulation failed and the child died.

During 1960 there were seven more postoperative deaths in infants who were hypothermic during operation. An investigation of the records of all children under 1 year old operated on during this year was therefore undertaken in an attempt to discover the causes of these deaths and to find ways of preventing them. There were 67 children in the series, with 9 deaths within 24 hours of surgery and a further 3 within 2 days of operation. Six of the children who died in the first 24 hours and 1 who died later suffered from hypothermia, with temperatures below 36.1°C (97°F), at the end of operation. Details of the fatal cases are summarized in table I, together with the midday theatre and outside figures for temperature and relative humidity on the days of operation.

Records of temperatures before and after operation were kept in 33 of the 67 cases. In 5 cases there was a rise of temperature during operation, in 2 it remained the same, in 10 (of whom 1 died) there was a fall of less than 0.5°C (1°F) and in 16 cases there was a fall greater than 0.5°C (1°F). Three of the latter died within 48 hours of operation; details of the survivors are given in table II.

Twelve of the 33 cases with complete temperature records were hypothermic at the end of their operations. Further details of these cases are given in table III.

Consideration of the histories of the seven hypothermic patients who died in 1960 reveals that all except two (cases 2 and 7) were seriously
ill and might have died anyway. However, it is difficult to avoid the conclusion that hypothermia imposed an additional strain on these infants and that they might have survived if they had not become hypothermic. Whether seriously ill or not, a baby undergoing surgery in these theatres tends to lose heat and suffer a fall of temperature. The observation that deaths were commonest in those who became hypothemic (see table III) strongly suggests that hypothermia contributed to their deaths. Conversely, there were no deaths in the infants whose temperatures remained steady or rose during operation.

**BRIEF DESCRIPTIONS OF THE FATAL CASES**

**CASE 2. February 20, 1960.**
A 1-day-old baby weighing 2.7 kg (6 lb.) underwent repair of exomphalos. The child was intubated and given intermittent intramuscular suxamethonium bromide to a total dose of 50 mg (18.5 mg/kg) while artificial respiration was carried out with nitrous oxide in oxygen using Rees’s modification of Ayre’s T-piece.

The pre-operative temperature was unrecorded but the fall during operation was 2°C (3.6°F) and the infant felt definitely cold. Respiration was present but poor and colour could only be maintained by giving oxygen. He was transferred to the neonatal ward and was given first caffeine sodium benzoate and then nikethamide, without improvement. He stopped breathing altogether 2 hours after the operation and although he was re-intubated and inflated with oxygen the heart had already stopped.

Postmortem examination showed that only the apex of the left lung was well expanded, the remainder of both lungs being extensively collapsed, and that the liver was an unusual shape, with patent but abnormal bile passages.

**CASE 3. June 23, 1960.**
A 10-weeks-old, 1.8 kg (4 lb.) child had a repair of a strangulated left lumbar hernia on June 19, 1960. A second operation became necessary because of large bowel obstruction.
**HEAT LOSSES UNDER SURGERY IN AIR-CONDITIONED THEATRES**

### TABLE II

*Children who survived after a fall of temperature greater than 0.5°C (1°F)*

<table>
<thead>
<tr>
<th>Age (wks.)</th>
<th>Weight (kg lb.)</th>
<th>Operation site</th>
<th>Operating time (min)</th>
<th>Main agent</th>
<th>IPPR</th>
<th>Temperature</th>
<th>Fall (°C (°F))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pre-operative °C (°F)</td>
<td>Post-operative °C (°F)</td>
</tr>
<tr>
<td>1</td>
<td>2.8 (6.5)</td>
<td>Abdomen</td>
<td>90</td>
<td>Halothane</td>
<td>No</td>
<td>37.4 (99.4)</td>
<td>33.3 (92)</td>
</tr>
<tr>
<td>1</td>
<td>3.1 (7.0)</td>
<td>Superficial</td>
<td>50</td>
<td>Halothane</td>
<td>No</td>
<td>37.7 (98.8)</td>
<td>36.1 (97)</td>
</tr>
<tr>
<td>8</td>
<td>3.1 (7.0)</td>
<td>Superficial</td>
<td>30</td>
<td>Cyclopropane</td>
<td>No</td>
<td>36.1 (97)</td>
<td>35.7 (95)</td>
</tr>
<tr>
<td>2/7</td>
<td>3.5 (8.0)</td>
<td>Abdomen</td>
<td>60</td>
<td>Halothane</td>
<td>No</td>
<td>37.2 (99)</td>
<td>35.5 (96)</td>
</tr>
<tr>
<td>4</td>
<td>4.0 (9)</td>
<td>Abdomen</td>
<td>30</td>
<td>Ether</td>
<td>No</td>
<td>37.2 (99)</td>
<td>36.3 (97.6)</td>
</tr>
<tr>
<td>12</td>
<td>4.0 (9)</td>
<td>Abdomen</td>
<td>70</td>
<td>Cyclopropane</td>
<td>No</td>
<td>37.8 (100)</td>
<td>36.8 (98.2)</td>
</tr>
<tr>
<td>12</td>
<td>4.9 (11)</td>
<td>Superficial</td>
<td>90</td>
<td>Halothane</td>
<td>No</td>
<td>36.6 (97.8)</td>
<td>35.5 (96)</td>
</tr>
<tr>
<td>16</td>
<td>4.9 (11)</td>
<td>Superficial</td>
<td>75</td>
<td>Cyclopropane</td>
<td>No</td>
<td>35.1 (95)</td>
<td>32.8 (91)</td>
</tr>
<tr>
<td>29</td>
<td>4.9 (11)</td>
<td>Superficial</td>
<td>35</td>
<td>Ether</td>
<td>No</td>
<td>37.7 (99.8)</td>
<td>36.9 (98.4)</td>
</tr>
<tr>
<td>29</td>
<td>5.9 (13)</td>
<td>Abdomen</td>
<td>70</td>
<td>Halothane</td>
<td>No</td>
<td>37.4 (99.4)</td>
<td>35.5 (96)</td>
</tr>
<tr>
<td>8</td>
<td>6.3 (14)</td>
<td>Superficial</td>
<td>50</td>
<td>Ether</td>
<td>No</td>
<td>37.2 (99)</td>
<td>36.4 (97.6)</td>
</tr>
<tr>
<td>29</td>
<td>7.0 (16)</td>
<td>Abdomen</td>
<td>165</td>
<td>Cyclopropane</td>
<td>No</td>
<td>38.4 (101.2)</td>
<td>36.9 (98.4)</td>
</tr>
<tr>
<td>38</td>
<td>?</td>
<td>Abdomen</td>
<td>20</td>
<td>Halothane</td>
<td>No</td>
<td>39.9 (103.8)</td>
<td>38.3 (101)</td>
</tr>
</tbody>
</table>

* Active cooling carried out during operation.

### TABLE III

*Analysis of details of 33 children who had a complete temperature record.*

<table>
<thead>
<tr>
<th></th>
<th>No. of cases</th>
<th>Deaths</th>
<th>Average age (weeks)</th>
<th>Average weight (kg lb.)</th>
<th>Average operating time (min)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Average pre-operative °C (°F)</td>
</tr>
<tr>
<td>All patients who had a complete temperature record</td>
<td>33</td>
<td>4</td>
<td>16</td>
<td>4.7 (10.5)</td>
<td>65</td>
<td>37.3 (99.1)</td>
</tr>
<tr>
<td>Patients whose temperatures fell by more than 0.5°C (1°F)</td>
<td>16</td>
<td>3</td>
<td>16</td>
<td>4.9 (11)</td>
<td>74</td>
<td>37.4 (99.4)</td>
</tr>
<tr>
<td>Patients whose temperatures fell by less than 0.5°C (1°F)</td>
<td>10</td>
<td>1</td>
<td>12</td>
<td>4.5 (10)</td>
<td>60</td>
<td>37.2 (98.9)</td>
</tr>
<tr>
<td>Patients whose temperatures did not change</td>
<td>2</td>
<td>0</td>
<td>1.5</td>
<td>2.8 (6.5)</td>
<td>15</td>
<td>110</td>
</tr>
<tr>
<td>Patients whose temperatures rose</td>
<td>5</td>
<td>0</td>
<td>19</td>
<td>5.4 (12)</td>
<td>50</td>
<td>37.1 (98.8)</td>
</tr>
<tr>
<td>Patients with post-operative temperatures below 36.1°C (97°F)</td>
<td>12</td>
<td>4</td>
<td>10</td>
<td>4.2 (9.5)</td>
<td>75</td>
<td>36.4 (97.6)</td>
</tr>
</tbody>
</table>
The patient was intubated and anaesthesia continued with cyclopropane. An obstruction which had developed at the hernial site was relieved in a 65-minute operation. The pre-operative temperature had been 35°C (95°F) but it was not recorded afterwards. Two hours after the operation the baby was found pale and gasping, and attempts at resuscitation were unsuccessful.

Postmortem examination failed to reveal any cause for death.

A 1-day-old child weighing 2.7 kg (6 lb.), with imperforate anus and tracheo-oesophageal fistula was submitted to a 2-hour operation consisting of a laparotomy followed by repair of the fistula. Diathermy was used, the pad being placed under the baby.

Anaesthesia consisted of nitrous oxide, oxygen and d-tubocurarine 1 mg (0.37 mg/kg) with controlled respiration. At the end of the operation the child was given atropine followed by neostigmine 0.5 mg and spontaneous respiration resumed, although the rate was slow. The child was returned to the ward where the temperature was found to be 30.6°C (87°F) and the respiratory rate 3 per minute. Forty-five minutes after the operation the child was placed in an incubator and the breathing improved, but later it became gasping in character. The temperature had by this time risen to 32.2°C (90°F). Respiration then became shallow and irregular and the child died 2 hours after operation.

Postmortem examination showed an imperforate anus, a single-lobed left lung and a two-lobed right lung, both extensively collapsed.

CASE 5. September 6, 1960.
A 16-weeks-old child was admitted with extensive burns of the legs and buttocks. She was transfused pre-operatively and taken to theatre. The temperature was then only 35.1°C (95.2°F). Anaesthesia with ether and oxygen lasted 75 minutes while the wound was extensively cleaned.

After the operation the temperature was 34.9°C (94.8°F) and 5 hours later the child was still described as hypothermic, with slow, regular respiration and an impalpable pulse. Oxygen was given and the child was covered with a blanket. Half an hour later respiration ceased and in spite of artificial respiration the child died.

A 1-year-old, 9.3 kg (21 lb.) child underwent repair of a ruptured lumbar meningo-myelocoele. The pre-operative temperature was 38°C (100.4°F) (5 hours beforehand), but after the 1-hour operation it was found to be 35°C (95°F). Anaesthesia was maintained with cyclopropane and oxygen. The child was kept in the recovery room until its temperature was 36.7°C (98°F), 2½ hours after the operation. Four hours after the operation the temperature had risen to 38.6°C (101.4°F) and respiration was then rapid and shallow. The child died 5½ hours after the operation.

A 5-week-old, 2.7 kg (6 lb.) baby with ectopia vesicae, but no other obvious abnormality. The child was placed on the operating table wrapped in gamgee tissue, with a hot water bottle beneath the upper part of the body. The lower half lay on the diathermy pad.

A bilateral uretero-colic anastomosis was carried out, lasting 3½ hours. Anaesthesia following intubation was by means of intermittent intramuscular suxamethonium and artificial respiration with 50 per cent nitrous oxide in oxygen using Rees's modification of Ayre's T-piece. The total dose of suxamethonium was 160 mg (59.2 mg/kg). The pre-operative temperature was 36.7°C (98.4°F) but by the end of the operation it had fallen below 34.4°C (95°F).

After the operation respiration had not returned and he was given atropine 0.3 mg and neostigmine 1 mg intramuscularly and a poor respiratory effort became apparent.

Active warming was applied and artificial respiration continued. The temperature rose to 35°C (95°F) at 1 hour and had reached 37.2°C (99°F) at 2 hours when warming was stopped. Quadruple strength plasma was given intravenously at 2 hours to provide an additional source of cholinesterase and a few minutes after this was started the child became cyanosed. Extra oxygen was added to the inspired mixture but the circulation, which had hitherto been good, failed and the baby died.

Due to the extreme length of the operation the child became cold in spite of attempts to keep it warm. The large dose of suxamethonium required is a reflection of the operating time.

An 8-days-old child weighing 3.1 kg (7 lb.) underwent excision of an occipital encephalocele lasting 1 hour. Anaesthesia consisted of nitrous oxide, oxygen and intermittent suxamethonium bromide (total 25 mg—8.1 mg/kg) and controlled respiration by intermittent occlusion of an Ayres T-piece.

The pre-operative temperature was 35.8°C (96.4°F) but by the end of the operation it had fallen below 35°C (95°F). Spontaneous respiration returned but it was periodic and the child appeared pale. He was placed in the recovery room and given nasal oxygen, and he improved in the next 1½ hours although the temperature remained below 35°C (95°F). He was returned to the ward with instructions to warm him until his temperature was 36.7°C (98°F). However, active warming was erroneously continued until the temperature reached 38.3°C (101°F) and it later rose to 38.9°C (102°F). It fell to 37°C (98.6°F) 15 hours after operation. The child died 2 days later.

DISCUSSION

THE INCIDENCE OF INADVERTENT HYPOTHERMIA

Until recently little notice has been taken of inadvertent falls of temperature under anaesthesia. In the past attention appears to have been mainly directed towards the prevention of hyperpyrexia. Bigler and McQuiston (1951) in a study of temperature changes in 215 children aged up to 13 years noted a fall below 36.1°C (97°F) in only nine cases, eight of whom were under 6 months old and the other under 1 year.
Rees (1950), writing on anaesthesia for the newborn did not mention hypothermia as a complication of anaesthesia, but the same authority (Rees, 1960) ten years later said that children under 6 months old tend to become hypothermic, and he mentioned controlled respiration as a cause. Hellings, Cope and Hawksley (1958) said that the temperature always falls during repair of oesophageal atresia, often to 31.1–31.7°C (88–89°F) or even 30°C (86°F). They allowed the baby to regain a normal temperature over two or three days. None of these papers describe any serious complication of hypothermia, although Rees (1960) does mention the possibility of sclerema. However, Stephen and his colleagues (1960) record two deaths associated with sclerema in infants hypothermic after operation.

**THE ILL EFFECTS OF HYPOTHERMIA**

Bering and Matson in 1953 described an electric heating pad for preventing hypothermia in infants, and remarked that recovery from operation and anaesthesia had been strikingly accelerated since it had been used. In 1955 Mann described a series of newborn infants in whom hypothermia occurring in a cold environment had been associated with lethargy, refusal to feed and occasional scleroedema. Respiration was depressed but the children were unusually pink. Mann and Elliot (1957) stated that when death occurred in hypothermic children it was due to respiratory failure. The temperature which they recommended for rewarming is within the range of the operating theatres in Ibadan in which hypothermia occurs. France (1957) of Glasgow described twelve neonates who had postoperative temperatures between 36.1°C (97°F) and 28.5°C (83.5°F), with five deaths (four of them in children under 2 kg (5 lb.) weight). He noticed that the children were drowsy at low temperatures, with slow respiration. He considered that death was definitely due to failure to rewar in two cases. Hackett and Crosby (1960) described feeding difficulties and slow resumption of normal activity in infants who became hypothermic during operation. Salanitre and Rackow (1961) noted that, other things being equal, there was a considerably higher incidence of postoperative respiratory insufficiency in children who became hypothermic. Seven of the nine cases who died at U.C.H., Ibadan, had postoperative respiratory depression in association with hypothermia. Figure 1 shows the occurrence of such depression in one case (case 9).

**CASE 9. January 10, 1961.**

A 6-months-old child weighing 5.4 kg (12 lb.) was originally admitted with purulent meningitis which responded to treatment. She also had an obstructive jaundice with a large mass in the region of the liver. Laparotomy and anastomosis of a choledochal cyst to the stomach was performed under cyclopropane and oxygen anaesthesia using an infant soda-lime canister, in the hope that this would tend to conserve heat. The temperature at the beginning of operation was 35.5°C (96°F) but 90 minutes later, at the end of operation, it had fallen to 34°C (93.2°F).

Active warming was applied in the recovery room until the temperature reached 36.1°C (97°F) 2 hours later. She was returned to the ward where the temperature rose to 37.4°C (99.4°F) after a further 6 hours, but it later fell again during the night to 34.4°C (94°F) at which time the respiration was described as sighing. Active warming was applied again until the temperature reached 37.2°C (99°F), when the respiratory rate was between 6 and 8 per minute. However, the child died 4 hours later, 23 hours after operation. The temperature chart of the last 24 hours of life is shown in figure 1.

Postmortem examination showed pus in the cerebral sulci, congestion in the posterior (dependent) parts of the lungs, and some bloodstained mucus in the bronchi. There was a gross abnormality of the bile duct system, with no connection between the gall bladder and the hepatic duct which itself ended blindly.

**FACTORS RESPONSIBLE FOR THE DEVELOPMENT OF HYPOTHERMIA IN ANAESTHETIZED CHILDREN**

**Factors Tending to Reduce Heat Production.**

The use of muscle relaxants.

The use of muscle relaxants and controlled ventilation of the lungs undoubtedly has a profound effect on the rate of heat loss in an anaesthetized child. Rees (1954) stated that a high proportion of the metabolic activity of a neonate is devoted to respiration, and (1960) that ventilation in neonates is barely adequate even in the absence of anaesthesia. He therefore advocated controlled respiration to ensure adequate ventilation. It is clear, however, that this procedure will also reduce heat production in proportion to the reduction in muscular activity, thus greatly accelerating the fall of temperature which is anyway encountered in small babies. The figures presented in table IV show that the
use of relaxants and controlled respiration was associated both with large falls of temperature under anaesthesia and with a high death rate. Of the 67 cases anaesthetized in 1960, 58 breathed spontaneously with 3 deaths, and nine had controlled respiration of whom 4 died. Controlled respiration with relaxants was formerly considered to be the method of choice in small infants in whom the stress of operation would be most damaging. It seems, however, that this choice was not a good one, and that these babies would have a far greater chance of survival if they had breathed spontaneously. Salanitre and Rackow (1961) studied postoperative respiratory complications in a series of young babies, and concluded that they were mainly due to a combination of hypothermia and the use of relaxants. When hypothermia developed in cases in whom relaxants were used, half of them had respiratory insufficiency severe enough to warrant assistance to respiration. They considered that the increased liability to hypothermia of babies anaesthetized with relaxants is due to inhibition of shivering. However, shivering is unusual in neonates, and older patients rarely shiver except when very lightly anaesthetized, although Burton and Bronk (1937) showed that under light anaesthesia muscle activity can increase in response to hypothermia, but not to the point of shivering. The main metabolic stimulant in neonates is probably circulating noradrenaline which enables them to produce heat without muscle activity, but what proportion of their normal heat production is accounted for by this mechanism is not known. Catecholamine output increases under certain types of anaesthesia (particularly ether) and there is evidence of increased production at low temperatures in infant mammals (Moore and Underwood, 1960). It seems probable, nevertheless that hypothermia developing under relaxant anaesthesia is due mainly to the abolition of muscle tone and respiratory effort, with a corresponding diminution of heat production.

Cannard and Zaimis (1959) showed that lowering of muscle temperature caused both an increase in magnitude and a prolongation of the action of depolarizing relaxants. The effect was reversed on rewarming. It appears that at about 28°C (82.5°F) the activity of suxamethonium is increased five or ten times, but the action of d-tubocurarine was reduced by about half on cooling to this level. Hypothermic patients would be expected to show these effects but neonates
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Table IV
The effect of controlled respiration on temperature drop and mortality.

<table>
<thead>
<tr>
<th></th>
<th>No. of cases</th>
<th>Deaths</th>
<th>Average age (weeks)</th>
<th>Average weight kg (lb.)</th>
<th>Average operating time (min)</th>
<th>Average pre-operative °C (°F)</th>
<th>Average post-operative °C (°F)</th>
<th>Average change °C (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients who died</td>
<td>7</td>
<td>7</td>
<td>12</td>
<td>4.0 (9.0)</td>
<td>98</td>
<td>36.1 (97)</td>
<td>34.3 (93.7)</td>
<td>-1.4 (2.5)</td>
</tr>
<tr>
<td>All patients who had IPP and relaxants</td>
<td>9</td>
<td>4</td>
<td>11</td>
<td>3.5 (8.5)</td>
<td>85</td>
<td>36.3 (97.4)</td>
<td>34.7 (94.4)</td>
<td>-1.7 (3.0)</td>
</tr>
<tr>
<td>All patients who breathed spontaneously throughout</td>
<td>58</td>
<td>3</td>
<td>21</td>
<td>5.2 (11.5)</td>
<td>65</td>
<td>37.0 (98.6)</td>
<td>36.5 (97.6)</td>
<td>-0.5 (1.0)</td>
</tr>
</tbody>
</table>

are on the whole insensitive to depolarizing relaxants (Hellings, Cope and Hawksley, 1958). When hypothermia develops in a young infant during the course of an operation, it is to be expected that the sensitivity of the infant to suxamethonium would increase, but that this effect could be abolished by rewarming the infant. There seems to be no doubt that cases 1 and 7 received doses of suxamethonium considerably greater than the maximum safe dose of 40 to 50 mg mentioned by Hellings, Cope and Hawksley (1958), and McDonald (1960), but cases 2 and 8 received doses of 50 mg (18.5 mg/kg) and 25 mg (8.1 mg/kg) respectively and they also showed postoperative respiratory depression, case 2 dying without resuming adequate respiration. It did not appear that this depression was reversed by rewarming. McDonald sums up the situation well when he says: “One of the most common and potent causes of poor postoperative breathing by the neonate is cold, whether relaxants have been used or not, and every effort should be made to keep the baby’s temperature normal.”

Illness.

Children who are ill in the tropics may develop hypothermia as reported by Morley (1960), of Ilesha, 80 miles from Ibadan. This response to illness was not confined to the youngest children and it may be due to undernourishment.

Many children in the present series, few of whom showed obvious evidence of malnutrition, arrived in the theatres with subnormal temperatures, possibly as a result of illness. This finding was also common in Gough’s (1960) series. There was no evidence that febrile children tended to become hyperpyrexic under anaesthesia, or that those with low initial temperatures necessarily became hypothermic (fig. 4). However, the figures presented here suggest that hypothermia is an added strain on a child who is ill and undergoing operation.

Factors increasing Heat Loss.

The effect of air-conditioning.

In the last few years air-conditioning has become much more common and it is now considered essential in the tropics and in hot weather in temperate climates. It seems that the introduction of air-conditioning increases the incidence of temperature falls and hypothermia in anaesthetized patients. Hackett and Crosby (1960), of Baltimore, compared temperature readings before and after the introduction of air-conditioning and found an increased incidence of hypothermia in infants which was not entirely prevented by active attempts to control the temperature.

The temperature and relative humidity in the operating theatres in U.C.H., Ibadan, are compared with corresponding figures for the outside atmosphere in figures 2a and 2b. The obvious distinction between young infants and older children reported by other writers has not been observed, and if there is an age above which they tend to become pyrexial under anaesthesia, it is
Fig. 2a
Outside temperature - - - - and percentage relative humidity ——
(Monday midday figures 1960).

Fig. 2b
Theatre temperature - - - - and percentage relative humidity ——
(Monday midday figures 1960).
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Higher than 1 year. However, gross rises of temperature under anaesthesia have not been observed. Adults in these theatres tend to maintain a steady temperature regardless of method of anaesthesia (Waters, D. J., personal communication).

Hercus (1960), of Sydney, reported some interesting findings in a series of children undergoing thoracotomy under nitrous oxide, oxygen and relaxant anaesthesia. His theatre temperatures were maintained at 21°C (70°F), and he found that children aged 1 to 7 years had a slight rise of temperature in the summer but a fall in the winter. Children under 1 year, however, showed a greater and more rapid fall, more pronounced in the summer. Of two neonates operated upon on the same evening one had a fall of temperature to 33°C (92.5°F) while the other, who was placed on an electric blanket during operation, suffered no temperature drop. Harrison, Bull and Schmidt (1960), in Durban, found that falls of temperature were universal. Their theatre temperature was about 24°C (75°F) with a relative humidity of 75 per cent. They noticed that if the theatre temperature did fall their patients suffered greater temperature drops, but they were unable to relate the degree of hypothermia to changes of relative humidity.

Although these authors do not state the outside atmospheric temperatures and humidities, it is remarkable that temperature drops of a similar order have been reported from such different parts of the world. The figures of Hercus, showing a greater fall of temperature in the youngest children in the summer, might suggest that patients acclimatized to hot weather would be most liable to suffer from hypothermia. However, this did not apply to the older children in his series, while neonates and young children would be the least likely to show acclimatization. The older children reported by Hercus tended to have a rise of temperature in warmer weather and vice versa. The author's suggestion that more care was taken to prevent temperature drops in winter may be the correct one, though this would be thought unnecessary in theatres kept at a constant temperature. The explanation may lie in a seasonal variation in theatre temperature or humidity.

Although little difference has been found between the relative humidities inside and outside the theatres, there has been a consistent difference between the wet-bulb temperature (fig. 3). Evaporative heat loss depends on the difference between the vapour pressure of water at skin temperature and that at the surrounding air temperature (Clark, Orkin and Rovenstine, 1960). Evaporation ceases when there is no difference, which occurs at wet-bulb tempera-

![Fig. 3](image_url)

Wet bulb temperatures in 1960.

--- operating theatre.

--- outside.
tasures above 35.5°C (96°F). Clark, Orkin and Rovenstine state that relative humidity is misleading because it bears no absolute relation to the water vapour pressure. In theatres which are not air-conditioned they noted a direct relationship between wet-bulb temperature and rise of temperature in their patients, which was most marked at wet-bulb temperatures above 24°C (75°F). It may be that the effect of air-conditioning in increasing evaporative rather than conductive heat loss (i.e. drying rather than cooling) has been underestimated. If this is so, then it might explain why six of our seven deaths occurred in the rainy season, when the difference between the theatre and outside wet-bulb temperatures is greatest. Of those patients who suffered a fall of temperature, sixteen had operations in the rainy season and eleven in the dry season.

The effect of body weight and surface area.

Harrison, Bull and Schmidt (1960) noticed much greater falls of temperature in children weighing less than 9 kg (20 lb.) or with a surface area of less than 0.3 sq.m, and many reports confirm this. The young infant has a large surface area for his weight, and as the cases dealt with in Ibadan tended to be thin or of normal build, they may have had larger surface areas and less subcutaneous fat than infants in other lands. The heaviest child in the present series was 1 year old and weighed 9.3 kg (21 lb.) (case 6), while the average age of all patients was 16.5 weeks, and the average weight 4.9 kg (10.8 lb.), whereas figures quoted in Geigy Scientific Tables (1956) give a weight of 6.6 kg (14.5 lb.) in European children at this age. For this reason, and because patients here are in any case often unsure of their ages, temperature changes have not been related to age. The relationship of body weight to rate of change of temperature is plotted in figure 5, but no record of body surface area was available. There is only a slight correlation between weight of the child and rate of fall of temperature, but a correlation with body weight/surface area ratio may exist, as suggested by Hercus.

The effect of duration of operation.

Hypothermia is most likely to occur when an operation is prolonged, if there is already a tendency for the temperature to fall. In the present series the average operation time was 65 minutes, but it was 60 minutes for cases whose temperature fall was less than 0.5°C (1°F) and 74 minutes in cases with a temperature fall greater than this. It is of interest that in the fatal cases the average operating time was 98 minutes, while in cases having relaxants and controlled respiration it was 85 minutes (see table IV). The greater fall of temperature in cases receiving relaxants is not explained by the longer
HEAT LOSSES UNDER SURGERY IN AIR-CONDITIONED THEATRES

operating time. These findings are similar to those of Hercus (1960), Harrison, Bull and Schmidt (1960), and Salanitre and Rackow (1961) with regard to hypothermia, and Bigler and McQuiston (1951) with regard to hyperpyrexia. These authors report a large change of body temperature in the early stages of anaesthesia with a levelling out after \( \frac{1}{2} \) to 1 hour. This may account for the large falls seen in some of our patients who had comparatively short operations (fig. 6).

Other factors affecting heat loss.

There is no doubt that heat loss by evaporation and convection will be increased if the patient is left uncovered. For this reason temperature falls will usually be greater during operations on the chest and abdomen than during superficial operations, and this is borne out by the figures given in table V. The rate of change of air in the theatre might also influence the rate of cooling, but unfortunately comparative figures are not available.

A factor responsible for a considerable conductive heat loss is the diathermy pad (Gough, 1960). The earthing electrode consists of a lead sheet covered with a towel soaked in saline, which is placed under the lower half of the body. Even if soaked in warm saline the towel becomes cold in 15 to 30 minutes. No record was kept of the number of times diathermy was used, but the adoption of a relaxant technique was usually determined by the surgeon's desire to use diathermy.

Factors influencing Temperature Regulation.

Small children particularly neonates, do not appear to have a well-developed thermo-regulatory mechanism (Lancet, 1955). The pre-operative temperatures of the children discussed here were frequently below 37°C (98.6°F), and in 12 out of 33 patients who had a complete temperature record it was below 36.1°C (97°F). Further evidence is supplied from the lack of correlation between pre-operative temperature and temperature changes under anaesthesia (fig. 4). This was a feature of the older children as well as the neonates. The wide range of pre-operative temperatures will be noted (figs. 4 and 7).

Anaesthesia itself has long been known to affect temperature regulation (Hemingway, 1941). In the present series, apart from the use of relaxants, no particular anaesthetic agent was implicated. Acclimatization to the tropics may also play a considerable part in the development of hypothermia in older children and adults, but it can hardly apply to neonates. A racial factor may be involved, but as all the children were Nigerian (negro) a comparison with children of other races could not be made. Although Hackett and Crosby (1960) and Harrison, Bull and Schmidt (1960) were working in racially...
mixed communities none of them makes any mention of racial differences in temperature response. Finally a factor such as that mentioned by Hercus (1960) may be involved, in which lack of appreciation of cooling is shown by the theatre staff, who have frequently been observed to remove all coverings from patients placed on the operating table.

To sum up, it seems that neonates have a poor thermo-regulatory mechanism and that in the tropics older children and even adults tend not to develop such a mechanism to the same extent as inhabitants of temperate climates; unless perhaps they too move to a temperate climate and become acclimatized.

THE PREVENTION OF HYPOTHERMIA

It has proved very much easier to prevent a fall of temperature occurring in an anaesthetized child than to treat it after it has occurred. Since, towards the end of 1960, it became obvious that hypothermia was dangerous, steps have been taken to minimize heat loss in the theatres.

The children are kept in the air-conditioned rooms for as short a time as possible and they are well wrapped in a blanket which is only removed at the last possible moment. Small children are brought to the theatre in a heated cot. Any part of the body, access to which is not needed at operation, is wrapped in gamgee tissue, and in the case of neonates hot water bottles at
HEAT LOSSES UNDER SURGERY IN AIR-CONDITIONED THEATRES

Temperatures during anaesthesia in cases in which precautions were taken to prevent heat loss.

Rectal temperatures — (cleft lip repairs)

Oesophageal temperatures --- (1) laparotomy, (2) herniorrhaphy, (3) excision of axillary dermoid (controlled respiration), (4) repair of imperforate anus, (5) excision of cystic hygroma.

about 38°C (100°F) are placed alongside the child. An attempt is made to persuade the surgeon not to use diathermy but, if he insists, the electrode is soaked in hot water and any exposed parts of it covered to minimize evaporative heat loss. Spontaneous respiration is allowed except when definitely contraindicated and the use of relaxants is avoided where possible. At the end of operation the child is wrapped up and removed to the non-air-conditioned recovery room as soon as possible.

Recently temperature monitoring has been carried out in all cases and has been found an invaluable aid. Leads are placed in the oesophagus or rectum, according to the operation site, on the skin underneath the towels, and on the anaesthetic apparatus to measure the ambient temperature. The results of some such estimations are given in figure 7, showing the success of the methods employed. There would be a considerable advantage in having a heated pad of the type described by Leigh and Belton (1960), Stephen et al. (1960), and Taylor (1961). This would permit a greater freedom in the use of controlled respiration and diathermy without fear of the development of hypothermia. The author has no doubt that the temperature of anaesthetized children should be kept as near normal as possible. Particular attention should be paid to temperature control before and after operation.

THE TREATMENT OF HYPOTHERMIA

Opinions differ on the relative merits of slow and rapid rewarming. Mann and Elliot (1957) emphasize the danger of rapid rewarming, which led to death in one case and heart failure in another, and they recommend "natural" rewarming in a room at 21°C-26.6°C (70°-80°F). Burton and Edholm (1955) make a distinction between acute and chronic hypothermia and they consider that the treatment of choice in the acute form is warming in a water bath at 45°C (113°F). As hypothermia occurring under anaesthesia is acute in onset, rapid rewarming would be thought best. This was borne out in cases 8 and 9 (fig. 1), but not by case 7, in whom a return to normal temperature was followed by heart failure (although this was probably due mainly to other causes). "Natural" rewarming, by wrapping up the child and leaving it at the ambient temperature, or by placing it in an incubator (case 4), did not seem to be effective in restoring a normal respiratory effort.

Mann and Elliot (1957) described hypoglycaemia and a rise of haematocrit as a feature of their cases, and therefore recommended oral glucose and the avoidance of intravenous fluids. They warned against the use of plasma, because of the risk that it may precipitate heart failure, for which they recommend digitalization. Case 7 died soon after the administration of quadruple-strength plasma had started. On the other hand, Burton and Edholm (1955) quoted Grosse-Brockhoff's statement that glycogen depletion will only occur in chronic hypothermia, and therefore glucose is only of value in the treatment of this condition. Experiments at Dachau, also quoted by these authors, showed a rise of blood sugar during acute cooling, which was reversed on rewarming. This evidence suggests that hypoglycaemia is a complication of chronic rather than acute hypothermia.

Rees (1960) stated that adrenal cortical output is deficient in the neonate, and that after the first week of life the maternally derived hormone level has become very low. It would therefore seem wise to give additional corticoids to children with severe hypothermia but this was not done in the present series.
CONCLUSIONS

Hypothermia in small children is associated with a definite morbidity. In this series of 67 cases, 7 of the 12 early postoperative deaths were associated with hypothermia.

Small children, particularly under 1 year of age, tend to lose heat under anaesthesia and this heat loss is greater when respiration is controlled.

Heat loss is particularly liable to occur in air-conditioned theatres in hot climates, especially in the tropics.

Heat loss in anaesthetized children, especially babies, can be prevented by careful insulation and by providing a source of heat. The body temperature should be monitored throughout anaesthesia and in the postoperative period, and steps should be taken to ensure that it is kept as near normal as possible.

It is suggested that heat loss is liable to occur when children used to a high ambient temperature are placed in a comparatively cool and dry environment, and possibly that heat gain is likely to occur when children acclimatized to a low ambient temperature are placed in this same environment.

ACKNOWLEDGMENTS

I wish to thank Mr. G. Oduntan, Deputy Chief Engineer, University College Hospital, Ibadan, for kindly supplying the theatre temperature and humidity figures, and Dr. R. E. Moore, of the Royal Free Hospital, for advice in the preparation of this paper.

REFERENCES


HEAT LOSSES UNDER SURGERY IN AIR-CONDITIONED THEATRES

SOMMAIRE

Description de rapports entre l'hypothermie surve- 

nant chez des bébés anesthésies et l'incidence de 

maladie et mort survenant rapidement après l'opéra-

tion. En 1960 soixante-sept enfants âgés de moins 

d'un an furent opérés et de ce nombre douze mouru-

rent. Or, sept des cas (dont la description est fourni 

traité en état d'hypothermie. Quoique d'autres 

facteurs y participaient sans doute, le facteur 

principal responsable du décès semble avoir été 

l'hypothermie.

L'hypothermie survient le plus probablement au 

cours d'interventions longues, dans des salles 

doctoration "à air conditionné" et lorsque la res-

piration est surveillée. L'auteur discute des moyens 

pour empêcher "l'hypothermie par inadvertance" et 

l'importance du contrôle régulier de la température 

et du maintien rigoureux de température normale.

ZUSAMMENFASSUNG

Eine Beziehung zwischen Hypothermie bei narko-

tisierten Säuglingen und früher postoperativer Mor-

bidität und Tod wird beschrieben. 67 Kinder im Alter 

von weniger als einem Lebensjahr waren 1960 operiert 

worden, zwölf davon starben; sieben dieser Fälle 

(dies beschrieben werden,) waren mit Hypothermie 

verbunden. Während andere Faktoren zweifellos 

beteiligt waren, scheint es, dass die Hypothermie der 

Hauptfaktor war, der für den Tod verantwortlich war.

Eine Hypothermie ist bei langdauernden Opera-

tionen am wahrscheinlichsten, in Räumen mit Klima-

kammern und bei künstlicher Atmung. Möglichkeiten 

zur Verhütung unerwünschter Hypothermie werden 

besprochen und die Wichtigkeit der Temperatur-

überwachung und strikter Erhaltung normaler Tem-

peratur betont.

BOOK REVIEW

International series of monographs on pure and 

applied biology: Modern trends in physiological 

sciences. Vol. 15: Cilia, ciliated epithelium, and 

ciliary activity. By J. A. Rivera. Published by 


figures; tables. Price 60s.

We live in the age of the specialist and this monograph 

attains the high standard expected of the specialist. 

At the price it must be regarded as luxury reading for 

the anaesthetist although it must be regarded as luxury reading for 

anyone proposing to investigate ciliary function. The book 

takes the form of a review quoting 1,335 sources 

amongst which the author does not appear. Almost 

none of the references is more recent than 1959 but 

they are considered in some detail and seldom merely 

listed. The book is well produced although there are 

some mistakes in the references, and one can scarcely 

credit the statement that "During one complete inspira-

tion, 15 g of water are taken up from the nasopharynx" 

(p. 55). The book is valuable for its reference to the 

many elegant methods of studying ciliary action in-

cluding the tissue culture, the stroboscope and the 

cilloscribe. The "ciliated membrane upon which foreign 

particles were raced against each other" (p. 72) suggests 

a novel basis for a laboratory sweepstake.

Anaesthetists will probably be more interested in 

the section dealing with factors affecting ciliary action. 

Here, as elsewhere, the reader must be careful in the 

extrapolation of data from other species. Chapter 

XII deals with the effect of temperature but must be 

interpreted in relation to actual temperatures in the 

respiratory tract. The next chapter dealing with the 

effect of moisture is disappointingly brief in view of 

the great importance of this factor during anaesthesia. 

The beautiful work of Burton (1962) is clearly too 

recent for inclusion, but one might have expected some 

reference to the Oxford work on the importance of 

humidification in artificial ventilation by IPP. Chap-

ter XVIII discusses the effects of anaesthetic and other 

drugs. This contrasts with the majority of current text-

books (but not Slome, 1959) in saying firmly that 

ether and nitrous oxide in clinical concentrations have 

little or no effect on ciliary action, a view which is 

confirmed by Burton. The oft-repeated tale of the para-

lytic effect of anaesthetics on cilia apparently relates 

to agents in the liquid state or as saturated vapours. 

The book certainly enhances one's respect for the 

cilia themselves. We read that they have continued 

to beat for 56 hours after the death of an executed 

criminal. They will continue to perform during long 

periods of total anoxia and they can move weights of 

15 grams. Finally they have apparently preserved the 

secret of how they work.

J. F. Nunn

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