A Guide to Radiant Warmer Care of Infants

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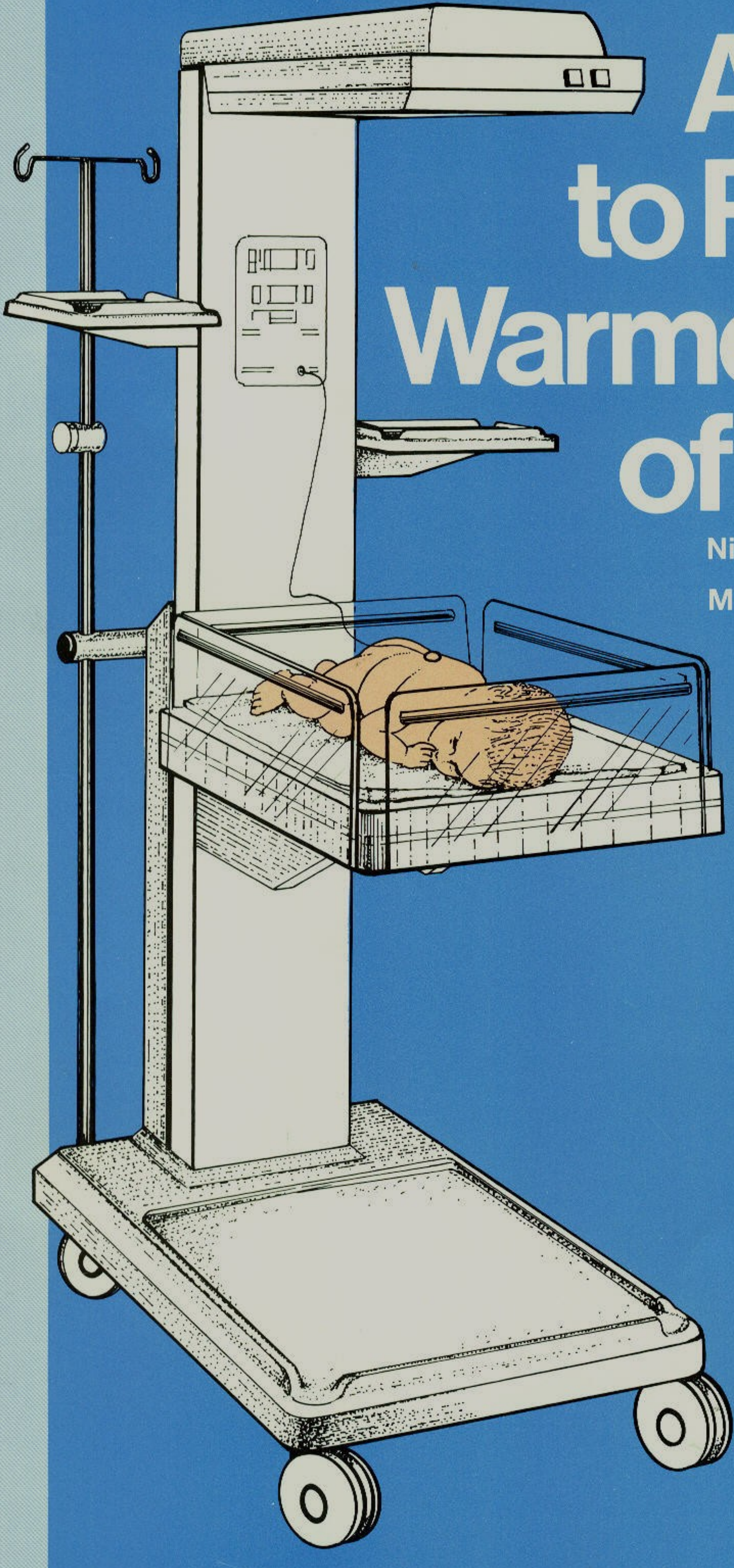

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Introduction

Of all the advances that have taken place in the care of the newborn baby, none has had more impact than the realisation that small babies need to be kept warm. The first infant incubator was devised and used as long ago as 1880 when Dr. Tamier, a Parisian obstetrician, got the idea from a zoo keeper who had built one to rear poultry. His successor, Professor Pierre Budin, realised the importance of keeping babies warm and routinely used the incubator for nursing premature babies. More recently, in the later 1950s and early 1960s, it was shown conclusively that preterm babies who were allowed to get cold were more likely to die. Now it is well recognised that the thermal environment of the preterm baby is one of the most important aspects of medical and nursing care. It is an area where obsessive attention to detail can pay dividends in terms of increased survival and growth of small babies.

This booklet is mainly concerned with the use of the overhead radiant warmer, an alternative method of keeping small babies warm which is particularly useful in the early neonatal period when the need for intensive care is greatest. An incubator to some extent insulates an infant from heat loss by enclosing him in a plastic box. A modest amount of additional energy is then provided to heat the box. Nursing an infant under a radiant warmer allows doctors, nurses and parents much greater access but since no attempt is made to insulate the infant, enormous heat losses must be offset by equally large heat gains from the warmer. Incubators are usually regulated effectively by controlling the box temperature, but since there is no such thing in a radiant warmer, skin temperature must be regulated instead.

There are two sections. The first considers the principles of heat balance in the newborn baby, the second deals with the use of radiant warmers in keeping babies warm, and the practical and safety aspects of the devices.

Section A

Principles of Heat Balance and Temperature Control

1.
Heat Balance in the Newborn
A baby's temperature is a balance between the heat which he produces himself and the heat which he loses. If his temperature is stable, then heat production and heat loss are exactly balanced. If losses exceed production a fall in temperature occurs and if production of heat exceeds losses his temperature rises. It is therefore important in keeping babies warm to have some knowledge of how a baby gains and loses heat.

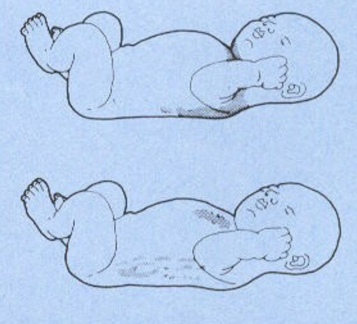
1.1
Heat Production
A baby produces heat by metabolic activity. The various chemical reactions which are occurring in the cells of the body release energy as heat. There is always a background metabolic heat production which occurs when the baby is asleep. This increases after a feed, when food is digested and absorbed, and when the baby is active. In this respect a baby is similar to an adult. In addition however, newborn babies have a specialised organ of heat production, brown fat. This is a type of adipose tissue found only in the newborn, which is distributed in the neck, between the scapulae and along the aorta (Fig. 1). It is the baby's central heating system. When the environmental temperature falls, nerve endings in the skin are stimulated. Catecholamines are released which act directly on the brown fat, causing heat to be released from the metabolic activity.

1.2
Heat loss
A baby can lose heat in four ways (Fig. 2):
a) Convection
By this method, heat is lost to the air surrounding the baby. The amount lost depends on the difference in temperature between the baby's surface and the air, the area of the baby's surface exposed to the air, and the speed of movement of the air. Convective losses are high if the baby is naked and the environment is cool. They can be reduced by insulating the baby with clothing and by raising the ambient air temperature. A baby attempts to reduce convective heat losses by reducing blood flow to the skin (vasoconstriction) and by lying in a flexed position so that as little of his surface as possible is exposed to the surrounding air.

Babies naked under radiant warmers have very high convective heat losses, since the ambient air temperature is usually 10°C lower than skin temperature and the air velocity over the skin surface is high. It has to be compensated by a gain in radiant heat.

b) Radiation
A baby loses heat by radiating energy from his surface to all surrounding surfaces. In practice these are the walls of a room or a cot. The amount of heat lost in this way depends on the difference in

THE DISTRIBUTION OF BROWN ADIPOSE TISSUE ('BROWN FAT') IN A NEWBORN INFANT.



In the newborn infant brown adipose tissue provides fully automatic, thermostatically controlled, oil-fired central heating.

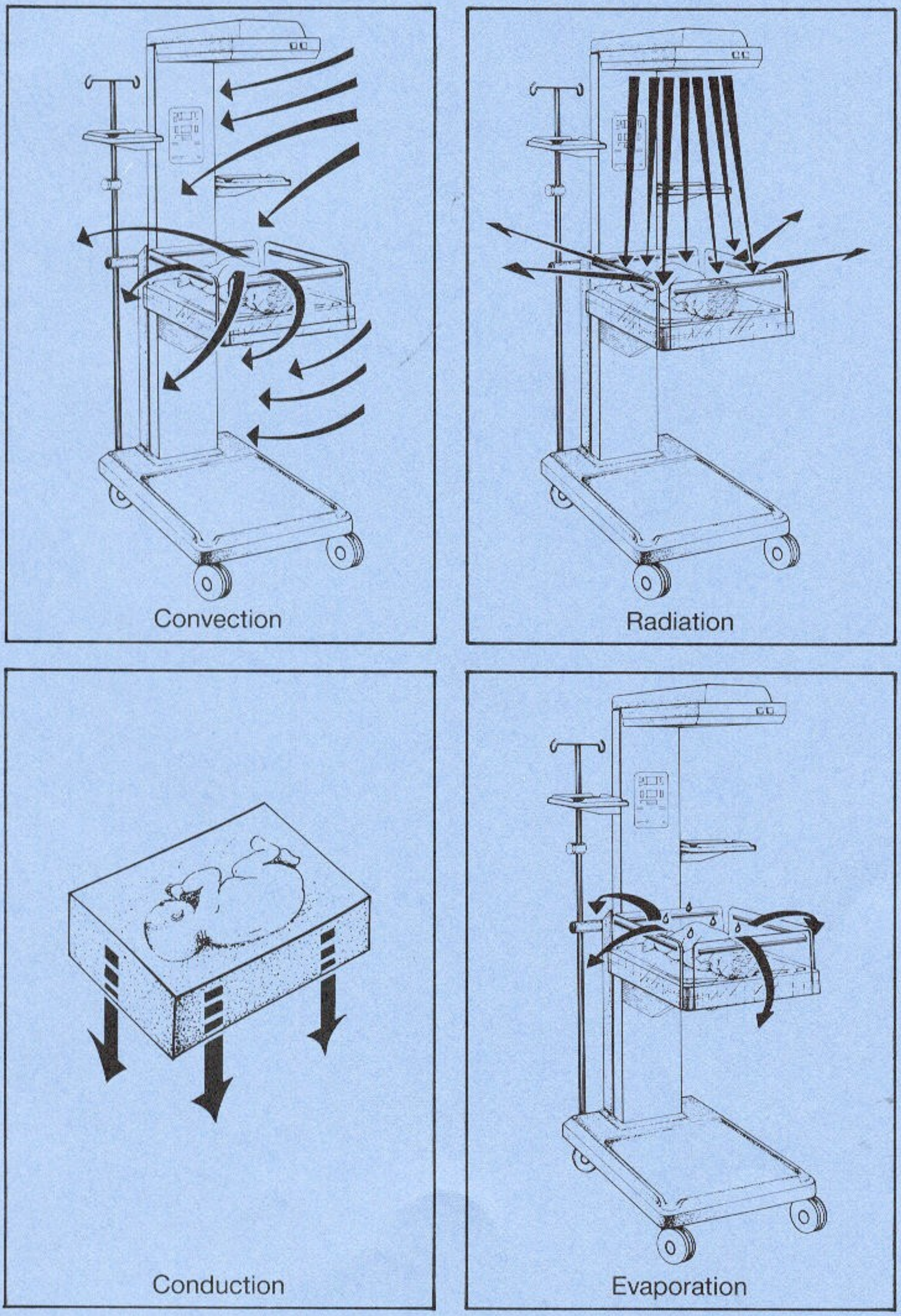
Fig 1

temperature between the baby's skin and the surrounding surfaces. ***It is independent of the air temperature***
For example, radiant heat losses can be quite high when a baby in a cot is nursed near a cold window, even though the room temperature is adequate. The heat lost by radiation can be reduced by insulating the baby with clothing. Vasoconstriction and a flexed posture will also reduce radiation losses.

Babies nursed naked under radiant warmers are exposed to a higher radiant temperature (the heating element of the warmer) and will therefore gain heat by radiation. This is needed to compensate for the high convective and evaporative losses, and for loss of radiant heat to the cool walls of the newborn nursery.

c) Evaporation
A baby loses heat when water evaporates from his skin or his breath. Each 1 ml of water lost by evaporation removes about 600 calories of heat. The amount of heat loss therefore depends on the water loss. In full term babies this is usually small, except immediately after birth when the skin is wet with amniotic fluid. However, when a mature baby is heat stressed, active sweating occurs in an attempt to remove heat. This is an important mechanism for preventing a rise in body temperature in warm surroundings.

Fig 2. THE FOUR CHANNELS OF HEAT LOSS IN A BABY NURSED NAKED UNDER A RADIANT WARMER



Evaporative heat losses are high in very immature babies whose skin lacks the waterproofing qualities of mature babies. In babies born before 30 weeks gestation, the keratinised stratum corneum which normally prevents most skin water loss is thin and poorly developed. The high evaporative heat losses are even higher when such babies are exposed to radiant heat from a radiant warmer or phototherapy unit. They can be reduced by covering the exposed skin with a waterproof sheet (e.g. polyethylene) or by raising the humidity around the skin using a waterproof tent.

d) Conduction
Babies lose small amounts of heat by direct conduction to solid surfaces in contact with them. In practice this is not a major source of heat loss because a baby usually lies on a mattress which insulates him from cold surfaces. If the surface which a baby lies on is warmer than himself, he will gain heat by conduction. This is the principle of the hot water bottle and the electric heating pad.

Infants under radiant warmers should be nursed on a thick mattress (at least 2.5 cm thick) of a good thermal insulator, in order to reduce conductive losses. If not, the baby will be hot on his exposed surface and cold on his shaded surface.

1.3
The Balance Between Heat Gain and Heat Loss
When a baby's body temperature is stable, heat gain and heat loss are balanced. What happens now if the baby's heat losses increase? Suppose that the environmental temperature falls, resulting in higher heat losses. The baby's own heat production is stimulated so that the increased heat loss is still balanced and his body temperature remains unchanged. As the environmental temperature continues to fall, the baby continues to increase his heat production. A point is reached, however, when the baby's heat production can no longer increase. Metabolic activity is at a maximum – brown fat is being metabolised and the baby is probably crying vigorously. Any further reduction in the surrounding temperature cannot be balanced by more heat production and the baby's body temperature therefore starts to fall. This is shown diagrammatically in Figure 3. ▶

At the other end of the scale, if the environmental temperature is increased the baby's heat losses are small. He can attempt to increase his own heat losses by vasodilation or by lying in an exposed posture, but he cannot reduce his own heat production. Metabolic activity is already at a minimum. If the environmental temperature continues to rise, the baby can only increase his heat losses by actively sweating. If this is not sufficient, his body temperature starts to rise.

It is difficult to define an environmental temperature for purposes of thermoregulation when a baby is nursed naked under a radiant warmer. The effective environmental temperature will be determined by the radiant temperature of the heater element, the size of the heater and its distance from the baby, and the temperature, speed of movement and humidity of the surrounding air. Skin temperature rather than the environmental air temperature has to be considered when judging whether the baby is under neutral thermal conditions. It can be seen from Figure 3 that it is possible to achieve thermal neutrality by controlling the skin temperature within a defined range.

A summary of the balance between heat production and the channels of heat loss in preterm infants nursed under radiant warmers is shown in Figure 4. For comparison, the heat balance of the same preterm infants when nursed in incubators is shown in Figure 5.

Note in Figure 3 that between environmental temperatures A and B, the baby's own heat production is at a minimum, his body temperature is stable and he is not sweating. The range of environmental temperature between the two points is termed the thermoneutral range. Babies should be nursed in an environment which is close to this range, preferably towards the lower end. If the environmental temperature is too high, the baby is uncomfortable and his body temperature may rise. In a preterm baby, this may mean that apnoea attacks are more likely, or that unnecessary investigations are carried out looking for a cause for the 'fever'. If the environmental temperature is too low, the baby is having to use much needed calories simply to keep warm. In preterm babies these calories are required for resisting illness and for growth. For this reason, preterm babies nursed in a cool environment have an increased chance of dying from the complication of prematurity and have diminished rates of growth.

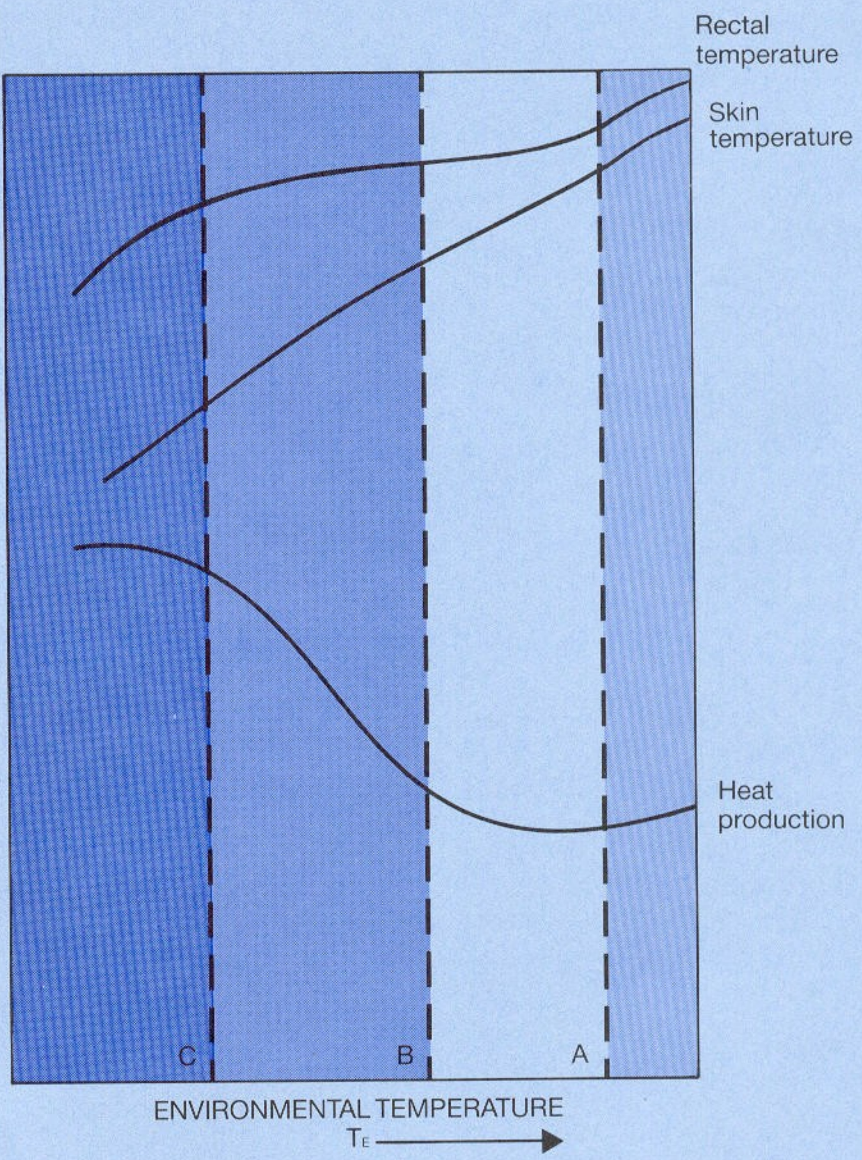


Fig 3

THE CHANGE IN HEAT PRODUCTION AND BODY TEMPERATURE OF A NEWBORN BABY WHICH OCCURS WITH CHANGE IN THE ENVIRONMENTAL TEMPERATURE T_E.

The range of environmental temperature between A and B is termed the thermoneutral range.

If T_E rises above the value A, the rectal temperature rises above the normal range.

If T_E falls below the value B, the rectal temperature remains within the normal range but the baby's heat production increases to compensate for increased heat losses.

If T_E falls below the value C, the baby can no longer increase his heat production and his body temperature falls below the normal range.

2.
Control of Body and Skin Temperature

Thermal control in the human infant as in all mammals is complex. Sensors in the skin, spinal cord and hypothalamus detect temperature and change of temperature. The input from these sensors is received and integrated by the hypothalamus which then effects changes which are designed to restore or maintain a constant body temperature. Such changes are in behaviour, posture, heat production, skin blood flow and sweating.

3.
Thermal Comfort

Adults and children can be asked whether they feel comfortable and can choose their own thermal environment. Most newborn mammals are able to choose their own thermal environment at birth and they sensibly choose one which is thermally neutral. The newborn infant cannot do this and has to rely on his caretaker to provide an appropriate environment. Since children and adults tend to prefer an environment which is at the lower end of the neutral thermal range, it is reasonable to assume that this is what the infant would prefer too. Adults tend to prefer being lightly clothed in a warm room to being exposed naked to fluctuating radiant heat, even though both environments may be thermally neutral. This is an argument for using alternative methods for keeping small babies warm (cots, incubators) as soon as the need for invasive intensive care has passed.

4.
How may a Baby's Condition be Assessed?

The most widely used way of assessing the 'thermal state' of a baby is to take the temperature. This is certainly a guide to the thermal state in that if the body temperature is low the baby is too cold, and vice versa. However, it can be seen from Figure 3 that a baby can have a normal body temperature but can still be cold stressed. He may be working very hard to produce heat in order to maintain this temperature. It is therefore not sufficient to say that because a baby's temperature is normal, the thermal environment is satisfactory. In practice though, preterm babies in the first few days of life, particularly if very small or ill, have a reduced capacity to increase their heat production and their temperatures soon fall if they are cold stressed. Thus body temperature is a good guide to the suitability of their thermal environment.

4.1
Rectal Temperature

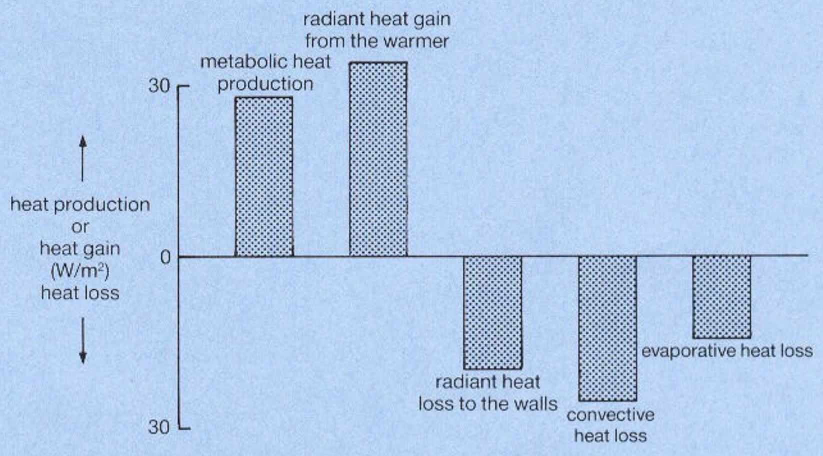
This is commonly recorded as an indication of the deep body temperature of a baby. It is taken by inserting the bulb of a mercury thermometer or the probe of a thermocouple or thermistor into the rectum. A distance of about 3 cm is recommended for full term babies and 2 cm for preterm babies. Insertion to 5 cm would be necessary to obtain accurate core temperature measurements in all infants but this is clearly too far for safety.

It takes about one minute for a stable temperature to be recorded with a mercury thermometer. If the bulb is not properly inserted into the rectum or else not left there long enough, a falsely low reading will be obtained. There is a small risk of perforation of the rectum with the bulb of the thermometer and it is possible for the glass to break, particularly if the baby is struggling. *The normal range is 36.6 – 37.2°C.*

▶

Fig 4

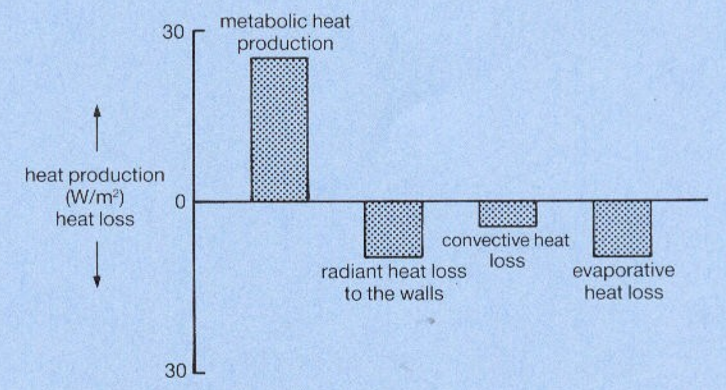
HEAT PRODUCTION AND CHANNELS OF HEAT LOSS IN A PRETERM INFANT NURSED UNDER A RADIANT WARMER



High convective, radiant and evaporative losses are balanced by a large radiant heat gain from the warmer.

Fig 5

HEAT PRODUCTION AND CHANNELS OF HEAT LOSS IN A PRETERM INFANT NURSED IN AN INCUBATOR



Modest radiant and evaporative losses and a small convective loss, are balanced by the infant's own metabolic heat production.

4.3

Skin Temperature

The skin temperature is usually recorded by lightly taping a thermistor probe to the skin. Central skin temperature, i.e. the skin of the trunk, is higher than peripheral skin temperature: it is also more stable. The change of skin blood flow (vasoconstriction or vasodilation) in reponse to small changes in environmental temperature are much more marked peripherally, especially on the hands and feet. The difference between central and peripheral skin temperature is therefore an index of skin blood flow, and is greatest in collapsed, shocked infants.

The normal range of abdominal skin temperature is 35.5 – 36.5°C. in term infants. Preterm infants, who have little subcutaneous insulation have skin temperatures closer to deep body temperature, 36.2 – 37.2°C.

4.4

Other Observations

An experienced nurse will also take other factors into account when assessing a baby's thermal state. A baby who is cold stressed will have cold hands and feet, may be lying curled up or may be crying vigorously in an attempt to keep warm. If a baby is heat stressed he will have red skin, warm hands and feet and may be lying in an extended, sunbathing posture. These external signs may be difficult to detect or non-existent in very immature babies.

Section B

The Use of Radiant Warmers

1.
The Need for a Radiant Warmer

The safest and most comfortable way of keeping a baby warm is to nurse the baby clothed, wrapped and in a cot. If the room is warm, the risks of overheating or cold stress are slight. Babies and their mothers prefer this method. There are two circumstances though, when cot nursing is not possible and an alternative is necessary.

a) The baby is very small. Babies of less than 1.5 kg birth weight need a high environmental temperature in the early neonatal period and tend to become cold if cot-nursed.

b) The baby is ill or likely to become ill. Such a baby needs to be undressed in order to be observed and to give staff access to him. In practice most ill babies will be small as well.

The radiant warmer is particularly useful for the latter babies. They can be nursed naked without becoming cold and there is easy access for the medical and nursing staff. Small babies who are otherwise very well are best nursed in incubators.

2.
The Radiant Warmer

This is a device which heats a naked baby lying on an open tray by radiant heat from an overhead element or series of elements. The elements are commonly contained within a curved canopy which focuses the heat on to the tray underneath and not to the surroundings. There are two types:

i) Fixed Output. These are low power heaters used to provide supplementary heat to a newborn baby who needs resuscitation and are not suitable for nursing purposes. If these devices are used for longer than 5 to 10 minutes, there should be an attendant standing at the bedside monitoring baby's temperature.

ii) Servo-Controlled (Fig 6). The output of the heater is controlled by a temperature probe fixed to the infant's skin. The device is set to keep the skin at a selected temperature (often called the set temperature) and the heater will cycle on and off to maintain this temperature. In practice, this is proportionally controlled rather

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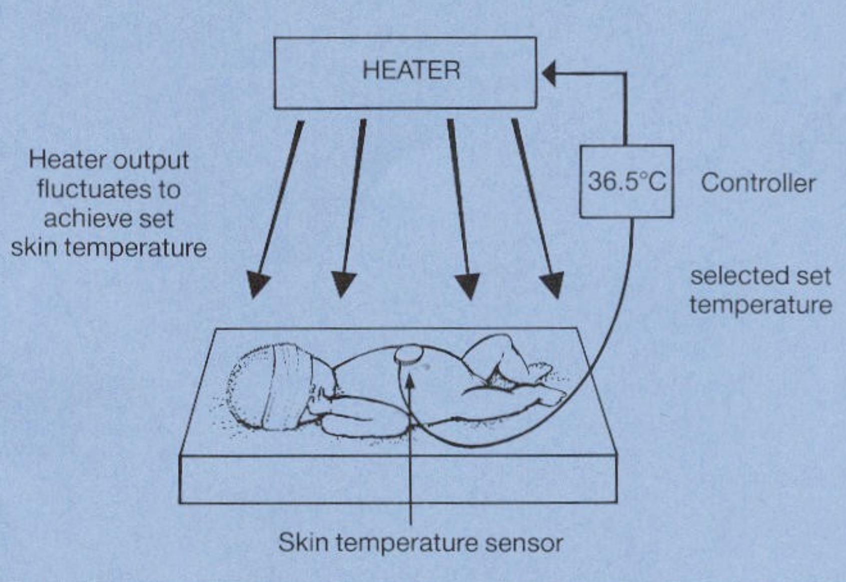
Fig 6
SERVO-CONTROLLED RADIANT WARMER



than an all or nothing phenomenon. As the baby's temperature approaches and then exceeds the set temperature, the power output of the heater is reduced from maximal to zero. When the skin temperature is more than 0.2 to 0.5°C below the set temperature the power output of the heater (which is considerable!) will be at a maximum. The radiant heat output of an overhead warmer in use on a preterm infant is shown in Figure 7.

A complete cycle of the thermostat takes 1-10 minutes. Since there is an unavoidable time delay between the perception of a difference between set temperature and skin temperature, the increase in heat output and a resultant change in skin temperature, the skin temperature will tend to oscillate slightly around the set temperature. Theoretically it is possible for enormous oscillations of skin temperature to occur, but this has not been a problem with most commercially available warmers. However, large unphysiologic fluctations in heat production and true environmental temperature are associated with the slight fluctuations in skin temperature which do occur. Their significance to infants is uncertain. Well designed modern servo control systems allow skin temperature to be controlled within a narrow range.

It is possible to use some overhead radiant warmers in the manual rather than the servo mode. The power output of the heater is therefore controlled directly by the user by means of a dial rather than by the baby's skin temperature. Manual mode is useful for warming up the mattress and tray before the baby is put under the heater. For normal operation, however, servo-mode should always be used. Manual mode should not be used with an infant in the warmer without an attendant standing at the bedside checking the baby's temperature at least every 5 minutes.

3.
The Skin Probe

This both measures and controls the baby's skin temperature. It should be placed on the uppermost surface of the baby's trunk – the most commonly chosen site is the abdomen. The probe should not be attached to the limbs because it is more likely to become detached, and will produce marked fluctuations in the heater output. It must not be inserted into the baby's rectum because of the marked time delay between change in heater power and change in deep body temperature. The baby should not lie on the probe.

4.
Shielding the Probe from the Heater

The ideal probe would measure the temperature of a small area of the baby's skin, but would not, by its presence, interfere with the temperature of that skin. It would also be unaffected by external influences such as direct heat from the radiant warmer or draughts of cold air. In practice this is unobtainable. The probe has a finite thickness, so that a temperature gradient exists between the underside of the probe in contact with the skin and the exposed side which is in contact with the ambient air and views the heater. This can be reduced by covering the probe with a

Fig 8

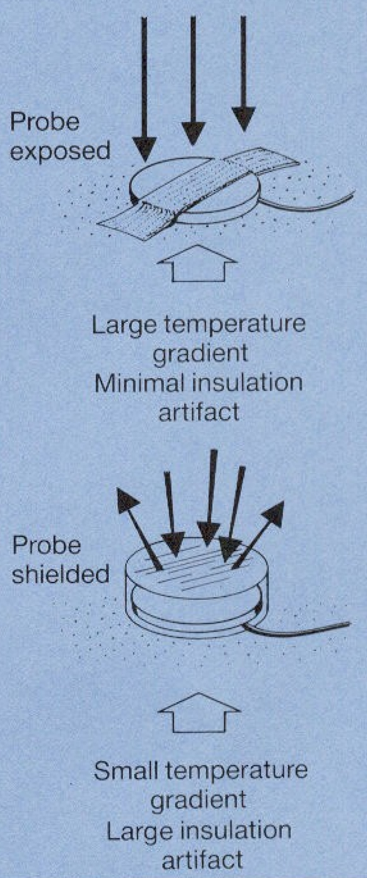
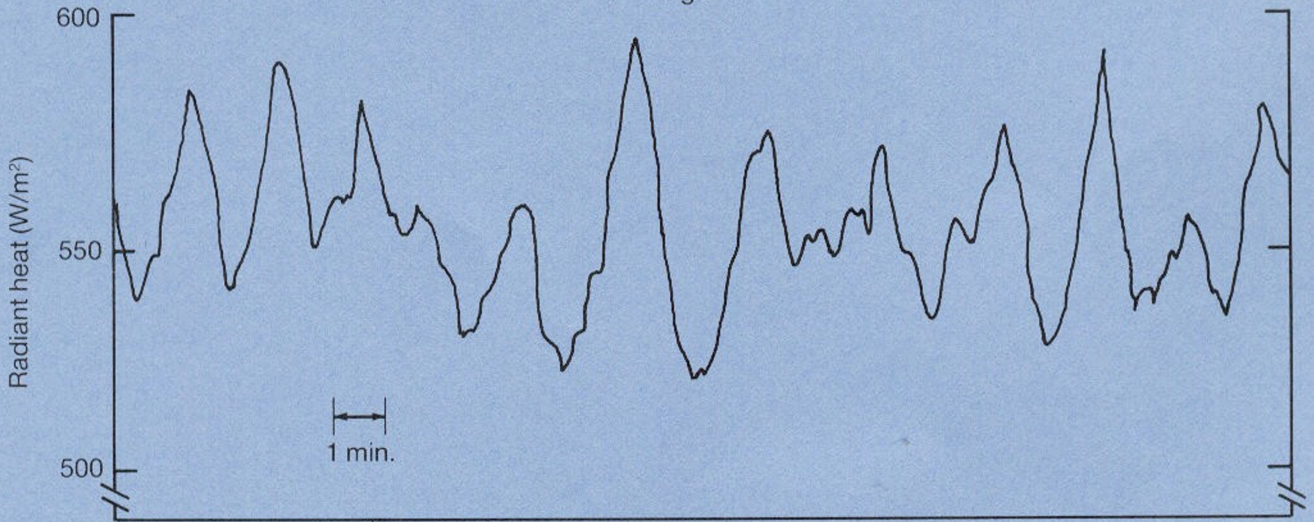


Fig 7



Typical recording of radiant heat energy recorded close to the upper abdomen of a baby nursed under a radiant warmer. Fluctuations are due to the cycling of the servo-control system.

small pad of foam with an outer silver reflecting foil. However, although this shields the probe from the surrounding air and the radiant heater, it will now insulate the measured skin from these ambient conditions. The temperature measured by the probe will not necessarily reflect skin temperature elsewhere (Figure 8).

In practice, however, radiant warmers appear to work satisfactorily whether the probe is shielded from the heater or not. Some users shield the probe, others do not, but consistency is important. An advantage of using a foil-backed foam pad is that it is an effective way of holding the probe in contact with the skin. The user must recognize, however, that the recorded temperature may not accurately reflect true skin temperature. The worst problems occur in infants of less than 28 weeks gestation and less than one week of age. In these infants the recorded skin temperature may be as much as 2°C above core temperature. This error is caused by insulating the skin around the probe from the very high evaporative water losses experienced by the rest of the skin. Humidifying the air around the infant will reduce the error in skin temperature measurement. Alternatively, the user may adjust the set temperature to bring the core temperature back into the normal range.

5.
Choosing a Set Temperature

There is no information about set skin temperatures in relation to thermal neutrality as is available for the air temperature of incubators. In practice, the normal abdominal skin temperature in a neutral thermal environment can be used – these will depend on the baby's size (Figure 9).

Fig 9

Birth weight (kg)	Set temperature (°C)
less than 1.0	37.0
1.0 – 1.5	36.8
1.5 – 2.0	36.6
2.0 – 2.5	36.4
greater than 2.5	36.2

Suggested set temperatures for babies nursed under radiant warmers.

6.
Monitoring the Baby's Temperature

It is important to monitor the baby's temperature independently of the probe. Since skin temperature under a radiant warmer may not accurately reflect true skin temperature, some measure of core temperature should be performed (rectal, axillary, esophogeal). An unstable body temperature, sometimes an indication of sepsis in small infants, will be overridden by the radiant warmer's servocontrol system and can no longer be used as a physical sign.

7.
Reduction of High Evaporative Water Loss

Very immature infants (below 30 weeks gestation, below 1 kg birth weight) have high skin water losses in the first week or so of life, before epidermal maturation is complete. If such an infant is nursed under a radiant warmer, losses will be particularly high because of exposure to dry, draughty room air and to direct radiant heat. The radiant heater will compensate for the evaporative heat loss which results but the infant still continues to lose water. Hypernatraemic dehydration and pre-renal failure may result. Estimation of the baby's hydration by measurement of plasma sodium, osmolality and urine osmolality or specific gravity will be a guide to the baby's need for more or less fluid (Fig 10 & 11). If accurate estimates of the baby's weight can be made each day, or even twice daily, this provides a very good independent check on fluid balance status. It is impossible to predict an infant's evaporative water loss – it has to be measured, either directly as weight loss or indirectly as the degree of concentration of the blood and urine.

Fluid replacement is simpler if steps are taken to reduce evaporative water losses. A waterproof material transparent to long wave radiation is placed over the infant. Polyethylene is a convenient material – it can be placed directly on the infant or kept away from the skin by a frame so that a plastic tent is formed over the infant. The latter has the advantage of preventing maceration of the skin and increased bacterial growth which occur when skin and polyethylene are in direct contact. The infant loses ▶

Fig 10
ASSESSMENT OF FLUID BALANCE

1. Physical signs
2. Accurate measurement of body weight
3. Blood tests – Haemoglobin, PCV
   Sodium (130-145 m mol/l)
   Osmolality (260-290 m. Osm/kg)
4. Urine tests – Osmolality (150-300 m. Osm/kg)
   Specific gravity (1.005-1.010)

Fig 11

TOO MUCH FLUID	
Produces	Oedema, hyponatraemia
May cause	Acute pulmonary oedema or haemorrhage Worsening of respiratory illness (RDS or BPD) Symptomatic patent ductus arteriosus Necrotising enterocolitis
TOO LITTLE FLUID	
Produces	Dehydration, hypernatraemia
May cause	Impaired renal function → renal failure Jaundice

water into the tent, saturates the contained air and further water loss is therefore greatly reduced. The air will also become warmer than room air and will be stiller, so that convective losses will be lower and thermal comfort improved. Note though, that as soon as the polytheylene cover is removed, water and heat losses will rise at once. Acrylic (Perspex) does not transmit long wave radiation and should not therefore be used to shield an infant under a radiant warmer.

8.
Alarms

Most radiant warmers will alarm if the temperature sensed by the probe differs from the set temperature by more than 0.5°C. This can happen under a number of circumstances:

a) The probe has become detached from the skin. This should always be checked first.

b) The probe has become wet. Urine, aqueous antiseptic solutions and spirit based antiseptics can easily get on to the probe. As they evaporate, they will cool it and may therefore cause the alarm to sound as well as bringing the heater on to full power. The probe should be dried and re-sited.

c) The baby is very cold. It is possible to rewarm a hypothermic baby using the radiant warmer under servo control but the alarms have to be periodically silenced. Manual mode should not be used because of the danger of personnel being distracted and forgetting to recheck the infant until he is dangerously overheated.

d) The baby is large and the room is very warm. Under these circumstances the baby may require very little supplementary heat to stay warm so that the heater is off most of the time. If the baby is mildly pyrexial and a normal skin temperature is selected for set temperature, there will be more than 0.5°C between the set and the sensed temperature and the alarm will continually sound. The heater can either be turned off altogether or used in the manual mode on the lowest setting.

9.
Safety

Because a radiant warmer designed for the care of small sick infants has such a powerful heater, it is intrinsically more dangerous than an incubator. Theoretically overheating would appear to be the major hazard, but in practice cold stress is the more common problem.

9.1
Overheating

This will occur if the radiant warmer continues to emit radiant heat when the baby does not need it. This may be an error of the user (e.g. the set temperature is too high for the baby). It will also occur if the probe becomes detached or wet. Although in most cases an alarm will sound because of the difference between the set and the sensed temperature, it is possible that the dislodged probe could find its way into a position where it remained about 0.3°C below the set temperature – in these circumstances no alarm would sound and the heater would remain on, with consequent overheating of the baby. ***The importance of frequent inspection of the probe, and an independent check on the baby's temperature must be emphasised.***

9.2
Cold Stress

If the radiant heat source is removed or interrupted but the baby remains naked on the exposed tray, heat losses will be large, with no compensating heat gain. This is most marked in the very small, sick, immature infant. Exposing such an infant naked to the temperature of a draughty neonatal unit is like exposing an adult to subzero temperatures. For this reason, the heat flow from the warmer must not be interrupted. Staff should not lean over the baby, putting themselves in the pathway of the radiant heat, the heater should not be turned off if it alarms, and procedures like X-rays which require the heater to be moved to one side should be as brief as possible.

10.
Radiant Warmers or Incubators?

Both of these devices, if used properly, are effective ways of keeping small or sick babies warm. There is no evidence that either device has a particular advantage over the other with regards to reduction in mortality or morbidity. However they produce very different thermal environments.

The incubator produces a very bland, constant, symmetrical thermal environment. The radiant warmers produce a fluctuating, asymmetrical thermal environment. Babies nursed under warmers have the same average skin temperature as babies nursed in incubators, but variations over different parts of the body are greater. Babies nursed in incubators tend to have lower rates of metabolism than babies nursed under radiant warmers.

The major advantages of radiant warmers are:

i) They are very effective at keeping small, sick infants warm, at the same time allowing them to be nursed naked for observation. In this respect radiant warmers are superior to incubators.

ii) They allow the infants to be more accessible to the medical and nursing staff. Although this may be a mixed blessing for the infant, it does simplify the carrying out of the practical procedures of neonatal intensive care. Most parents welcome the improved accessibility. In this respect too, they are superior to incubators.

The major disadvantages of radiant warmers are:

i) They are inherently less safe than incubators.

ii) They lead to greater difficulties in fluid balance control.

iii) They provide a thermal environment which children and adults would find uncomfortable.

Section C

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