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Humidification of incubators

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SUMMARY The effect of increasing the humidity in incubators was examined in 62 infants of less than 30 weeks' gestation. Thirty three infants nursed in high humidity for two weeks were compared retrospectively with 29 infants from an earlier study who were nursed under plastic bubble blankets or with topical paraffin but without raised humidity. Humidification reduced skin water loss and improved maintenance of body temperature from birth, but did not delay the normal postnatal maturation of the skin. Infants nursed without humidity frequently became hypothermic in spite of a high incubator air temperature. These advantages must be weighed against the finding that overheating was more common and *Pseudomonas* was more commonly isolated from the infants. It is recommended that incubator humidity is raised for babies under 30 weeks' gestation in the first days of life but meticulous attention should be paid to fluid balance, avoiding overheating, and cleansing of the humidifier reservoir.

In 1933 Blackfan and Yaglou[1] reported increased survival of preterm infants when nursed in a high ambient humidity. A series of carefully controlled trials by Silverman and colleagues confirmed that a high ambient humidity was associated with improved survival,[2] but showed that this was a result of improved maintenance of body temperature rather than an effect of the humidity itself.[3 4] Increased survival could be obtained by using a higher incubator air temperature alone. Humidification of incubators became increasingly unpopular when it was suggested that this contributed to infection in the newborn nursery.[5–7]

More and more extremely immature, very low birthweight infants are now receiving neonatal intensive care. It has become apparent that when such infants are nursed naked in unhumidified incubators, they are often unable to maintain a normal body temperature. They easily become hypothermic despite the use of the maximum incubator air temperature setting, heat shields, thermal blankets, or topical paraffin. This is a consequence of their very high evaporative water loss,[8] which is in turn a result of their poorly developed epidermis. Humidification is a highly effective way of decreasing evaporative water loss and it is therefore being advocated again, specifically for the nursing of very small, immature infants. Although many neonatal units have reverted to the use of humidification, no assessment of its use in this group of infants has yet been reported.

Humidification of incubators for nursing of very low birthweight infants was reintroduced into the neonatal intensive care unit at Nottingham City Hospital at the end of 1981—we felt it would be useful to monitor and report our experience. The effectiveness of humidity in maintaining a normal body temperature, the risk of infection of the humidifying system, and the maturation of the barrier function of the infant's skin were studied. There was no contemporary control group of infants nursed without added humidity. A previous study from this unit showed, however, that the use of plastic thermal blankets or topical paraffin to reduce evaporative water loss did not result in the maintenance of a normal body temperature in low birthweight infants, despite the use of maximum incubator air temperatures and careful nursing.[9] So that some comparison could be made between infants nursed with and without added humidity, some results on infants from this earlier study are included.

Subjects and methods

Subjects. The first 33 infants of less than 30 weeks' gestation who were nursed in high humidity from arrival on the neonatal unit formed the study group. The comparison group was taken from an earlier controlled prospective study in which thermal blankets and topical paraffin were compared as methods of reducing evaporative water loss in infants nursed

Table *Details of the infants studied*

	Infants nursed in high humidity	*Infants nursed without added humidity*
No	33	29
Gestation (weeks)		
Mean (SD)	27·3 (1·6)	27·6 (1·2)
(Range)	(25 to 29)	(25 to 29)
Birthweight (kg)		
Mean (SD)	0·98 (0·19)	0·97 (0·18)
(Range)	(0·72 to 1·60)	(0·68 to 1·35)

in dry incubators.[9] In this study there were 29 infants below 30 weeks' gestation (14 treated with a thermal blanket and 15 with topical paraffin). Gestation was assessed from the mother's menstrual dates and the infant's physical characteristics. The two groups were well matched for gestation and birthweight (Table).

Ambient conditions. All infants were nursed in an incubator (79, Vickers Medical UK) used in the air mode. They were naked apart from a bonnet and booties. The nurses selected the incubator air temperature which kept the infant's rectal temperature in the range 36·6 to 37·2°C, the only limiting factor being the maximum air temperature setting of the incubator (36·9°C). Humidification of the incubator in the study group started on arrival on the neonatal unit and continued for two weeks. The humidifier reservoir was filled with sterile water and the setting turned to maximum humidity. The water was changed daily, leaving an hour between draining the existing water and adding the new water. An aliquot of drained water was sent for bacteriological culture each day. The relative humidity in the centre of the incubator when the portholes were closed and the air temperature was on the maximum setting (36·9°C) was between 80 and 90%. This fell to about 60% when the portholes were opened.

In the earlier study used for comparison no added humidification was provided. Infants were either covered with a clear plastic thermal 'bubble' blanket or covered in a thin layer of soft white paraffin at eight hourly intervals. Incubator humidity was about 30 to 40% at the maximum temperature setting and did not change substantially when the portholes were opened.

Measurements. Rectal temperature was recorded by a mercury thermometer at least six hourly in all infants, and the daily rectal temperature was calculated as an average of these readings. Incubator air temperature was recorded at least four hourly and a daily average calculated. The immediate effect on rectal temperature of adding and removing humidity was measured in two infants. The first infant (26 weeks' gestation, birthweight 960 g) had a steady rectal temperature of 35·8°C at 10 hours of age, despite use of the maximum incubator air temperature setting. At this stage, humidification was started. The second infant (27 weeks' gestation, birthweight 780 g) became overheated on the fifth day, with a rectal temperature which was stable at 37·9°C in an air temperature of 36·2°C. Humidification was therefore removed. In both infants skin water loss was measured using a skin evaporimeter (Evaporimeter EPI, Servomed, Sweden). An overall skin water loss was calculated from measurements at 11 sites as previously described.[10] The evaporimeter was also used to record the relative humidity of the incubator air (%).

The incidence of bacterial contamination and infection in the 33 infants was studied and compared with the infants in the earlier study. Endotracheal secretions and surface swabs were sent for routine culture—other cultures (for example blood, urine, and cerebrospinal fluid) were performed when clinically indicated. When incubators were humidified an aliquot of water drained from the humidification system was sent for culture each day.

Fourteen of the 33 infants nursed in humidity had serial measurements of skin water loss measured on the upper abdomen by evaporimeter from day 1 up to age 14 days. Measurements were made an hour after the humidity reservoir had been drained immediately before being refilled with sterile water, when the ambient humidity had fallen to unhumidified levels. The results were compared with data obtained in 12 infants below 30 weeks' gestation who had been nursed without added humidity and had previously been studied serially.[11] These infants were slightly more mature (mean gestation 28·0 weeks *v* 27·1 weeks) and heavier (mean birthweight 1174 g *v* 954 g). Results were compared using Student's *t* test and χ^2 analysis.

Results

Temperature control. The magnitude of the individual changes are illustrated by the detailed observations on two infants. In the first infant ambient relative humidity increased from 36 to 61% when water was added to the incubator humidifier (Fig. 1). This is an artificially low increase because the incubator portholes had to be open for the measurements of skin water loss. Nevertheless the infant's rectal temperature, which had been subnormal for several hours in spite of the maximum

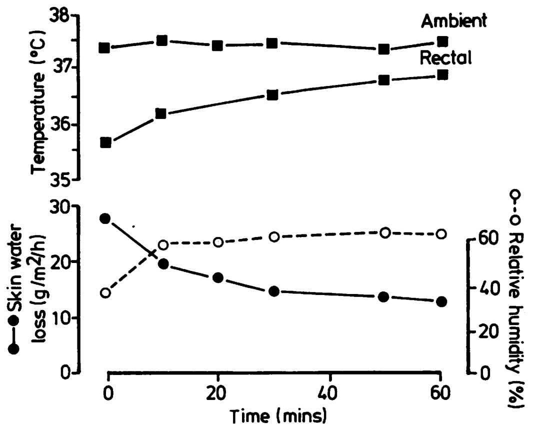

Fig. 1 *The effect of increasing the relative humidity from 36 to 61%.*

Humidity is added to the incubator of an infant who has been hypothermic for several hours despite a high air temperature. Skin water loss falls rapidly and rectal temperature rises to normal.

incubator air temperature, steadily rose as the skin water loss fell.

In the second infant, when water was drained from the incubator humidifier, skin water loss rose and the previously high rectal temperature fell to normal values (Fig. 2). In both cases the incubator air temperature was left unchanged.

The mean daily rectal temperature was lower over the first five days in infants nursed without added humidity; the difference being most noticeable in

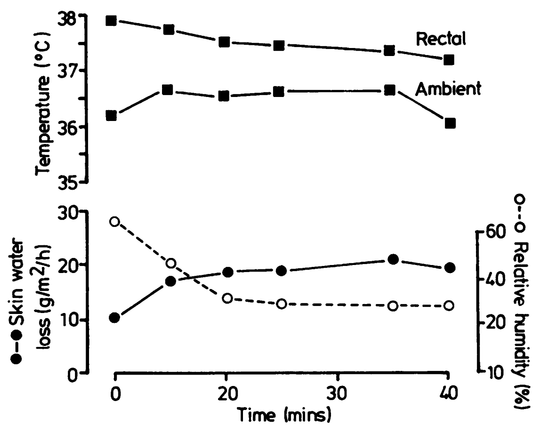

Fig. 2 *The effect of decreasing the relative humidity from 65 to 30%.*

Humidity is removed from the incubator of an overheated infant. Skin water loss rises and rectal temperature falls to normal without alteration in air temperature.

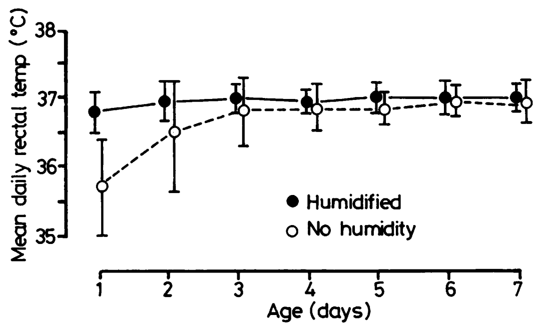

Fig. 3 *Daily rectal temperatures (mean (SD)) in study infants (humidified) and comparison infants (unhumidified) during the first week of life. The differences on the first three days are statistically significant.*

the first three days when it was statistically significant (Fig. 3). Infants nursed in high humidity had normal rectal temperatures even on the first day of life (mean (SD), 36·8°C (0·3)) and only one infant had a low daily rectal temperature (36·1°C). This infant had been born in the accident and emergency department of a distant seaside resort and had an initial temperature of 31°C. After the first 24 hours there were no daily mean rectal temperatures below 36·6°C and only five isolated readings of less than this, occurring when an incubator had broken down, where the water in a humidifier had been drained and not replaced, or when the infant was very sick and being handled. By contrast, infants nursed without increased humidity had a daily rectal temperature of mean (SD) 35·7°C (0·7) on the first day and only two infants in this group had a daily rectal temperature in the range 36·6 to 37·2°C. Ten of the surviving comparison infants had daily rectal temperatures below 36·6°C on at least one subsequent day and one infant remained hypothermic until the sixth day of life.

Infants nursed in added humidity were more likely to have rectal temperatures above the normal upper limit of 37·2°C but overheating did occur in both groups. One infant in each group had a rectal temperature of 38·5°C recorded, but this was not related to illness. The average daily incubator air temperature was lower in the humidified group than in the comparison group. Mean incubator air temperature in the infants who received humidity was 36·6°C on the first day and 36·3°C on the second day. By contrast, mean incubator air temperatures in the earlier study were 37·0°C and 36·9°C on the first two days, the maximum attainable in this incubator. Even on the seventh day, when both humidified and non-humidified infants had normal rectal temperatures, the mean incubator air temperature was lower in the infants who received humidity (35·3°C cf 35·8°C).

Infection. Of the hundreds of samples of humidifier water sent for culture only 11 grew any bacteria. Eight grew *Pseudomonas,* one *Escherichia coli* and two mixed coliforms. All bacterial counts were low (less than 100 organisms per ml). Seventeen infants nursed in humidity (57%) grew *Pseudomonas* species from at least one site during their admission compared with six infants in the earlier study (21%), a significant difference ($P<0·05$). The commonest site of isolation was from endotracheal tube secretions during prolonged ventilation. In six infants, *Pseudomonas* was isolated for the first time after cessation of incubator humidification. If these infants, and those who died in the first 24 hours, are excluded, there is no statistically significant difference in *Pseudomonas* isolation between the two groups. Four infants nursed in humidity had positive blood cultures; two grew *Pseudomonas* at 3 and 5 days of age and died, one grew prenatally acquired *E coli* and died, and one had a mixed growth of coliforms at necropsy. In the early study, one infant died with *Pseudomonas* and group B streptococci on blood culture on the second day, one grew *E coli,* and one grew *Staphylococcus epidermidis,* and both survived.

Maturation of the skin barrier. Skin water loss fell steadily to mature values over the first two weeks, with most of the decrease occurring in the first week (Fig. 4). There was no appreciable difference in the initial values of water loss on the first day and the subsequent fall when infants nursed with and without humidity were compared.

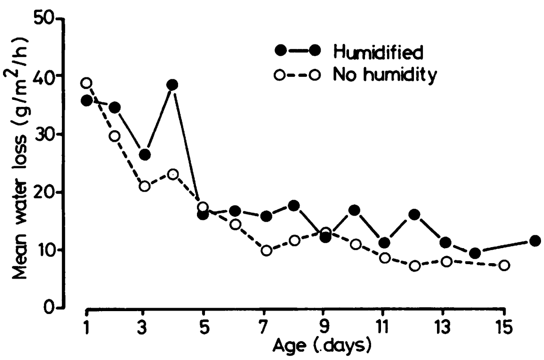

Fig. 4 Mean abdominal skin water loss over the first two weeks in study infants (humidified) and comparison infants (unhumidified), measured at a time when there was no added humidity in the incubator.

There is little difference between the two groups, suggesting that use of humidification does not delay the usual postnatal maturation of the epidermal barrier in preterm infants.

Discussion

This study is limited by its design. Infants nursed without added humidity were selected retrospectively and were not contemporaries of those nursed in humidity, so that like was not compared with like. Nevertheless, the two groups were well matched for birthweight, gestation, and illness, so that it is possible to derive some useful information about the use of humidity.

Adding humidity to incubators clearly improves the control of body temperature in infants of less than 30 weeks' gestation, to the extent that hypothermia becomes exceptional, even on the first day of life. By contrast, infants nursed in dry incubators and covered with a plastic bubble blanket or a thin layer of soft paraffin are commonly hypothermic in the first few days, in spite of the use of the maximum air temperature setting. Water is lost from the skin of the preterm infant by passive diffusion along a concentration gradient. Water loss is highest in the first week when the epidermal barrier to diffusion is poorly developed (a function of gestation rather than birthweight). A high ambient humidity reduces this concentration gradient so that skin water loss falls (Fig. 1). If the relative humidity of the surrounding air reaches 100%, water loss ceases. A modern incubator can achieve a relative humidity of 80 to 90% when the humidifier setting is on maximum and the portholes are closed. Skin water loss is low at this humidity and a normal body temperature can be maintained —in fact it is easy to overheat the infant (Fig. 2). When humidity is used, rectal or skin temperature should be closely monitored. Although high rectal temperatures were recorded in all infants, this was initially more common in those nursed in humidity. As nursing staff became accustomed to the use of humidification the incidence of overheating fell. If there is overheating, it is preferable to remove the humidity rather than lower the air temperature. In the study we found that misting of the incubator (condensation of water on the inner perspex walls) was uncommon and slight. This is because the incubator temperature was high (which raises the dew point) and the room temperature (29 to 30°C) was high (which raises the temperature of the incubator walls). Lowering the incubator or room temperature at maximum humidity will cause misting which obscures the infant and soaks the incubator contents. Use of humidity is unnecessary after the first few days because maturation of the epidermal barrier is rapid in very immature infants.[12] This postnatal maturation probably occurs in response to the change from a fluid to a gaseous environment and seems to be unaffected by the moist environment of a humidified incubator.

Maintenance of a normal body temperature is associated with improved survival in preterm infants.[13–15] Although these earlier studies did not include very immature infants of less than 30 weeks' gestation, there is no reason to believe that they behave differently and benefit from hypothermia. The design of our study makes it impossible to say whether the use of humidity improves survival.

It was the possibility that humidity encouraged growth of bacteria in the incubator, particularly *Pseudomonas*, and therefore gave rise to serious infection, that led to its unpopularity and gradual disuse. We were careful to avoid bacterial contamination of water in the humidifier reservoir—the water was drained off each day, the incubator run dry for an hour, and the reservoir refilled with sterile water. Examination of the drained water showed that we were largely successful since bacteria were rarely found and were in very low concentrations. *Pseudomonas aerogenosa* was grown on eight occasions but its growth from the humidifier was always preceded by its isolation from another site (usually the endotracheal tube). *Pseudomonas* was commonly isolated from low birthweight infants nursed in high humidity, particularly from those who had received ventilation for more than a few days. In 1983, after the study finished, we continued using humidity but *pseudomonas* isolations became very uncommon and no infant developed a septicaemia with this organism. Such fluctuations in the isolation of *Pseudomonas* in an intensive care unit are well known and make it difficult to determine the contribution of incubator humidity. A small number of neonatal units in the United Kingdom have continued to humidify incubators since the 1960s—anecdotal reports to the authors suggest that neonatal infection is not increased. The previous reports linking humidity with infection[5–7] do not compare directly with modern practices. Nevertheless two infants nursed in humidity died of pseudomonas septicaemia—one was a ventilated infant recovering from respiratory distress syndrome, the other previously healthy, so that a link between infection and humidity cannot be lightly dismissed.

Because added humidity reduces evaporative water loss, a preterm infant nursed in humidity needs less fluid than if nursed without humidity to achieve the same water balance. The intake of fluid needs to be tailored to the infant's requirements by the frequent monitoring of urine and plasma osmolality and careful daily weighing. When humidification was reintroduced in this study, infants received the same daily fluid volumes as they had done previously (mean fluid intake in the first week was 114 ml/kg/day compared with 117 ml/kg/day in infants in the earlier study without humidity). This might have been expected to lead to a higher incidence of delayed closure of the ductus arteriousus, which is strongly related to fluid overload.[16 17] In fact delayed closure of the ductus was more common in infants who received added humidity, although the uncontrolled nature of the study makes direct comparison impossible.

We recommend that when infants of less than 30 weeks' gestation are nursed in incubators, humidity should be used since it greatly improves the control of body temperature. To minimise the risk humidification should be stopped after a few days when the infant's body temperature control improves—four to seven days of humidity is likely to be enough. Overheating of infants can occur and should be looked for. Fluid requirements are likely to be less than those calculated for infants nursed without humidity. It is not necessary to humidify incubators when nursing older or more mature infants unless their body temperature cannot be kept within the normal range.

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Annual meetings

1985	16–20 April	York University
1986	15–19 April	York University
1987	7–11 April	York University