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Change in the body temperature of healthy term infant over the first 72 hours of life

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Abstract: Objective: To determine the range of body temperature in a group of healthy Chinese term neonates over the first 72 hours of life and to assess the influence of body weight, gestational age and route of delivery. Method: All 200 consecutive cases of neonates delivered at our hospital from March to August 2001 were included in this retrospective study. Temperatures were measured immediately after delivery, after 30 minutes, 1 hour, 2 hours, 8 hours and 15 hours and on the 2nd and 3rd day. Axillary temperatures ranging from 36.5 ºC to 37 ºC were regarded as normal. No cases of maternal fever or systemic infection of the newborns were discovered. All infants were discharged in good general condition. Results: The mean rectal temperature at birth was 37.19 ºC. The lowest average temperature was reached at 1 hour after delivery (36.54 ºC) with a significant difference between natural delivery (36.48 ºC) and section (36.59 ºC) ($P<0.05$). Temperature subsequently rose to 36.70 ºC at 8 hours and 36.78 ºC at 15 hours ($P<0.05$). Hypothermia was seen in 51.8% and hypothermia in 42.5% of the patients. On the 3rd day after delivery, 96% of all temperatures were in the normal range. A significant relation was found between hypothermia and both low birth weight ($P<0.001$) and low gestational age ($P<0.05$). Conclusion: The reference range presently used did not include all physiological temperatures in the first 72 hours of life. Considering other factors, such as birth weight, route of delivery, gestational age and body temperature on the 2nd and 3rd day of life, may help to correctly assess the significance of temperatures beyond the reference range.

Key words: Body temperature, Term infant, Rectal temperature, Axillary temperature
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INTRODUCTION

Measuring body temperature has long become an indispensable means for the evaluation of a patient's general health status. Temperature as one of the key factors in physiological homeostasis is subject to minute regulation, while being a readily accessible diagnostic indicator as well. Circadian rhythms were reported in newborns as early as on the 2nd day of life (Sitka *et al.*, 1994). Likewise, a variety of other benign factors, such as environmental temperature, seasonal variations, state of arousal, metabolic state, ethnicity and others, are also known to affect peripheral and core body temperature (Azaz *et al.*, 1992; Takayama *et al.*, 2000; Waterhouse *et al.*, 2000). On the other hand, abnormal temperatures may indicate serious infection in neonates, and early therapeutic intervention can reduce mortality in such cases (Bonadio, 1993). Accurate measurement of temperature is important for ensuring a thermo-neutral state of the newborn (Keeling, 1992).

Given the importance of temperature measurement in daily clinical practice, it seems surprising that normal temperature ranges for neonates have not been clearly defined so far. Many textbooks and studies do not say what is normal for newborns, while the reference temperatures, when provided, show wide variations with lower limits as low as 35.5 ºC and upper limits as high as 37.9 ºC (Klaus and Fanaroff, 1986, Herzog and Coyne, 1993). The American Academy of Paediatrics (AAP) suggested the narrow range between 36.5 ºC and 37.0 ºC to be the most appropriate range for the axillary temperature of newborn infants (Freeman and Poland, 1992).

The purpose of our study was to determine the range of body temperature in a group of healthy Chinese term neonates over the first 72 hours after delivery and to assess the influence of factors such as body weight, gestational age and route of delivery. Furthermore, we looked for responses of the nursery staff to temperatures beyond the established normal range and as well as for the outcome of these newborns.

MATERIALS AND METHODS

From March to August 2001, a total of 200 neonates were delivered at our hospital. The nursery admission log was reviewed weekly and the patients consecutively included in this retrospective study. Six preterm infants (<36 weeks) and one high-risk full-term infant with severe asphyxia were transferred to the intensive care unit of a nearby Children's Hospital and thus excluded from our study. No serious maternal or foetal complications were reported prior to delivery, nor were any congenital abnormalities discovered. There were no cases of maternal fever at the time of delivery and no cases of prolonged rupture of membrane.

The characteristics of the patients included in this study are shown in Table 1. Of the 193 full-term or near-term neonates in this study, caesarean section was performed in 115 cases, while 78 had vaginal delivery. All sections were done under epidural anaesthesia. Forceps extraction was used in 4 cases of vaginal delivery. We defined three groups of body weight with the cut-off at one standard deviation less and higher than the average body weight with group 2 thus containing 68% of all subjects (group 1: <3030 g, group 2: 3030 g–3871 g, group 3: >3871 g).

Table 1 Characteristics of the study subjects (*n*=193)

Sex	99 girls, 94 boys
Delivery	115 sections, 78 vaginal (4 forceps)
Body weight	median 3400 g, *SD* = 421g [2200 g ... 4700 g]
Gestational age	median 40 weeks, [36^+ weeks ... 44 weeks]
Apgar 1 min	median 10, [3 ...10]
Apgar 5 min	median 10, [7 ... 10]

Rectal birth temperatures were measured in the delivery room (vaginal delivery) or in the operation room (section) immediately after delivery when the newborn had been dried and placed under a radiant warmer. Subsequently, the newborn was transferred to the nursery and axillary temperatures were routinely measured and recorded at 30 minutes, 1 hour, 2 hours, 8 hours, 15 hours and on the 2nd and 3rd day after delivery. All temperatures were measured with a common mercury thermometer. In accordance with the recommendation of the AAP, axillary temperatures from 36.5 ºC to 37.0 ºC were regarded as normal. No cases of systemic infection of the newborns were discovered and none of them received intravenous antibiotic treatment. All infants were discharged in stable and good general condition after 2 to 8 days, with longer hospitalization time being related to maternal health factors. Responses of the nursery staff to temperatures outside normal range were taken as recorded in the standardized nursing chart.

Temperature means were compared using the paired-sample *t*-test. Nominal and ordinal data, e.g. delivery routes and episodes of hypothermia, were tested using Chi-Square tests. Relationships between continuous variables were analyzed with linear regression models. Descriptive and multivariate statistics were performed with SPSS V10.0

for Windows and WinStat V3.1.

RESULTS

The regular number of temperature measurements per neonate was 8 times, a total of 1474 temperatures were actually measured. Thus, about 4.5% of the measurements were missing.

Course of the mean temperature

The mean rectal temperature at birth was 37.19 ºC. We corrected the rectal birth temperature by subtracting 0.2 ºC from all rectal temperatures in order to make them comparable to the axillary temperatures. The course of the mean temperatures is given in Table 2 and the corresponding box plot Fig.1. Within 30 minutes after delivery, the mean temperature dropped by 0.40 ºC (P<0.001). At one hour after birth, the lowest average temperature was reached, a drop of 0.45 ºC compared with the corrected mean birth temperature (P<0.001). From this point on, temperatures rose by 0.24 ºC to 36.78 ºC at 15 hours after birth (P<0.001) and stabilized around 36.7 ºC on the 2nd and 3rd day. The standard deviation of the mean temperature was 0.28 at birth, increased to 0.35 at 30 minutes after delivery and later continuously decreased to 0.20 on the 3rd day.

Table 2 Course of temperatures with minimum, maximum, mean temperature (all in ºC) and standard deviation (*SD*)

	min	max	mean	*SD*
Birth (rectal)	36.2	37.8	37.19	0.28
Birth (corrected)	36.0	37.6	36.99	0.28
30 min	35.5	37.8	36.59	0.34
1 hour	35.4	37.8	36.54	0.31
2 hours	35.8	37.4	36.62	0.27
8 hours	35.8	37.3	36.68	0.25
15 hours	36.2	37.6	36.78	0.26
2 days	36.4	37.4	36.78	0.25
3 days	36.5	37.4	36.74	0.20

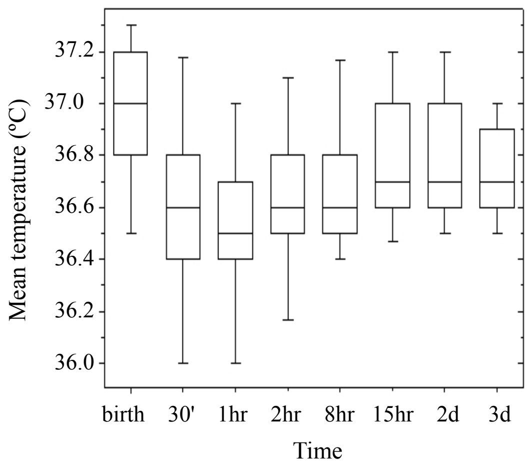

Fig.1 Box plot of the mean temperatures measured over the first 72 hours after delivery

Differences in mean temperatures between section and vaginal delivery

A significant difference was found for the mean rectal temperature at birth (37.24 ºC section, 37.11 ºC vaginal delivery, P<0.05) and at one hour after birth (36.59 ºC section, 36.48 ºC vaginal delivery, P<0.05). None of the other temperatures showed significant differences.

Differences in mean temperatures between groups of different body weight

No significant differences were found between group 1 (<3030 g) and group 2 (3030 g–3871 g). Differences between group 1 and group 3 (>3871 g) were not significant at birth, but showed a highly significant difference of 0.24 degrees at 1 hour after birth (P<0.001). Likewise, the mean temperature in group 2 was significantly lower than that in group 3 at 1 hour after birth (P<0.05).

Hypothermia

As many as 51.8% of all newborns in this study showed one or more hypothermic episodes over the course of hospitalization. While only 4.7% of all birth temperatures were in the hypothermic range, this rate increased to 27.4% after 30 minutes and 28.7% after 1 hour (Fig.2). Later this percentage decreased, so that after 24 hours only 0.5% of all temperatures were lower than normal. No hypothermia was found on the 3rd day after delivery.

Of the 100 newborns with hypothermic episodes in this study, 44 had one temperature in the

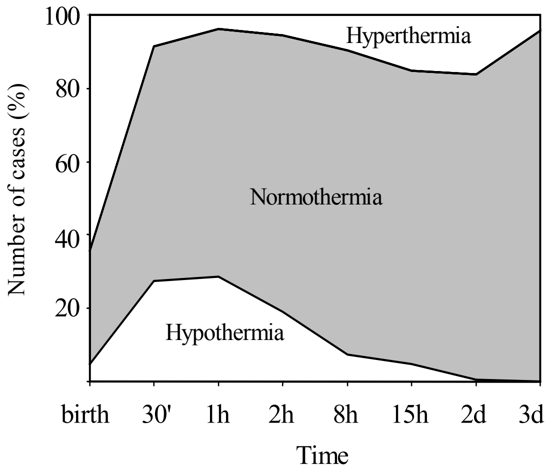

Fig.2 Stacked area chart of sums of cases in the hypothermic, normothermic and hyperthermic range. The birth temperature given is the corrected rectal temperature

hypothermic range only, 32 had two hypothermic measurements and 24 showed prolonged hypothermia with more than 2 temperatures lower than the reference range in the first 24 hours after birth.

Hypothermia was associated with low birth weight. While 23 (79.3%) out of 29 patients in weight group 1 had at least one temperature in the hypothermic range, this was true for 67 (49.3%) of the 136 patients in group 2 and 9 (32.1%) of the 28 patients in group 3 only. Pearson's Chi-Square test showed a highly significant relation between the incidence of hypothermia and the weight group ($P<0.001$). Hypothermia was also found to be associated with the gestational age ($P<0.05$).

Hyperthermia

The majority of the corrected birth temperatures (64.2%) were found to be higher than 37.0 ºC. The rate of hyperthermic measurements decreased to 8.6% after 30 minutes and to 3.7% after 1 hour. The temperatures after 2 hours (5.5%), 8 hours (9.6 %), 15 hours (15.2%) and on the 2nd day (16.3%) showed continuous increase in the rate of hyperthermia. On the 3rd day after delivery, hyperthermia occurred in 4.2% only, while 95.8% of the patients showed temperatures within the reference range.

Of the 80 patients with hyperthermic episodes in this study, 48 had one hyperthermic measurement only, 21 had two measurements higher than normal, 10 had three, and one infant showed mild hyperthermia throughout the first 48 hours and reached normothermia only on the 3rd day after delivery.

Unlike in hypothermia, temperatures higher than the reference range did not show statistically significant relations to body weight or gestational age, although the incidence of hyperthermia was higher in weight group 3 (53.6%) than in group 2 (39.7%) and group 1 (37.9%).

Correlations

Significant correlations were found between a variety of factors. Pearson correlation was significant for gestational age and birth weight ($r=0.41$, $P<0.001$). Spearman's rho showed significance for gestational age and hypothermia ($r=-0.169$, $P<0.05$), birth weight and hypothermia ($r=-0.302$, $P<0.001$), weight and hyperthermia ($r=0.155$, $P<0.05$), hypothermia and hyperthermia ($r=-0.350$, $P<0.001$).

Temperatures at 30 minutes after birth correlated significantly with temperatures at 1 hour ($r=0.545$, $P<0.001$), 2 hours ($r=0.309$, $P<0.001$), 8 hours ($r=0.205$, $P<0.01$), 15 hours ($r=0.227$, $P<0.01$) and on the 2nd day ($r=0.173$, $P<0.05$) after birth. Birth temperatures did not correlate well with subsequent temperature measurements.

Gestational age ($r=0.283$) and birth weight ($r=0.368$) both showed highly significant correlation with the temperature at 1 hour after birth ($P<0.001$).

No satisfactory model could be established by using linear regression. Several models tested showed low values for model fit and high values for residuals as well as a serious problem with collinearity between the different variables.

Responses of nursery staff to hypothermia

At 1 hour after delivery, the incidence of hypothermia was as high as 28.7%, yet the only response recorded by the nursery staff consisted of bundling and skin-to-skin (kangaroo) care.

DISCUSSION

Body temperature measurement surely is one of the oldest diagnostic means. Abnormally high and low temperatures may signify loss of physiological homoeostasis and disease. Both acute and gradual changes in body temperature may provide valuable information for diagnosis and for the assessment of therapy effects. However, the normothermic state may also be disturbed by a variety of benign internal and external factors.

Particularly in the case of newborns, where adaptation to the sudden and drastic changes of the external environment is still underway and regulatory cycles are yet instable and not fully matured, body temperature can be expected to be more immediately influenced by external factors than it is the case in older children and adults. It may be this comparably wide range of physiological variations, which makes standardization difficult and leaves room for interpretations addressed in a great number of publications, cumulating in questions like "What is fever?" (Herzog and Coyne, 1993) and "What is normal?" (Takayama *et al.*, 2000).

Apart from the lack of reliable reference ranges, recent studies have shown that the technical aspect of taking a patient's temperature is not to be neglected. Rectal, axillary and tympanic temperatures are known to differ to various degrees across studies depending on the patients' age group, as well as the route of measurement and the technical equipment used. A recent systematic review conducted as a meta-analysis on 40 studies with a total of more than 5500 patients showed "wide variations across studies" with "implications for clinical situations where temperature needs to be measured with precision" (Craig *et al.*, 2000).

In our study, we looked into temperatures of healthy newborns starting immediately after delivery and proceeding over the first 72 hours of life.

Course of the mean temperature

The course of the mean body temperature over the first hour of life as demonstrated in our study differs significantly from what had been described earlier (Takayama *et al.*, 2000). Takayama *et al.* measured their "mean birth temperature" of 36.5 ºC at 34 minutes after birth and mentioned an "initial rapid increase in temperature over several hours followed by a much more gradual increase and stabilization over the ensuing days". In our study, all birth temperatures were measured immediately after the operational or vaginal delivery with the child placed under a radiant warmer in the operation room or the delivery room. The birth temperature was measured as a rectal temperature for two reasons. Firstly, rectal measurement may be less easily affected by the heat radiation coming from the radiant warmer. Secondly, congenital atresia ani needs to be excluded. For infants with a birth weight >2500 g, reported differences between rectal and axillary temperatures ranged from 0.15 ºC (Craig *et al.*, 2000) to 0.4 ºC (Roll *et al.*, 1998). We therefore subtracted 0.2 ºC to adjust the rectal measurement, which seems a reasonable approximation.

The striking difference, compared with the results reported by Takayama *et al.*, was a highly significant decrease of the mean body temperature by 0.4 ºC from 36.99 ºC to 36.59 ºC over the first 30 minutes after birth ($P<0.001$). Within the following 30 minutes, the mean temperature again dropped slightly by 0.05 ºC and reached its lowest average at 1 hour after birth. In the hours that followed, the temperature rose gradually and stabilized on the second day of life. Our mean temperatures measured at 30 minutes and 1 hour after birth correspond well to the "birth temperature" reported by Takayama *et al.*, so that it seems reasonable to assume that the initial decrease of the body temperature was not found in the earlier study simply because of the different observation intervals chosen.

The initial rapid decrease observed in our study may well reflect the sudden change in the external environment the neonate is invariably exposed to. Within the first 30 minutes of life, the child was cleaned, examined and transferred to the rooming-in ward. Depending on the handling by the delivery or operation room staff, the setting of the radiant warmer and the handling during the transfer, the decrease in the body temperature may be more or less obvious. A decrease, however, seems but natural and can be expected for the transition from the intrauterine life with no need for thermoregulation to a life in an environment which is no longer thermo-neutral. One can perhaps also assume that a certain amount of cold stress may help to trigger the physiological adaptation programmes of the newborn organism. Low temperatures at 30 minutes correlated highly with low temperatures after 1 hour (r=0.545, P<0.001), however, the correlation with low temperatures in the hours that followed grew weaker, as the body temperature in all infants increasingly stabilized.

Interestingly, the standard variation of the mean temperatures measured also seems to reflect this adaptation. While the *SD* was low at birth (0.28), it showed a marked increase at 30 minutes after birth (0.34) and from then on decreased to ever smaller ranges. On the 3rd day, when external factors as room temperature, amount of clothing, feeding or frequent shuttling of the newborn between family members can be expected to vary significantly among the subjects, the *SD* of the mean body temperatures actually reached its lowest value (0.20) (Table 2). This depicts one aspect of a successful adaptation to the new outer environment in our group of healthy newborns.

Significant lower birth temperatures for newborns delivered by caesarean section had previously been reported. Effects of anaesthetics on the mother's body temperature were considered to be responsible (Christensson *et al.*, 1993). We found significantly higher temperatures for the group delivered by section at birth and at 1 hour after birth. Yet, with a difference not more than 0.12 ºC and no significant differences after the first hour of life between the two groups in this study, the clinical significance of this finding may be questioned.

Birth weight is known to have a direct impact on thermoregulation, most notably in premature newborns. The higher ratio of body surface to body volume in infants with a low body weight at birth results in higher radiant heat loss. While the birth temperatures in our study did not show any significant relation with body weight, we found significant higher average temperatures for infants in weight group 3 (>3871 g) at one hour after birth. It seems that, in term infants just as in preterm infants, higher body weight is a favourable factor for thermoregulation.

Hypothermia and hyperthermia

As in earlier studies, hypothermia was commonly seen in our patients during the first day of life (Fig.2). While few of the birth temperatures were in the hypothermic range, the rate of hypothermia was highest in the first hour of life. More than one half of our patients had at least one measurement of less than 36.5 ºC. This rate is similar to what was reported earlier (Takayama *et al.*, 2000). Fourteen temperatures were lower than 36.0 ºC, the lowest at 35.4 ºC. Even two or three consecutive measurements showing hypothermia could retrospectively be characterised as within the physiological range. Therefore, temperatures far below the established reference range did occur in a relatively controlled hospital setting and did not indicate a pathological condition. The only response by the nursery staff recorded aimed at keeping the infant warm by bundling or skin-to-skin care with the mother. Low birth weight and low gestational age were two factors found to be closely associated with the occurrence of hypothermic episodes.

Intervening factors

Three factors should be discussed that are known to influence body temperature. Room temperature could be excluded as an intervening factor in our study, as a constant room temperature is maintained through central air-conditioning in our hospital. The delivery rooms are actually located next door from the rooming-in wards. Newborns delivered in the operation room do not leave the air-conditioned area during transfer to the ward. With regard to seasonal influences, the analysis did not reveal a statistical difference between infants born in spring (March to May) and summer (June to August). The most likely explanation again is that the newborns did not leave the air-conditioned environment. Finally, in order to study the influence of the circadian rhythm, we divided the temperature measurements into four groups (12 a.m. to

6 a.m., 6 a.m. to 12 p.m., 12 p.m. to 6 p.m., 6 p.m. to 12 a.m.) and conducted a covariation analysis. While there was literally no difference over the first 48 hours of life, the night temperatures on the 3rd day (12 a.m. to 6 a.m.) were slightly lower, yet without reaching statistical significance. Although there were reports on circadian rhythms as early as the 2nd day of life (Sitka *et al.*, 1994), we cannot count on finding such relatively small differences in our study which was conducted in a clinical, not an experimental setting.

Clinical implications

From the results in this study, it seems that temperatures beyond the established reference range for newborns are linked to the adaptation process of the newborn organism over the first 24 hours of life. Hypothermia as a physiological phenomenon is most likely to occur within the first 8 hours after birth. It was rarely seen on the second and was not encountered on the 3rd day after birth. Physiological hypothermia, on the other hand, reached its peak between 15 hours after birth and the 2nd day of life. On the 3rd day of life, the vast majority of temperatures were found to be within the reference range. Neonates whose temperatures remain higher or lower than the normal range on the 2nd and 3rd day after delivery should thus be subjected to careful evaluation and check-up. Further studies on larger groups of newborns including both healthy and diseased patients should investigate the diagnostic value of temperature measurements in the immediate postnatal period in terms of sensitivity, specificity and predictive values. Further diagnostic measures and antibiotic therapy in response to high or low body temperatures within the first 24 to 48 hours may not be necessary in an otherwise healthy child of a healthy mother, unless other accompanying factors suggest an underlying pathological cause. Unfortunately, it was not possible to continue the measurements after the 3rd day, as a significant number of infants and mothers were discharged from the hospital. It would have been interesting to know more about the natural course of adaptation over the first weeks of life. Yet, for a number of practical reasons, such studies cannot easily be conducted.

Unlike opinions expressed in earlier publications, we do not think that the reference temperature ranges for newborns should be redefined. Our data showed that the established reference range worked fine after the 2nd day of life. What we need for the first 24 to 48 hours is not a reference range largely inflated to include the whole scope of measurements likely to occur in newborns. What we need is a better understanding of what body temperature actually is and how it is affected by changes in the external and internal environment. Interwoven with seasonal variations, circadian rhythms and short-term effects resulting from a multitude of factors, such as environmental temperature, state of arousal, metabolic rate, techniques used by the nursery staff and others (Azaz *et al.*, 1992; Waterhouse *et al.*, 2000), body temperature appears to be more than a simple, physical parameter, easily measured and readily translatable into therapeutic consequences. The interpretation of temperature measurements in the immediate postnatal period rather requires a synopsis of the conditions of mother and child, as well as of the environment the child is born into. For the time being, however, warming of the infant may be the most reasonable and most readily available response to low temperatures.

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