Neonatal hypothermia in sub-Saharan Africa: A review

R Onalo

Department of Paediatrics, University of Abuja Teaching Hospital, Gwagwalada, Abuja

Abstract

Background: Hypothermia is a major factor in neonatal morbidity and mortality in developing countries. High prevalence of hypothermia has been reported widely even from warmer tropical countries. In spite of the World Health Organization's recommendation of maintenance of warm chain in newborn care, hypothermia continues to be a common neonatal condition which has remained under-recognized, under-documented, and poorly-managed.

Objective: This review aims at providing the incidence of and risk factors for neonatal hypothermia as well as provides a pathophysiological overview and management options for neonates with the condition in sub-Saharan Africa.

Materials and Methods: All available published literature on neonatal hypothermia was searched electronically and manually. The principal electronic reference libraries and sites searched were PubMed, Embase, Ajol, Cochrane Reference Libraries and Google Scholar. The search terms used included 'neonatal hypothermia,' 'Cold stress in newborn' 'thermal care of the newborn,' 'neonatal thermogenesis,' 'neonatal cold injury,' among others. Pertinent books and monographs were accessed. Data in formats inaccessible to the reviewer were excluded.

Result and Conclusion: Neonatal hypothermia is a major condition of public health importance in countries of sub-Saharan Africa. Awareness of the burden of the disease is still low in some communities. Risk factors for neonatal hypothermia in the region include poverty, home delivery, low birthweight, early bathing of babies, delayed initiation of breastfeeding and inadequate knowledge among health workers. Low-tech facilities to prevent heat losses and provide warmth are available in sub-Saharan Africa and are thus recommended as well as continuous efforts at sensitizing caregivers on the thermal needs of newborns.

Key words: Neonatal hypothermia, neonatal thermogenesis, sub-saharan africa, thermal care

Date of Acceptance: 05-Apr-2012

Introduction

Over 1.1 million neonatal deaths, comprising 28% of the global burden, occur in sub-Saharan Africa with Nigeria, Ethiopia, Democratic Republic of the Congo and Tanzania contributing 6%, 4%, 3%, and 2% of the global burden of neonatal deaths, respectively.[1] Hypothermia plays a significant role in some of these deaths.[2,3] The recognition of the thermal needs of newborns and the interplay between warm and humid environment and the survival of low birthweight babies led to the development of incubators in the 1900s.[4] Aside this, the World Health Organization (WHO) has set up guidelines in response to the increasing challenges in the management of newborns at risk of hypothermia.[5] In spite of these developments, neonatal hypothermia has remained a challenge to newborn survival in developing countries. Although the exact incidence of the condition is unknown, it is estimated that 17 million newborns develop hypothermia annually in developing countries[6] and in some parts of the sub-Saharan Africa, incidence of 60% to 85% have been documented.[2,7] The high incidence of neonatal hypothermia may not be unrelated to the persistence of harmful traditional

Address for correspondence:
Dr. Richard Onalo,
Consultant Paediatrician,
Deparment of Paediatrics, University of Abuja Teaching Hospital,
Gwagwalada, Abuja.
E-mail: richardonalo@yahoo.com

Access this article online	
Quick Response Code:	Website: www.njcponline.com
	DOI:
	PMID:

practices[8,9] like sprinkling of cold water on babies at birth, early bathing of newborns, delayed initiation of breastfeeding, among others and under-recognition of the disease by healthcare providers.[5,9,10] Neonatal hypothermia is associated with high morbidity and mortality. A study from Tanzania has demonstrated a nearly four-fold increase in mortality in neonates with hypothermia.[2] Therefore this review is aimed at enlightening healthcare givers of the thermal needs of newborn so as to ensure timely prevention, recognition, and intervention. Knowledge of pathophysiological changes induced by hypothermia is useful in providing anticipatory care for at-risk babies.

Pathophysiology of neonatal hypothermia

Fetal-to-neonatal thermoregulatory transition. During fetal life, maternal thermogenesis maintains the fetal temperature.[11-13] In addition to this, the fetus also generates heat as a by-product of cellular respiration at a fairly constant rate of 33 to 47 calories/kg/min,[13] thus accounting for fetal-maternal temperature difference of 0.45°C to 0.5°C.[13,14] Brown fat thermogenesis does not occur in utero.[15] Placental factors identified to be prostaglandin E_2 and probably adenosine are inhibitors of thermogenesis in utero.[15] Effective thermogenesis after birth requires the combination of separation from the placental inhibitors of lipolysis, increased oxygenation from breathing and the stimulation of cutaneous cold receptors.[15] Unlike the older children and adults that have well developed thermogenic mechanisms, the response of the newborn to cold stress is not adequately effective. In addition, preterm infants have unstable vasomotor responses and do not vasoconstrict adequately to slow down heat losses.[11] These thermogenic inadequacies occur on the background of high body surface area/body weight ratio, relatively larger head and thinner layer of skin and subcutaneous fat. As a result of these differences in physical characteristics, heat loss in the newborn is about four times that of the adult per unit body weight.[15,16]

Four mechanisms known to be involved in the heat loss process include conduction, convection, evaporation and radiation. Transfer of radiant energy by radiation from the body surface through emission of infrared electromagnetic waves to surrounding cooler solid surfaces in close proximity but not in direct contact with the body may be the most important route of heat transfer in infants older than 28 weeks gestational age[17] while evaporative loss forms the major route of heat loss in the extremely low birthweight infants due to the high rate of transepidermal vaporization through the non-keratinised epidermis.[17] Vaporization of moisture from the skin and respiratory tract may occur at the rate of 19.1 calories/ kg/ min especially in areas with low relative humidity.[18] Heat loss by convection occurs to cooler surrounding air and it is dependent on the speed and temperature of air current around the infant while conductive losses occur through heat transfer to a colder surface in direct contact with the body such as the beddings.[17]

Heat production in the newborn is predominantly achieved by the nonshivering thermogenesis, which is initiated when skin temperature falls to 36°C.[17,19] Although behavioral changes such as adoption of a tightly flexed posture, shivering or moving towards warmer areas may be observed in some term infants,[15,20] it does not contribute significantly to heat generation in cold babies. Nonshivering thermogenesis primarily occurs in brown fat, a highly specialized tissue laid down at about 26-28 weeks of gestation principally around the scapular region, nape of neck and around the neck muscles, extending under the clavicles into the axilla.[11,19,20] It is also found in the mediastinum around the trachea, oesophagus, heart, and lungs. Some proportions of the brown fat are situated around large blood vessels of the neck and thorax, intercostals, and mammary arteries and abdominal aorta, resulting in rapid heat transfer to the circulation.

Brown fat has rich capillary network, numerous mitochondria with respiratory chain enzymes and densely innervated by sympathetic nerve fibers.[12,19,21] Cold stress stimulates the sympathetic nerve endings to release norepinephrine which subsequently bind to β_3 and α_1 adrenergic receptors on the fat cells and triggers an increase in adenosine 3′, 5′-cyclic phosphate through the action of adenylate cyclase.[12,15,19,21] The intracellular signal is transmitted via cAMP and protein kinase A, leading to the release from triglycerides of fatty acids.[21] The ensuing β-oxidation of the fatty acids as well as the activity of the citric acid cycle lead to the formation of the reduced electron carriers which are then oxidized by the electron transport chain.[21] This results in a pumping out of protons from the mitochondria and the formation of a proton-motive force that drives the protons back into the mitochondrial matrix through the uncoupling action of a 32-kDa protein called uncoupling protein thermogenin.[12,15,19,21] The energy stored in the proton-motive force is then released as heat.[21] About 2.5 calories are liberated per gram of brown fat.

Soon after birth, precipitous drop in body temperature occurs,[11] especially in the absence of appropriate preventive measures. Some environmental and neonatal factors account for heat loss observed in newborn babies: the average delivery room temperature is considerably lower than that of the amniotic fluid by at least 10 °C,[11] the infant is wet and his body surface area is large.[20] Relative to body weight, the body surface area of a newborn is approximately three times that of an adult.[22] Heat loss depends on surface area.[22] Thus heat loss in newborns is approximately four times that of adult.[22] The preterm babies are particularly prone to heat loss because of low subcutaneous fat, lack of stratum corneum layer of the skin and inadequate development of the autonomic anatomic and chemical pathways.[20] Although the term newborn is able to increase heat generation up to twice the intrauterine rate in response to the cold stimulus of his new environment,[19] the increase is insufficient to prevent a fall in body temperature especially on the first day of life.[23] The rate of heat loss may be as high as 100-200 calories/kg/min,[16,18] with a corresponding drop in body temperature at a rate of 0.2 to 1.0 °C per minute.[11] When heat loss proceeds in excess of heat production, the body temperature drops below the normal range of 36.5 ° to 37.5 °C[5,17] and hypothermia with its attendant consequences results.

Heat loss is observed even in newborns in relatively hot countries of sub-Saharan Africa.[10,24,25] Changes in core temperatures were observed within five minutes of delivery in some newborns in the relatively hot and humid part of southern Nigeria.[24] Therefore heightened vigilance is strongly recommended.

Pathophysiological effects of neonatal hypothermia

There is paucity of data on the pathophysiological changes in newborns with hypothermia. Observations made in newborns undergoing therapeutic hypothermia[26-30] have generated some useful information. This, coupled with results of animal studies[31,32] and observations in adult,[33-36] have provided valuable insight on the pathophysiological effects of neonatal hypothermia, knowledge of which is required for optimum management of the condition.

The initial reaction of the baby to cold stimulus is heat conservation via peripheral vasoconstriction followed by heat generation,[35,37] both mediated by sympathetic activities. The sympathetic drive, in addition to inducing lipolysis, accelerates the heart and increases the stroke volume and, hence, the cardiac output and blood pressure. These homeostatic mechanisms result in increased heat generation and distribution. However, as the hypothermic process continues, these initial responses begin to decline at a rate directly proportional to the degree of hypothermia.[35]

Contrary to a belief that cold stress is needed at birth to initiate or stimulate breathing,[5] there is no evidence that hypothermia has any beneficial effect in the initiation and maintenance of spontaneous regular respiration at birth.[5] On the other hand, there is abundant evidence that hypothermia is harmful. Prolonged hypothermia is linked with impaired growth, vulnerability to infection and higher mortality.[5,38] Hypothermia affects virtually all systems, although the degree of affectation varies from system to system.

Changes in metabolism

At the onset of hypothermia, metabolic rate increases with oxygen consumption rate rising from 4-6 ml/kg/min at normothermia[23,39-42] to as high as 15 ml/kg/min under hypothermic conditions.[39] However, with prolongation and progression of hypothermia, oxygen consumption and hence total body metabolism may decrease at a rate of about 6% per degree Celsius fall in body temperature. Wasting of the body's stores of carbohydrate, protein and fat may occur due to the effect of cortisol, cathecholamine and other stress hormones released.[15,29] In a series of 53 vigorous newborns in Benin City, Nigeria, Omene *et al.*,[24] observed an inverse relationship between heat lost and serum glucose level, suggesting a tendency to hypoglycaemia in hypothermic newborns.

Changes in serum electrolytes

Hypothermia may presents with unpredictable fluctuations in serum electrolytes.[43] Experimental and clinical studies[26,27,31,44] have shown few cases of hypokalaemia in moderate hypothermia. Hypokalaemia is thought to be due to intracellular shift of potassium, but with severe hypothermia, cellular loss of potassium may eventually occur, resulting in severe hypokalaemia, with values as low as 2.8 mmol/1[27] being reported. Hypokalaemia may contribute to the development of arrhythmia and thus warrants monitoring during therapeutic hypothermia. Although hypomagnesaemia and hypophosphataemia have been reported in therapeutic hypothermia,[45] serum sodium concentration remains within normal limits despite these conditions.[44] Further studies are, however, needed to evaluate the effect of hypothermia on serum anion and cation concentrations.

Changes in the respiratory system

Aside from the initial increase in spontaneous respiration, hypothermia depresses respiration at a rate directly proportional to its degree.[36] In addition, publications by Ceruti[42] and McCormick *et al.*[32] revealed a blunting out of the initial ventilatory response to hypoxia in hypothermic newborn infants and piglets. Kiley *et al*'s study[36] in cats showed that cooling of the brain to 30.5 °C resulted in a large decrease in respiratory frequency with prolongation of both inspiratory and expiratory times. The reduction in ventilation may be due to a reduction in metabolism,[46] a direct effect of cold on the respiratory centre,[40] and inhibition of the release of central excitatory amino acid neurotransmitters such as glutamate in the nucleus solitaries.[32,36,47]

Effect on blood gases

Oxygen saturation is generally normal in hypothermia,[28] although, one of the patients in the study of Thoresen and Whitelaw[28] had a period of marked desaturation when the rectal temperature dropped below 33 °C. Hypothermia, however, increases the affinity of hemoglobin for oxygen but the concomitant decrease in oxygen requirement in moderate and severe hypothermia makes this event clinically unimportant. Transcutaneous pulse oximetry has been shown to remain accurate in babies with hypothermia,[48] thus making the assessment of oxygen saturation less cumbersome. Hypothermia decreases arterial pCO_2 and increases blood pH.[49] This is relevant, because low $PaCO_2$ induces cerebral vasoconstriction and, hence, further worsening the low cerebral perfusion already existing in patients with hypothermia.[49]

Changes in cardiovascular system

At the outset of hypothermia, a powerful sympathetic drive is swung into action causing a transient increase in the heart rate, cardiac output and mean arterial pressure.[28] However, with progression of the hypothermic episode, a linear fall in cardiac output at the rate of 7% per degree Celsius fall in core temperature may be observed.[50] Bradycardia may occur due to decreased depolarization of cardiac pacemaker cells, and its usually refractory to sympathomimetic drugs such as atropine.[43] Electrocardiographic (ECG) studies of hypothermic infants revealed decreased sinus rate, prolongation of PR interval, widening of QRS complex, prolongation of Q-T interval[27,51,52] and elevation of ST segment at temperatures below 33°C. In the series of Gunn et *al.*,[51] ECG performed in infants with bradycardia showed markedly prolonged QT interval but no arrhythmia was observed. Although such prolonged QT interval in the absence of ventricular arrhythmia may be safe, close monitoring is clearly essential and drugs that lengthen the QT interval should be avoided.[51] Significant arrhythmia has only been reported in newborns when temperature is below 32 °C,[26,27] suggesting that arrhythmia is uncommon in neonates. On the contrary, some authors[33,34] have observed frequent occurrence of atrial fibrillations even at temperature as high as 35 °C in adults. The appearance of J-wave of Osborn in ECG tracing is considered by some authors[33,35] as a warning sign of the possible onset of ventricular fibrillation. Although J waves have not been described in neonatal studies,[50,51] the importance of ECG monitoring in the management of neonatal hypothermia is thus highlighted.

Effects on the kidneys

The effects of hypothermia on neonatal renal functions are not known with certainty. A study on newborn rabbits subjected to hypothermia indicated a 30% decrease in renal perfusion and a 20% decrease in glomerular filtration and urine flow rates when the temperatures was lowered by 2°C.[52] Further studies are required to establish the effects of hypothermia on neonatal kidney. Adult studies indicate that cold diuresis occurs with mild hypothermia as a result of increased sympathetic activity and decreased sodium and water resorption.[33,53] These observations have not been documented in neonatal population.

Changes in the gastrointestinal tract

Blood flow to the intestines is reduced secondary to hypothermia-mediated decrease in cardiac output.[54] This may account for the decrease in intestinal motility and subsequently, the dilatation of stomach and intestines, and abdominal distension observed at temperatures below 34°C in some infants and adult patients.[33,55] This highlights the need for caution in enteral feeding of babies with hypothermia, as the risk of developing necrotizing enterocolitis is further increased by the condition. In the study of Yu *et al.*,[56] hypothermia was the only adverse factor that was more frequently present in patients with necrotizing enterocolitis. There is, however, a recent publication[57] indicating that hypothermia may be protective against necrotizing enterocolitis in preterm infants probably by decreasing oxidative stress and prevention of neutrophil infiltration of the intestine.[57] Further studies are therefore required on the definite effect of cold stress on the gastrointestinal tract.

Changes in the blood

Severe hypothermia in adults causes a significant increase in blood viscosity and packed cell volume that are reversible with normothemia.[58,59] In general, hematocrit level tends to increase by 2% for each 1°C drop in core tempaterture.[43] In the newborn population, Mann and Elliott[60] reported a hypothermic newborn with hematocrit of 73%. Elevation of hematocrit is thought to be secondary to sequestration of plasma in the capillaries.[35] Unlike hematocrit, the platelet count tends to fall with hypothermia. Several newborn studies[29,30,47,61] have shown lower platelet count and prolonged prothrombin times in cooled infants. Four of the 16 asphyxiated infants studied by Azzopardi *et al.*[27] had abnormal coagulation that required treatment with fresh frozen plasma. The severity of coagulation defects in these patients may be related to the combined effect of asphyxia and hypothermia and as such it may be difficult to implicate hypothermia as the sole cause of coagulation failure in this series.

The causes of coagulation defects in hypothermia are multifactoral and included thrombocytopenia[62] (from sequestration of platelets in the reticuloendothelial system and probably in the intestine),[36] thrombocytopathy and consumption coagulopathy.[47,63] Kaplan and Eidelman[62] reported platelet levels of less than 50 000/mm^3 in about 50% of babies with severe hypothermia. Coagulopathies may also result from failure of enzymatic reactions of the clotting cascade caused by the decreased core temperature.[43] Cold-mediated stagnation of blood, disintegration of red blood cells and platelets with consequent release of thromboplastin are among the factors thought to be the initiator of coagulation defects in hypothermia.[63] White blood cell dysfunction resulting from decreased neutrophil chemotactic activity,[64] impaired phagocytosis,[65] and delayed cytokine release[66] are among the reasons for the increased susceptibility of hypothermic individuals to bacterial infections.

Changes in the nervous system

Hypothermia decreases cerebral blood flow[49] and hence cerebral metabolic rate which tends to decrease at the rate of 6%-7% per degree Celsius fall in temperature in some adult studies.[35,43] The combined effect of decreased blood flow and decreased microcirculation (secondary to increased viscosity) may cause decreased mental alertness and loss of consciousness.[33,43] The cascade of events leading to loss of cerebral functions in hypothermia have been pictured to occur in a step-wise fashion. Consciousness begins to reduce at temperatures below 35°C and at 30°C, it is usually lost. The pupils dilate and become unreactive at temperature below 30 °C.[43] Pupillary response to light is lost at core temperatures of 28°C to 32°C,[67] and brain-stem reflexes disappear when the core temperature drops below 28°C.[67] At temperatures below 20°C, the electroencephalograph becomes flat.[35,43] Although this pattern of neurologic response to hypothermia was mainly observed in adults, there is little to doubt of a similar progression in newborns. These neurologic changes have clinical implications particularly in the evaluation of critically ill patients for brain death. Following the discovery of the usefulness of hypothermia in reducing cerebral cytotoxins, metabolic needs and prevention of apoptosis,[68] there have been increasing use of the condition in neonatal encephalopathies and thus a higher tendency to false diagnosis of brain death. In view of this challenge, the American Academy of Pediatrics recommended warming up of the patients to a temperature (core) >35 °C before attempting the diagnosis of brain death.[69] Finally, the magnetic resonance imaging findings of cerebral thrombosis and cerebellar infarction in three newborns with hypothermia[27] suggests that these conditions could occur in babies with hypothermia and will therefore need vigilance for early detection and prompt management.

Incidence of neonatal hypothermia in sub-Saharan Africa

The exact incidence of neonatal hypothermia in sub-Saharan Africa is not known as there has been rarity of community-based study on the subject in the region. However, data emanating from hospital-based studies[2,7,10,69] from various countries of sub-Saharan Africa suggest a high prevalence even though there are country-to-country variations [Table 1]. In the West African sub-region, a study from Sagamu, Nigeria[7] recorded a prevalence rate of 62% among 150 babies at the point of admission, while a much earlier study from the same sub-region in 1981 reported a prevalence of 94.9% among a newborn population of 74 in Dakar, Senegal.[69] In another location, Guinea-Bissau, Sodemann *et al.*[3] assessed the temperatures of 2926 babies and found that 8.1% of them had developed temperatures below 34.5°C within 12 hours of birth. In these studies,[3,7] the risk of mortality was between two and five times higher in hypothermic babies than their normothermic counterparts. These observations suggest that the burden of neonatal hypothermia is high in West Africa and efforts at prevention should be started as soon as possible, definitely before the 12th hour of life, irrespective of the circumstances of delivery.

Neonatal hypothermia has also been reported from South African sub-region but unlike the high prevalence in West Africa, the incidence reported from Zambia[70] and Zimbabwe[2] ranged between 44% and 51.5%. In a more recent publication[71] from Johannesburg, South Africa, 3% of the 474 very low birthweight infants studied were hypothermic in spite of meticulous neonatal care, of which 61.5% died. In another study[72] from Johannesburg metropolitan region, the prevalence of hypothermia was 21% among 96 newborns involved in inter-facility transport. Although these studies were not primarily on neonatal hypothermia, the figures from Johannesburg, South Africa further highlighted the ubiquitous nature of neonatal hypothermia.

In the East African axis, report from Kenyatta National Hospital, Nairobi, Kenya,[73] revealed a neonatal hypothermia prevalence of 27.2% among 533 low birthweight babies on admission. In another study from Tanzania, Manji and Kisenge[74] reported an incidence of 22.4% among 1632 newborns on admission. Unlike the low prevalence in Tanzania, the report of Byaruhanga *et al.*[10] from Uganda showed that 83% of 300 newborns on admission developed a rectal temperature of less than 36°C at 1 hour of delivery. Furthermore, recent study from the horn of Africa (Eritrea) heightened the contribution of hypothermia to neonatal morbidity and mortality among newborns with pneumonia.[75] Although data on neonatal hypothermia is lacking in the Central African zone, it is unlikely to have newborn population devoid of hypothermia. Even in areas with low prevalence, under-reporting plays at least a minor role, thus there is need to awaken vigilance among health workers on this seemingly forgotten disease of newborns.

The high burden of neonatal hypothermia in sub-Saharan African is an issue of public health importance because the factors predisposing newborns to the condition are prevalent in the region and are largely preventable,[76] even though, the facilities for prevention and treatment of neonatal hypothermia remain scarce and concentrated in secondary and tertiary institutions. Efforts at educating the community on the available low-tech preventive measures and early detection and referral will certainly provide, at least, a noticeable reduction in the incidence of hypothermia in newborns.

Risk factors for neonatal hypothermia in sub-Saharan Africa

A combination of environmental factors,[37] cultural practices,[8,9,25,77] and socioeconomic[78.79] conditions compound the already existing risk of hypothermia in newborns consequent upon their physiologic make-up.

The average temperature of delivery room is at least 10°C lower than the temperature of the amniotic fluid.[11,24] In some countries like Zambia, Ghana and Nigeria, babies are placed on the delivery surface uncovered while awaiting

Table 1: Prevalence of hypothermia in some countries of sub-Saharan Africa

Country of study	Authors	Year of publication	Type of study	Sample size	Definition of hypothermia in the study	Study outcome	Recorded prevalence incidence
Nigeria (Sagamu)	Ogunlesi, *et al.*[7]	2008	Hospital-based	150	Axillary temperatures <36.5°C	Prevalence at admission	62.0%
Senegal (Dakar)	Briend, *et al.*[69]	1981		78	Rectal temperatures <36.0°C	Point prevalence	94.9%
Guinea-Bissau (Bissau)	Sodemann, *et al.*[3]	2008	Community-Based	2926	Axillary temperatures <34.5°C	Prevalence within 12 hours of delivery	8.1%
Zambia (Lusaka)	Christenssen, *et al.*[70]	1995	Hospital-based	261	Rectal temperatures <36.0°C		44.0%
Zimbabwe (Harare)	Kambarami, *et al.*[2]	2003	Hospital-based	313	Axillary temperatures <36.0°C	Prevalence at admission	85.0%
South Africa (Johannesburg)	Thwala[72]	2011	Hospital-based	96	Axillary temperatures <36.0°C	Prevalence at admission	21%
Kenya (Nairobi)	Simiyu[73]	2004	Hospital-based	533	Not stated	Morbidity among low birthweight	27.2%
Tanzania (Dar-es-Salaam)	Manji and Kisenge[74]	2003	Hospital-Based	1632	Axillary temperatures <36.5°C	Prevalence at admission	22.4%
Uganda (Nsambya)	Byaruhanga, *et al.*[10]	2005	Hospital-based	300	Rectal temperatures <36.5°C	Prevalence at 10, 30, 60 and 90 minutes postpartum	29, 82, 83, and 79% respectively

delivery of the placenta[9,25,79] thereby accelerating the heat loss processes. In addition, early bathing of babies is a common cultural practice in some countries of sub-Saharan Africa.[8,9,25,79] The study of Bergstrom *et al.*[8] have clearly shown that bathing a newborn soonest after birth contribute significantly to the development of hypothermia even if warm water was used for the bathing. Early bathing increases the risk of hypothermia by nearly 4-fold.[8] The risk may be higher in rural Ghana[25] where the first birth is usually done with cold water. Apart from total body exposure required during bathing, the removal of vernix caseosa increases the rate of heat loss in babies,[37,80] thus delaying the bathing process for at least 6 hours is recommended.[8]

The erroneous belief that colostrum is harmful in some rural communities of Nigeria[77] underlies the practice of delayed initiation of breast feeding and thus contributing to the risk of hypothermia. In a study[76] by Ogunlesi *et al.*, 79.2% of hypothermic infants did not have timely initiation of breastfeeding and the association between lack of breastfeeding and development of hypothermia was shown to be significant ($P = 0.028$). Thermal supply from specific dynamic action of food (SDA) as well as heat exchange between newborn and mother and the supply of fuel (fat) essential for heat production[81] that early breastfeeding allows is lost in babies denied timely initiation of breastfeeding thus explaining the propensity to hypothermia in newborns that were not breast fed early.[76] It is a common knowledge that skin-to-skin contact, that breastfeeding allows, is at least as effective as incubator in the thermal care of newborns.[82,83]

Poverty plays a pivotal role in the high prevalence of home deliveries (only 41% deliveries are attended by skilled birth attendants in sub-Saharan Africa[1]). Home delivery contributes to the high incidence of neonatal hypothermia in sub-Saharan Africa. The average ambient temperature within sub-Saharan Africa is 20 to 30°C, yet with wide diurnal and seasonal variations. Thus for deliveries at home where heating facilities are non-existent, the low ambient temperatures will rapidly overwhelm the newborn capacity to generate heat.[37] In Nigeria the introduction of out-of-pocket payment for health services resulted in increased rate of home deliveries and neonatal hypothermia among infants that required post-delivery transport to hospital.[78] The length of time required to transport a newborn to the nearest health facility has been demonstrated to have a positive correlation with the risk of dyeing from hypothermia.[84] Therefore efforts at increasing *in utero* transport in sub-Saharan Africa must include economic empowerment.

It is worrisome that some health workers in certain countries of sub-Saharan Africa[85] were among the healthcare providers with limited knowledge on the presentation of neonatal hypothermia, thus they might have contributed to the incidence and outcome of hypothermia in the region by delaying to institute appropriate treatment and preventive measures. This further reinforce the belief that hypothermia in newborns is due to a lack of knowledge or practice and not a lack of equipment.[86] It is therefore pertinent to heightened awareness of the condition among healthcare givers.

The high low-birthweight rate in sub-Saharan Africa itself contributes to the burden of neonatal hypothermia in the region. Although 65% of deliveries in the region are not weighed,[87] low birthweight rate stands at 14% with

South and West African regions having figures higher than the regional average.[87] The thermal challenge in low birthweight babies is higher than in the term normal birthweight infants. Estimates hold that the risk of hypothermia is increased by 31.3% for every 100 grams below 2000 grams and by 7.4% for every 100 grams below 3000 grams birthweight.[37] In a similar vein, a study[88] from Tanzania have shown that low birthweight infants have 11 times risk of hypothermia compared with normal weight babies while that of Ogunlesi *et al.*[76] equally identified low birthweight as a major risk factor for neonatal hypothermia in Nigeria ($P < 0.0001$). Thus communities with higher low birthweight rates will have more cases of neonatal hypothermia unless strict adherence to the WHO warm chain is observed.

Other highly prevalent host factors that might have contributed to the burden of hypothermia in sub-Saharan Africa include perinatal asphyxia,[76] neonatal hypoglycaemia and neonatal infections.[1] Unlike the small-for-gestational age and preterm babies that do not have adequate store of brown fat for thermogenesis, the hypoglycaemic and asphyxiated babies do not have the necessary fuel to generate the brown fat oxidation.

Management of neonatal hypothermia

The management of neonatal hypothermia is anchored on a 4-pronged principle: early recognition, prevention of further heat loss, restoration of normothermia and avoidance of further complications. In order to enhance early recognition, hourly temperature measurement has been recommended for babies that are particularly prone to hypothermia,[5] while in community setting, merely touching the extremities may provide a clue to the thermal state of the baby.[89] Further heat loss must be prevented by removing wet clothes and drying up the baby. Merely drying the infant reduces heat loss during the first 30 minutes of life by 19.1 calories/ kg/ min.[90] The use of plastic bags, plastic caps and stockinet have been recommended as a barrier to heat loss in low birthweight infants. A recent Cochrane review[91] of these synthetic external insulators shows that the plastic materials significantly lower the rate of hypothermia among early preterm babies. These plastic bags and sheets are locally available at low cost and should be used promptly,[81] while use of external heat source such as radiant warmer, light-bulb heated cot, transwarmer mattress and hot water bottles, though effective in maintaining normothermia, requires a steady power source and thus may constitute a challenge in places with erratic power supply. This further emphasises the need to ensure proper adherence to the WHO warm chain. The warm chain,[3] which consist of 10 interrelated procedures, is a low-tech highly effective means of ensuring adequate thermal care at birth and thereafter and comprises of warm delivery room, immediate drying, skin-to-skin contact, breastfeeding, bathing and weighing postponed, appropriate clothing/bedding, rooming mother and baby together, warm transportation, warm resuscitation, and training and awareness raising.

Although it may not be uncommon to find various versions of the warm chain in the existing traditional and orthodox birth practices, frantic effort should be made to standardize what obtains in the various settlements of sub-Saharan Africa. For instance, in Nigeria,[79] heating of the birth place before delivery is not practiced but in 82.3% of deliveries in some localities heating of the room was commenced soon after delivery,[79] signifying that these communities have some knowledge of the thermal needs of newborns. In the report from rural Ghana,[25] a significant proportion of newborns delivered at home had adequate but delayed drying and wrapping. Thus a little campaign will improve their newborn care practices. Early bathing of babies which has remained prevalent in the region[8,9,25,79] should be aggressively discouraged to bring down the statistics from 93-98.2% currently observed in west African subregion.[25,79]

In cases of mild hypothermia (36.0-36.4°C), passive rewarming can be achieved by Kangaroo Mother Care or by use of warm clothing in a warm room.[5] With successful rewarming the temperature should appreciate to normalcy within 2 hours of commencing the procedure unless there are underlying pathologies.[5,92] The moderately hypothermic infants (32.0-35.9°C) will require slow active external rewarming aimed at raising the temperature at the rate of 0.5 to 1.0°C per hour.[92] Slow rewarming is preferred to rapid rewarming in moderate hypothermia, as the later may lead to increased oxygen consumption and apnea[62] even though the process of slow rewarming may entail a risk of prolonging the hypothermia and its physiologic consequences.

The severely hypothermic baby (temperature below 32°C) will require resuscitation before or concurrently with rewarming. Unlike newborns with moderate hypothermia, severely hypothermic babies fare better with fast rewarming. Studies[62,93] showed that slow rewarming over several days carries higher mortality when compared with fast rewarming for few hours.

Neonates with core temperatures above 30°C may be rewarmed successfully with active external measures alone. However, those with core temperatures below 30°C require a combination of internal and external rewarming, as external rewarming alone may worsen an already precarious clinical situation.[11] External rewarming can create a vasodilated vascular bed with metabolic needs that cannot be met by a cold, poorly functioning heart. In addition, dilatation of the peripheral vascular bed may induce hypotension.[33] Finally, influx of cold fluid and acid metabolites released from the deep vascular beds into the heart may further depress the myocardium. There is also the risk of localized burns at the site of external rewarming, since the poor circulation may not be able to dissipate the heat emitted by external warming sources effectively.

Less aggressive internal warming techniques such as use of heated, humidified oxygen (maintained at 36.2 to 43°C)[94] by face or via endotracheal tube provides heat in the range of 17-30 kcal per hour and a corresponding temperature rise of 0.3-1.2°C per hour, while more aggressive methods such as use of intravenous solutions heated to 37-65°C,[43,95] warm gastric, peritoneal or thoracic lavage with 45°C fluid[43] could provide heat at levels as high as 100 kilocalories per hour or an equivalent temperature rise of 6.1°C per hour. Although internal rewarmimg provides rapid correction of hypothermia, the logistic involved may render the practice unattractive in resource-constrained communities. Thus emphasis is placed on prevention of hypothermia through implementation of WHO warm chain in sub-Saharan Africa.

The choice of method of rewarming depends on the duration and degree of hypothermia, availability of facilities and time involved in mobilizing them, and specific contraindication to the use of the procedure. In community setting where the modern facilities for thermal care are not available, use of warm blanket and transparent plastic sheets as well as feeding bottles filled with warm water and hot stones may be used to warm the cot and hence the baby.[5,11] Oil massage, a common practice in sub-Saharan Africa,[79,96] could also offer thermal protection. In Nigeria, over 60% of newborns received oil massage soon after delivery.[79] Topical application of safe, non-toxic emollients such as petrolatum, olive, palm kernel and sunflower oil have been shown to reduce transepidermal water and heat losses[37,96] and their use should be promoted but frequent and prolonged exposure during massage should be avoided as this could result in cold stress. In the direst of circumstances, hair dryer and heat lamps may be utilized but great caution must be excised because of the risk of burns.

Conclusion

Neonatal hypothermia remains a major problem in neonatal practice in sub-Saharan Africa. Awareness of the morbidity and mortality associated with the condition will help in the management. Therefore concerted efforts at sensitizing care givers are mandatory in achieving significant reduction in the consequences of neonatal hypothermia. Use of low-tech measures like warm room, Kangaroo care, hot water bottles and hot stones may be life saving in low income setting.

References

1. Paul VK. The current state of newborn health in low income countries and the way forward. Semin Fetal Neonatal Med 2006;11:7-14.
2. Kambarami R, Chidede O. Neonatal hypothermia levels and risk factors for mortality in a tropical country. Cent Afr J Med 2003;49:103-6.
3. Sodemann M, Nielsen J, Veirum J, Jakobsen MS, Biai S, Aaby P. Hypothermia of newborns is associated with excess mortality in the first 2 months of life in Guinea-Bissau, West Africa. Trop Med Int Health 2008;13:980-6.
4. Stern L. Thermoregulation in the Newborn Infant: Historical, Physiological and Clinical Considerations In: Historical Review and Recent Advances in Neonatal and Perinatal Medicine. In: Smith George F, Vidyasagar D, editors. Mead Johnson Nutritional Division; 1980.
5. World Health Organization. Thermal protection of the newborn: A practical guide. (Report No.: WHO/RHT/MSM/97.2). World Health Organization: Geneva, 1997.
6. Mathur NB, Krishnamurthy S, Mishra TK. Evaluation of WHO classification of hypothermia in sick extramural neonates as predictor of fatality. J Trop Pediatr 2005;51:341-45.
7. Ogunlesi TA, Ogunfowora OB, Adekanmbi FA, Fetuga BM, Olanrewaju DM. Point-of-admission hypothermia among high-risk Nigerian newborns. BMC Pediatr 2008;8:40.
8. Bergström A, Byaruhanga R, Okong P. The impact of newborn bathing on the prevalence of neonatal hypothermia in Uganda: A randomized, controlled trial. Acta Paediatr 2005;94:1462-7.
9. Choudhary SP, Bajaj RK, Gupta RK. Knowledge, attitude and practices about neonatal hypothermia among medical and paramedical staff. Indian J Pediatr 2000;67:491-6.
10. Byaruhanga R, Bergstrom A, Okong P. Neonatal hypothermia in Uganda: Prevalence and risk factors. J Trop Pediatr 2005;51:212-15.
11. Baumgart S, Harrsch SC, Touch SM. Thermal regulation. In: Avery GB, Fletcher MA, MacDonald MG, editors. Neonatology: Pathophysiology and Management of Newborn. 6th edition. Philadelphia: Lippincott Williams and Wilkins; 2005. p. 446-57.
12. Carlton DP. Transitional changes in the newborn infant around and the time of birth. In: Rudolf CD, Rudolph AM, Hostetter MK, Lister G, Siegel NJ, editors. Rudolph's Pediatrics. 21st ed. New York: McGraw-Hill Companies; 2002. p.79-82.
13. Power GG, Schröder H, Gilbert RD. Measurement of fetal heat production using differential calorimetry. J Appl Physiol 1984;57:917-22.
14. Morishima HO, Yeh MN, Niemann WH, James LS. Temperature gradient between fetus and mother as an index for assessing intrauterine fetal condition. Am J Obstet Gynecol 1977;129:443-8.
15. Gunn TR, Gluckman PD. Perinatal thermogenesis. Early Hum Dev 1995;42:169- 83.
16. Adamsons SK Jr, Towell ME. Thermal Homeostasis in the fetus and newborn. Anesthesiology 1965;26:531-48.
17. Soll RF. Heat loss prevention in neonates. J Perinatol 2008;28:S57-9.
18. Dahn LS, James LS. Newborn temperature and calculated heat loss in the delivery room. Pediatrics 1972;49:504-13.
19. Garnong WF. Temperature regulation. In: Ganong WF, editor. Review of Medical Physiology. 20th edition. New York: McGraw-Hill Companies; 2001.
20. Guha DK, Dadhich JP. Temperature control in newborn. In: Guha DK, editor. Neonatology: Principles and Practice. 2nd edition. New Delhi: JP Brothers Medical Publishers; 1998. p. 253-61.
21. Cannon B, Nedergaard J. Brown adipose tissue: Function and physiological significance. Physiol Rev 2004;84:277-359.
22. Carlo WA. The newborn infant. In: Kliegman RM, Stanto BF, Schor NF, St. Geme JW, Berhrman RE, editors. Nelson Textbook of Pediatrics. 19th edition. Philadelphia: Elsevier Saunders; 2011. p. 538-40.
23. Smales OR, Kime R. Thermoregulation in babies immediately after birth. Arch Dis Child 1978;53:58-61.
24. Omene JA, Diejomaoh FM, Faal M, Diakparomre MA, Obiaya M. Heat loss in Nigerian newborn infants in the delivery room. Int J Gynaecol Obstet 1979;16:300-2.
25. Hill Z, Tawiah-Agyemang C, Manu A, Okyere E, Kirkwood. Keeping newborns warm: beliefs, practices and potential for behavior change in rural Ghana. Trop Med Intl Hlth 2010; 15: 1118-24.
26. Clifton GL, Allen S, Berry J, Koch SM. Systemic hypothermia in treatment of brain injury. J Neurotrauma 1992;9:S487-95.
27. Azzopardi D, Robertson NJ, Cowan FM, Rutherford MA, Rampling M, Edwards AD. Pilot study of treatment with whole body hypothermia for neonatal encephalopathy. Pediatrics 2000;106:684-94.
28. Thoresen M, Whitelaw A. Cardiovascular changes during mild therapeutic hypothermia and rewarming in infants with hypoxic-ischemic encephalopathy. Pediatrics 2000;106:92-9.
29. Eicher DJ, Wagner CL, Katikaneni LP, Hulsey TC, Bass WT, Kaufman DA, *et al.*

Moderate hypothermia in neonatal encephalopathy: Safety outcomes. Pediatr Neurol 2005;32:18-24.

30. Gunn AJ, Gluckman PD, Gunn TR. Selective head cooling in newborn infants after perinatal asphyxia: A safety study. Pediatrics 1998;102:885-92.
31. Sprung J, Cheng EY, Gamulin S, Kampine JP, Bosnjak ZJ. Effect of acute hypothermia and beta-adrenergic receptor blockade on serum potassium concentration in rats. Crit Care Med 1991;19:1545-51.
32. McCormick A, Suguihara C, Huang J, Devia C, Hehre D, Bruce JH, *et al.* Depressed ventilatory response to hypoxia in hypothermic newborn piglets: Role of glutamate. J Appl Physiol 1998;84:830-6.
33. Reuler JB. Hypothermia: Pathophysiology, clinical setting and management. Ann Intern Med 1978;89:519-27.
34. Johnson DG, Hayward JS, Jacobs TP, Collins ML, Eckerson JD, Wiliams RH. Plasma norepinephrine responses of man in cold water. J Appl Physiol 1977;43:216-10.
35. Wong KC. Physiology and pharmacology of hypothermia. West J Med 1983;138:227-32.
36. Kiley JP, Eldridge FL, Millhorn DE. The effect of hypothermia on central neural control of respiration. Respir Physiol 1984;58:295-312.
37. Kumar V, Shearer JC, Kumar A, Darmstadt GL. Neonatal hypothermia in low resource settings: A review. J Perinatol 2009;29:401-12. Epub 2009 Jan 22.
38. Da Mota Silveira SM, Gonçalves de Mello MJ, de Arruda Vidal S, de Frias PG, Cattaneo A. Hypothermia on admission: A risk factor for death in newborns referred to the Pernambuco Institute of Mother and Child Health. J Trop Pediatr 2003;49:115-20.
39. Miller HC, Behrle FC, Nieman JL, Driver R, Dudding BA. Oxygen consumption in newborn premature infants. Am J Dis Child 1962;103:39-46.
40. Adams FH, Fujiward T, Spears R, Hodgman J. Gaseous metabolism in premature infants at 32-34 degrees C ambient temperature. Pediatrics 1964;33:75-82.
41. Mestyan G, Varga F, Fohl E, Heim T. Oxygen consumption of hyper- and hypothermic premature infants. Arch Dis Child 1962;37:466-9.
42. Ceruti E. Chemoreceptor reflexes in newborn infants. Effect of cooling on the response to hypoxia. Pediatrics 1966;37:556-64.
43. Edelstein JA, Li J, Silverberg MA, Decker W. Hypothermia. Available on the internet at http://www.emedicine.medscape.com/article/770542, accessed on 6/02/2012.
44. Tokutomi T, Miyagi T, Morimoto K, Karukaya T, Shigemori M. Effect of hypothermia on serum electrolyte, inflammation, coagulation, and nutritional parameters in patients with severe traumatic brain injury. Neurocrit Care 2004;1:171-82.
45. Polderman KH, Peerdeman SM, Girbes AR. Hypophosphatemia and hypomagnesemia induced by cooling in patients with severe head injury. J Neurosurg 2001;94:697-705.
46. Dill DB, Forbes WH. Respiratory and metabolic effects of hypothermia. Am J Physiol 1941;132:685-97.
47. Gunn AJ, Bennet L. Cerebral hypothermia in the management of hypoxic-ischemic encephalopathy. NeoReviews 2002;3:e116-22.
48. Iyer P, McDougall P, Loughnan P, Mee RB, Al-Tawil K, Carlin J. Accuracy of pulse oximetry in hypothermic neonates and infants undergoing cardiac surgery. Crit Care Med 1996;24:507-11.
49. Groenendaal F, De Vooght KM, van Bel F. Blood gas values during hypothermia in asphyxiated term neonates. Pediatrics 2009;123:170-2.
50. Zanelli S, Fairchild K. Physiologic and pharmacologic effects of therapeutic hypothermia for neonatal hypoxic ischemic encephalopathy. Newborn and Infant Nursing Reviews 2009;9:10-7.
51. Gunn TR, Wilson NJ, Aftimos S, Gunn AJ. Brain hypothermia and QT interval. Pediatrics 1999;103:1079.
52. Battin MR, Penrice J, Gunn TR, Gunn AJ. Treatment of term infants with head cooling and mild system hypothermia (35.0 degrees C and 34.5 degress C) after perinatal asphyxia. Pediatrics 2003;111:244-51.
53. Segar WE, Riley PA Jr, Barila TG. Urinary composition during hypothermia. Am J Physiol 1956;185:528-32.
54. Powell RW, Dyess DL, Collins JN, Roberts WS, Tacchi EJ, Swafford AN Jr, *et al.* Regional blood flow response to hypothermia in premature, newborn, and neonatal piglets. J Pediatr Surg 1999;34:193-8.
55. Arniel GC, Kerr MM. Severe hypothermia in glasgow infants in winter. Lancet 1963;2:756-59.
56. Yu VY, Joseph R, Bajuk B, Orgill A, Astbury J. Perinatal risk factors for necrotizing entercolitis. Arch Dis Child 1984;59:430-4.
57. Higgins RD, Shankaran S. Hypothermia: Novel approaches for premature infants. Early Hum Dev 2011;87:S17-8.
58. Poulos ND, Mollitt DL. The nature and reversibility of hypothermia-induced alterations of blood viscosity. J Trauma 1991;31:996-98.
59. Chen RY, Chien S. Hemodynamic functions and blood viscosity in surface hypothermia. Am J Physiol 1978;235:H136-43.
60. Elliott RI, Mann TP. Neonatal cold injury due to accidental exposure to cold. Lancet 1957;272:229-341.
61. Zhou WH, Shao XM, Cao Y, Chen C, Zhang X. Safety study of hypothermia for the treatment of hypoxic-ischaemic brain damage in term neonates. Acta Pharmacol Sin 2002;23:64-8.
62. Kaplan M, Eidelman AI. Improved prognosis in severely hypothermic newborn infants treated by rapid rewarming. J Pediatr 1984;105:470-4.
63. Chadd MA, Gray OP. Hypothermia and circulatory defect in newborn. Arch Dis Child 1972;41:819-21.
64. Clardy CW, Edwards KM, Gay JC. Increased susceptibility to infection in hypothermic children: possible role of acquired neutrophil dysfunction. Pediatr Infect Dis 1985;4:379-82.
65. Salman H, Bergman M, Bessler H, Alexandrova S, Beilin B, Djaldetti M. Hypothermia affects the phagocytic activity of rat peritoneal macrophages. Acta Physiol Scand 2000;168:431-6.
66. Kimura A, Sakurada S, Ohkuni H, Todome Y, Kurata K. Moderate hypothermia delays proinflammatory cytokine production of human peripheral blood mononuclear cells. Crit Care Med 2002;30:1499-502.
67. Widjicks EF. The diagnosis of brain death. N Engl J Med 2001;344:1215-21.
68. Nakagama TA, Ashwal S, Mathur M, Mysore M, and the Society of Critical Care Medicine, section on critical care and section on neurology of the American Academy of Pediatrics and the Child Neurology Society. Guidelines for the determination of brain death in infants and children: an update of 1987 task force recommendations. Pediatrics 2011;128:e720; doi: 10.1542/peds 2011-1511.
69. Briend A, de Shampheleire I. Neonatal hypothermia in West Africa. Lancet 1981;317:846-7.
70. Christensson K, Bhat GJ, Eriksson B, Shilalukey-Ngoma MP, Sterky G. The effect of routine hospital care on the health of hypothermic newborn infants in Zambia. J Trop Pediatr 1995;41:210-4.
71. Ballot DE, Chirwa TF, Cooper PA. Determinants of survival of very low birthweight neonates in a public sector hospital in Johannesburg. BMC Pediatr 2010;10:30.
72. Thwala MD. The quality of neonatal inter-facility transport systems within the Johannesburg metropolitan region. Dissertation). Available online at http://wiredspace.wits.ac.za/handle/10539/11031. Accessed on 15th March, 2012.
73. Simiyu DE. Morbidity and mortality of low birthweight infants in the newborn unit of Kenyatta National Hospital, Nairobi. East Afr Med J 2004;81:367-74.
74. Manji KP, Kisenge P. Neonatal hypothermia on admission to special care unit in Dar-essalaam, Tanzania: a cause for concern. Cent Afr J Med 2003;49:23-7.
75. Shatal SI, Zemichael O, Meng HD. Predictors of mortality, length of stay and co-morbid hypothermia in hospitalized neonates with pneumonia in Eritrea, Africa. J Trop Pediatr 2011;58:238-41.
76. Ogunlesi TA, Ogunfowora OB, Ogundeyi MM. Prevalence and risk factors for hypothermia on admission in Nigerian babies <72 hours of age. J Perinat Med 2009;37:180-4.
77. Okolo SN, Adewumi WB, Okonji MC. Current breasfeeding knowledge, attitude, and practice of mothers in five rural communities in the Savannah region of Nigeria. J Trop Pediatr 1999;45:323-6.
78. Owa JA, Osinaike AI, Costello AM. Charging for health services in developing countries. Lancet 1992;340:732.
79. Adelaga LM. A survey of home delivery and newborn care practices among women in a suburban area of western Nigeria. ISRN Obstet Gynecol. 2011;2011:983542.
80. Darmstadt GL, Dinulos JG. Neonatal skin care. Pediatr Clin North Am 2000; 47:757-82.
81. Huffman SL, Zehner ER, Victora C. Can improvements in breast-feeding practices reduce neonatal mortality in developing countries? Midwifery 2001;17:80-92.
82. Christensson K, Bhat GJ, Amadi BC, Eriksson B, Hojer B. Randomised study of skin-to-skin versus incubator care for rewarming low-risk hypothermic neonates. Lancet 1998;352:1115.
83. Ibe OE, Austin T, Sullivan K, Fabanwo O, Disu E, Costello AM. A comparison of kangaroo mother care and conventional incubator care for thermal regulation of infants <2000 g in Nigeria using continuous ambulatory temperature

monitoring. Ann Trop Paediatr 2004;24:245-51.
84. Daga AS, Daga SR, Patole SK. Determinants of death among admission to intensive care unit for newborns. J Trop Pediatr 1991;37:53-6.
85. Dragovich D, Tamburlini G, Alisjahbana A, Kambarami R, Karagulova J, Lincetto O, *et al*. Thermal control of the newborn: knowledge and practice of health professional in seven countries. Acta Paediatr 1997;86:645-50.
86. Costello A, Francis V, Byrne A, Puddephatt C. State of the world's newborns: A report from saving newborn lives. Available on the internet at http://www.eric.ed.gov/PDFS/ED458972.pdf
87. The United Nations Children's Fund and World Health Organisation. Low Birthweight: Country, regional and global estimates. New York: UNICEF; 2004.
88. Manji KP, Massawe AW, Mgone JM. Birthweight and neonatal outcome at the Muhimbili Medical Centre, Dar es Salaam, Tanzania. East Afr Med J 1998;75:382-7.
89. Singh M. Assessment of newborn baby's temperature by human touch: A potentially useful primary care strategy. Indian Pediatr 1992;29:449-52.
90. Glass L, Silverman WA, Sinclair JC. Effect of thermal environment on cold resistance and growth of small infants after the first week of life. Pediatrics 1968;41:1033-46.
91. McCall EM, Alderdice F, Halliday HL, Jenkins JG, Vohra S. Interventions to prevent hypothermia at birth in preterm and/or low birthweight infants. Cochrane Database Syst Rev 2010;CD004210.
92. World Health Organisation. Managing neonatal problems: A guide for doctors, nurses and midwives 2003; F69-75.
93. Tafari N, Gentz J. Aspects of rewarming newborn infants with severe accidental hypothermia. Acta Paediatr Scand 1974;64:595-600.
94. Mekjavic IB, Eiken O. Inhalation rewarming from hypothermia: an evaluation in –20°C simulated field conditions. Aviat Space Environ Med 1995;66:424-9.
95. Ledingham IM, More JG. Treatment after exposure to cold. Lancet 1972;1:534-35.
96. Andrew C, Kenmogne MH, Nguefack S, Obadeyi B, Mah E, Meka FZ, *et al*. The empiric use of palm kernel oil in neonatal skin care: justifiable or not? Chin J Integr Med 2011;17:950.

How to cite this article: ???

Source of Support: Nil, **Conflict of Interest:** None declared.