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Temperature Measurement and Thermoregulation in the Term and Preterm Infant

Jacqueline Smith

**For the Degree of Doctor of Nursing Science
in the School of Nursing, Midwifery & Nutrition**

James Cook University

September 2012

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28 September 2012

Jacqueline Smith

Date

STATEMENT OF CONTRIBUTIONS OF OTHERS

Nature of Assistance	Contribution	Co-contributors
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ABSTRACT

Background

Prevention of hypothermia is one of the basic tenets of effective neonatal care. Concerns about cold stress and its link to increased morbidity and mortality in neonates were first documented in 1907 (Budin 1907), but it was not until 1958 that Silverman et al. (1958) demonstrated the association between more effective temperature regulation and decreased mortality. Cold stress, or hypothermia, is known to result in complications such as an increased need for oxygen, difficult resuscitation, an increased incidence of disseminated intravascular coagulation (DIC), post delivery acidosis, delayed adjustment from foetal to newborn circulation, worsening respiratory distress syndrome, and increase morbidity from infection (Soll, 2008; Knobel, 2007).

Unfortunately, hypothermia (temperature $<36.5^{\circ}\text{C}$) remains a common finding in premature neonates following delivery, resuscitation, stabilisation and admission to the neonatal intensive care unit (NICU). During this period, body temperature is highly dependent on the environmental temperature and its surroundings. Predisposing factors for hypothermia, especially in the premature infant, include a large surface area to body mass ratio, wet at birth, skin immaturity, and prematurity. Evaporation, convection, conduction and radiation all participate in the frequently rapid fall in body temperature. Heat loss is the greatest in the first few minutes of life as infants are born wet into a relatively cool environment when compared to the uterus (Cramer et al., 2005; Soll, 2008). Given that the Townsville Hospital neonatal unit is set in a regional, tropical area that includes a high proportion of Indigenous Australians prone to preterm birth, and as preterm and low birth weight are more likely in rural and regional areas than in urban environments (AIHW, 2010), the need for an intervention to help improve admission temperature to the NICU and decrease heat loss at birth was considered important.

The measurement of temperature is also an important part of the care of the neonate admitted to the NICU. Accurate temperature assessment enables early intervention

and/or treatment as a change in body temperature can indicate the presence of infection or disorders of the thermoregulatory system. The necessity for regular observations such as temperature measurement does however require prolonged handling and disturbance. Finding ways to reduce the need to disturb the preterm neonate are essential.

Study 1: In an attempt to decrease hypothermia at birth and on admission to the NICU the use of the plastic wrap in infants less than 30 weeks gestation was trialled. A randomised controlled trial was conducted. The study enrolled 92 infants < 30 weeks gestation. Randomisation concealment was by the use of sealed opaque envelopes. The infants' temperatures were assessed for two hours following admission to the NICU.

Study 2: In order to try to reduce handling time in the neonatal population a study was conducted to assess the concordance of two alternative thermometers to the BD Digital thermometer, currently the thermometer of choice at The Townsville Hospital.

Results study 1: The results of the study indicate an increase in admission temperature between intervention and control group (36.26°C versus 35.79°C), confirming that the application of the plastic wrap at birth increases admission temperature in infants born less than 30 weeks gestation.

Results study 2: This study found that the BD digital and the SureTemp®Plus model 692 measurements showed moderately good agreement. The results confirm that the SureTemp®Plus model 692 thermometers can be used safely instead of the BD digital thermometer in term and preterm neonates.

Non-thesis components of degree

During the course of the degree a number of coursework requirements were completed. These subjects included literature review and research statistics subjects. In addition, a number of teaching and learning modules were developed on areas of neonatal specialist content. The four distance learning modules, currently in use at James Cook University and The College of Nursing, were written as part of the Doctoral Specialisation subjects (1 & 2) (see Appendix VIII and VIII for an overview of the subjects). These

subjects will be used to enhance the knowledge and skills of neonatal nurses, especially when hypothermia and hyperthermia are evident. Education opportunities for nurses working in specialised areas, such as the NICU, is important to ensure evidence based care is delivered in the area.

Other work that contributes towards this portfolio is also included. During the course of the professional doctorate I gave five conference presentations and three local seminars, and presented four conference posters related to the neonatal specialty area. Copies of some of this work are also included in the Appendices.

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CHAPTER 1: INTRODUCTION TO THERMOREGULATION IN THE TERM AND PRETERM NEONATE

Introduction

Premature infants, although born too soon, are not necessarily 'ill'. The immature systems and organs of the preterm neonate require support to survive outside the womb and to overcome the related problems. These problems can involve: the lungs (unable to sustain their own respiratory function), immune system (susceptible to infections), the liver (a high percentage of premature infants become jaundiced), gastrointestinal system (unable to tolerate feeds and have prolonged periods of nothing by mouth), eyes (risk of retinopathy of prematurity), and the brain (immature vessels which are very fragile and are at risk from intraventricular haemorrhages and apnoea resulting from an immature central nervous system). Full term infants on the other hand encounter a different set of challenges ranging from birth asphyxia (a lack of oxygen during delivery), congenital abnormalities (this can include heart, brain, gastrointestinal, limbs and spine), birth trauma (injuries from birth, although very rare), jaundice, infection, and low birth weight. One of the main problems facing sick term and preterm infants is thermoregulation; or the need to keep the body warm.

Figure 1: Note the premature skin in a 26-week gestational infant



As the term and preterm neonate may be incapable of thermoregulation, this presents a challenge to the carer who is charged with the responsibility of ensuring the neonate's temperature is maintained within a range conducive with life.

The process of maintaining a constant body temperature for these neonates involves many processes and procedures. For example, it is essential for the nurse or other health care team members to ensure the neonate is kept at a constant and suitable environmental temperature, the neonate's core body temperature is measured accurately and regularly, and that illnesses or factors that have the potential to impact on temperature regulation are managed. As an experienced neonatal intensive care specialist, I have vast experience in the management of term and preterm neonates' temperature. It has been my experience in this area that led to my interest in the issue of thermoregulation, which resulted in the research projects and activities reported in this thesis.

This chapter provides an overview of the research and projects undertaken as components of the Doctor of Nursing Science degree. It addresses human thermoregulation in general, and describes how the body adjusts to changes to environmental temperature; it also describes the principles of thermoregulation of the foetus in utero and how the foetus prepares for birth; outlines the coping mechanisms necessary for the transition to extra uterine life; explains the challenges the newborn faces as it attempts to maintain a normal body temperature; and, provides an overview of the detrimental effects of hypothermia on the premature infant. Further information is included to explain the specific importance of thermoregulation to preterm neonates such as the reasons this population are more prone to the effects of hypothermia.

To enable the neonatal nurse to comprehend the complexities of thermoregulation in the neonate the nurse must be able to understand the anatomy and physiology of the neonate and the complexities that hyperthermia and hypothermia can cause in the preterm and term infant.

Thermoregulation in humans

Humans are homoeothermic or capable of regulating their core temperature within a narrow limit (Nadel, 2003). Control of body temperature is achieved by a complex

system via negative feedback, which includes an important balance between heat loss and heat gain.

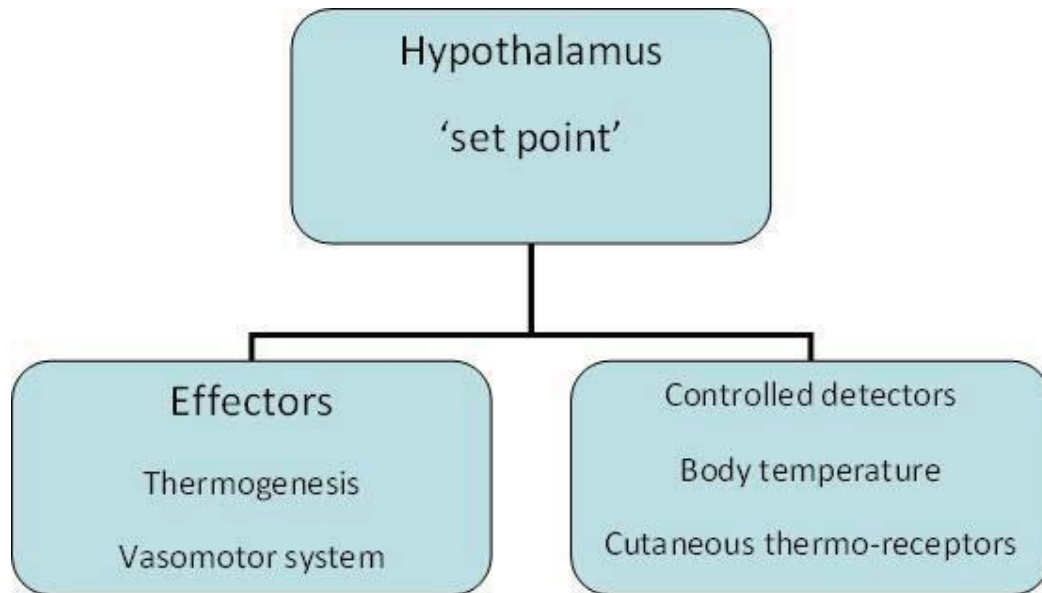


Figure 2: Schematic diagram of the thermoregulatory system (Okken, 1995, p. 221)

The temperature regulation centre in the human hypothalamus is responsive to the temperature of circulating blood via receptors that pass through the brain (core temperature). The hypothalamus also controls the body temperature through the autonomic nerve stimulation of the sweat glands when body temperature rises (external temperature). Both of these responses are needed to enable the body to adjust its core temperature (see Figure 1). The management of body temperature via this response system is very important as large elevations in body temperature can cause nerve malfunction, protein denaturation, and interfere with the brain's ability to control body temperature (Vander, Sherman, & Luciano, 2001). Alternatively, severe hypothermia is problematic as it can cause the heart rate to slow down (Mercer, 2001).

The body uses three responses to process thermoregulatory information: afferent sensing, central regulation, and efferent responses. A stimulus is received and a response is initiated to a change in temperature by neurons that have thermo-sensitive receptors present in the skin, deep tissues, spinal cord and brain (Widmaier, Raff & Strong, 2005). The

afferent input from these changes (neurons) is processed in the brain and the appropriate efferent response is initiated. Depending on the response needed, the body will shiver, sweat, or provide active cutaneous vasodilation; that is, one of the three major autonomic responses against an increase or decrease in temperature is initiated (Kurz, 2008).

Temperature regulation In Utero: Getting Ready For Birth

Foetus' develop and grow within the uterus under aerobic metabolism (Bissinger & Annibale, 2010). Whilst in utero, the foetus does not have to thermoregulate as it relies on the mother for regulation of any increase or decrease in temperature. Thus, this makes the foetus entirely dependent on the mother for temperature regulation. As a result, foetal mechanisms for cold or heat stress response are not active in-utero (as the mother constitutes a massive heat reservoir). The foetus is unable to dissipate any heat except through the mother and this transfer maintains the foetal temperature at a steady rate of only 0.5°C greater than maternal temperature and the foetus' peripheral and core temperatures are almost exactly the same (Gunn & Gluckman, 1989). Amniotic fluid surrounding the foetus is ~ 0.3°C lower than foetal temperature, which confirms that the uterus is a conduit for heat loss from the foetus to the uterine wall (Laburn, 2001). To achieve a steady thermal state in the foetus there has to be a positive feto-maternal temperature gradient to ensure heat is transferred away from the foetus (Laburn, 2001). In contrast to the newborn, the foetus cannot produce extra heat because the foetus is exposed in utero to inhibitors of non-shivering thermogenesis (Asakura, 2004). These inhibitors are produced in the placenta and enter the foetal circulation. The two most important inhibitors passed via the placenta to the foetus are adenosine and prostaglandin E₂; both strong anti lipolysis. The inhibitors play an important role in the metabolic adaptation of a physiological hypoxic foetus because non-shivering thermogenesis (NST) requires adequate oxygenation. Furthermore, the presence of NST inhibitors allows the foetus to accumulate an adequate amount of brown adipose tissue before birth.

The usual method of estimating foetal heat production is based on oxygen consumption. Generally it is assumed that about five calories of heat are produced for each millilitre of oxygen used. For example, a three-kilogram foetal lamb or human consuming eight ml of oxygen/minute per kg is thought to produce 120 calories/minute, or about nine watts (Brown & Landers, 2011). Therefore, the rate of oxygen consumed/heat production is altered in response to changes in oxygen supply to the foetus. Foetal tissues in utero are metabolically active and foetal sheep have been estimated to produce heat at about twice the rate of an adult (Mostyn, Pearce, Stephenson & Symonds, 2004). Because the foetus can vary its metabolic rate to match oxygen availability, the term '*adaptive hypo metabolism*' is used. This has been shown to be a prominent defence against hypoxia and anoxia in some animal studies (Bennet et al., 2007). No researcher to date has been able to define the mechanisms by which adaptive hypo metabolism works in the newborn, but Bristow et al. (1983) state that the liver may play a lead role, as when the foetus or newborn becomes hypoxic the liver decreases its need for oxygen. Furthermore, because the liver is also very active in protein synthesis, which is an oxygen costly process, protein synthesis may also be temporarily be suspended when the neonate becomes hypoxic.



Figure 3: Safe and warm in the womb

<http://www.thehindu.com/todays-paper/tp-features/tp-sundaymagazine/article499184.ece>

The primary route of thermoregulation to the foetus, as discussed above, mainly occurs across the umbilical circulation. The thin membrane barrier, large surface area and vascular bed (rate of blood flow) permit sufficient heat exchange via the placenta. The amount of heat radiated from the placenta and uterine vascular bed, depends on blood flow and the heat of the blood (Blackburn, 2003). As the foetus relies on the placental blood flow for thermoregulation, blood flow reduced during contractions may lead to heat transfer impairment, causing an increase in foetal temperature. It is worth noting that when a pregnant woman becomes febrile an increase in blood flow to the skin readily evaporates heat. When this happens, blood flow to other organs such as the kidneys, intestine and uterus is decreased. This can have a detrimental effect on the foetus as blood flow has been reduced which can result in foetal hypoxia and acidosis (Blackburn, 2003). Such findings can cause deleterious effects on the unborn foetus. Another episode, which can have a deleterious effect on the foetus, is placental abruption, which endangers maternal life and foetal life. In this situation, blood flow to the foetus is severed and there is no way the foetus can dissipate heat, which in turn has a potential impact on the brain, skeletal and other anatomic structures (Asakura, 2004). This was confirmed by a study undertaken by Asakura (2004), who found that the skin temperature of human new-borns shortly after birth was relatively higher if the umbilical cord was coiled; concluding that the foetal temperature rapidly changes in response to a disturbance in umbilical blood flow because heat accumulates within the foetus.

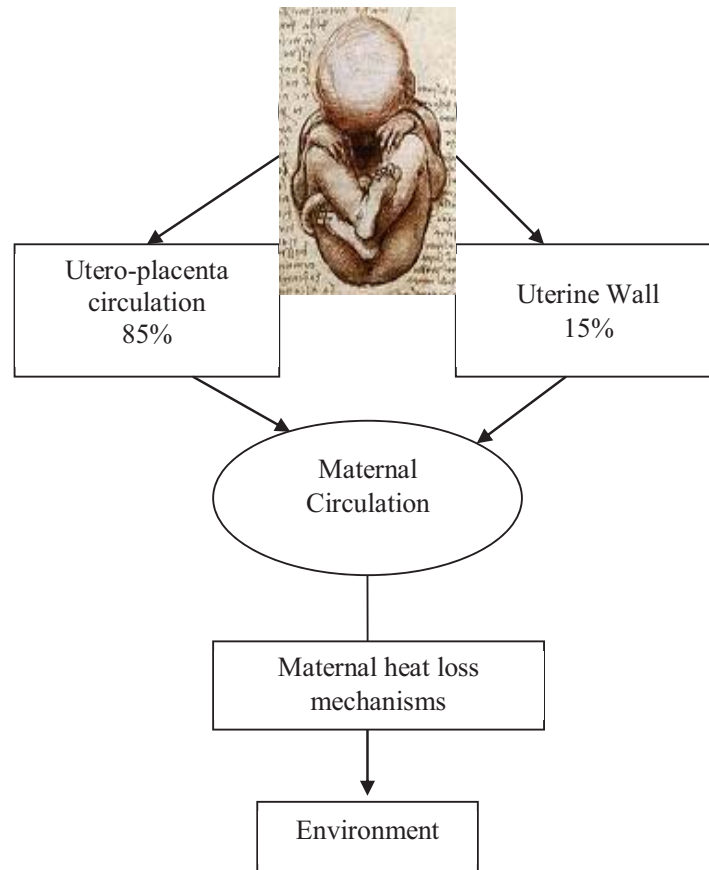


Figure 4: Pathways of heat loss from the foetus

Birth

Regulation of body temperature depends on vasomotor and sudomotor (sweating) activity. When an infant is born, in order to maintain its deep body core temperature they go through discrete physiological and behavioural responses. These are initiated by hypothalamic and cutaneous temperature receptors (Rutter, 2005). Vasodilation is a quick response to an increase in environmental temperature, which increases blood flow from the warmer body core to the peripherals helping to dissipate heat as a way of cooling the body. The opposite process is vasoconstriction; this reduces the skin blood flow and reduces any loss of heat.

The full-term, healthy newborn infant is faced with a dramatic drop in temperature when born; this change triggers heat production. When the infant is dried, wrapped in warm towels and then placed skin-to-skin with the mother, he or she will be able to maintain his

or her skin temperature. However, if left naked with no covering, heat loss will exceed heat production, and the infant will be at risk of hypothermia (Charpack et al., 2005; Knobel, Vohar, & Lehman, 2005).

Immediately after birth, body temperature can drop between 1°C - 3°C (Laburn, 2001); usually the greatest drop occurs in the first few minutes after birth but can last for several hours. If adults were submitted to the same rapid fall in temperature it would be life threatening. However, newborn infants are very resilient and apparently do not usually suffer any side effects to this sudden drop in temperature (Fellows, 2011).

In preterm infants however the risk of cold stress is greater. This occurrence is largely due to insufficient brown fat which can lead to poor heat production, increased surface area to body ratio which can also lead to heat loss, the inability to change posture due to the immaturity of musculoskeletal system, and immature skin that is poorly keratinized leading to large heat and moisture loss (Knobel, & Holditch-Davis 2007).

What constitutes normal temperature in preterm and term infants is still unclear resulting in a wide range of temperatures being accepted as normal. For this research we have used the World Health Organization (WHO) guidelines (1997) for temperature range, which is between 36.5°C and 37.5°C. Hypothermia is considered as a temperature >36.5°C, mild hypothermia is a temperature between 36°C – 36.5°C, moderate hypothermia is classed as a temperature between 32°C - 36°, and severe hypothermia <32°C. Hyperthermia will be classed as any temperature >37.5°C. Premature neonates have an immature thermoregulatory system; they need help with temperature control from the moment of birth, especially if <1kg (Lyon & Freer, 2011). Some heat loss after delivery may be an important stimulus for metabolic adaption but it is important to avoid a continuous drop in body temperature proven to be detrimental to premature infants (Soll, 2008).

Hypothermia (temperature $<36.5^{\circ}\text{C}$) is a common finding in premature infants following delivery, resuscitation and stabilization in the neonatal intensive care unit (NICU). During this period body temperature is highly dependent on the environmental temperature. Evaporative water losses in preterm infants are also a major problem during the first few minutes of life. Predisposing factors include a large surface area to mass ratio, being wet at birth and skin immaturity. Evaporation, convection, conduction and radiation all play a role in the frequently rapid fall in body temperature.

Prevention of hypothermia is thus one of the basic tenets of good neonatal care. Cold stress in neonates was first documented in 1907 (Budin, 1907) but it was not until 1958 that Silverman et al. (1958) demonstrated the association between higher environmental temperatures and decreased mortality. Hypothermia can cause complications such as an increase in oxygen requirements, difficult resuscitation, increase incidence of disseminated intravascular coagulation, increased glucose utilisation, post delivery acidosis, delayed adjustment from foetal to newborn circulation, worsening respiratory distress syndrome, necrotising enterocolitis, and increase morbidity from infection (Soll, 2008; Knobel, 2007) (see Figure 3).

Thermoregulatory mechanisms are also immature in preterm infants. Premature infants have limited subcutaneous fats and glycogen, particularly brown fat stores. Brown fat is laid down between 26-28 weeks gestation (Kumar, et al., 2009; Carter, 2008) and is used by infants to produce heat by non-shivering thermogenesis. Brown fats stores diminish quickly during cold stress.

Conventional practice is to dry the newborn infant and place the infant under a radiant heater immediately after birth (McCall et al., 2010). Although this is an effective way of maintaining temperature in term infants, hypothermia remains a common problem in preterm infants. In 2003, infants born at the Townsville Hospital at less than 30 weeks gestation had a mean temperature on admission to the NICU of 36.1°C , with 66% of infants having an admission temperature of $< 36.5^{\circ}\text{C}$. According to Knobel, Wimmer and Holber

(2005), approximately 66% to 93% of extremely low birth weight infants (ELBW) are admitted to the neonatal intensive care units with hypothermia. A neonatal unit is a special area in a hospital dedicated to the care of sick term and preterm newborn's. Neonatal intensive care units (NICU) usually include a number of units dedicated to the specialist care of premature infants from 24 weeks gestation as well as sick term infants requiring special but not intensive care due to a range of conditions. Infants can be admitted to the NICU via a number of avenues including: birth suite, theatre, emergency department, and outlying hospitals. In most cases, infants admitted to a neonatal unit are classed as ill or premature.

A number of strategies have been developed in an attempt to manage hypothermia in preterm neonates. Baum and Scopes (1968) tested an aluminium lined 'silver swaddler' and found this effective for infants with birth weight > 3000grms, but as the material is opaque it was impractical during any resuscitation. Bell, Weinstein and Oh (1980), and Le Blanc (1991), compared the effects of convectively heated incubators and radiant warmers with artificial skins and body hoods. No significant differences were found in any of the studies. Single layer gowns were used (Hobbs, et al., 1975) as was bubble wrap (Besch, 1971), and both approaches were found to be effective in preventing heat loss, but only in healthy full term infants. These studies were the catalyst for numerous other studies undertaken to improve NICU admission temperatures in premature infants.

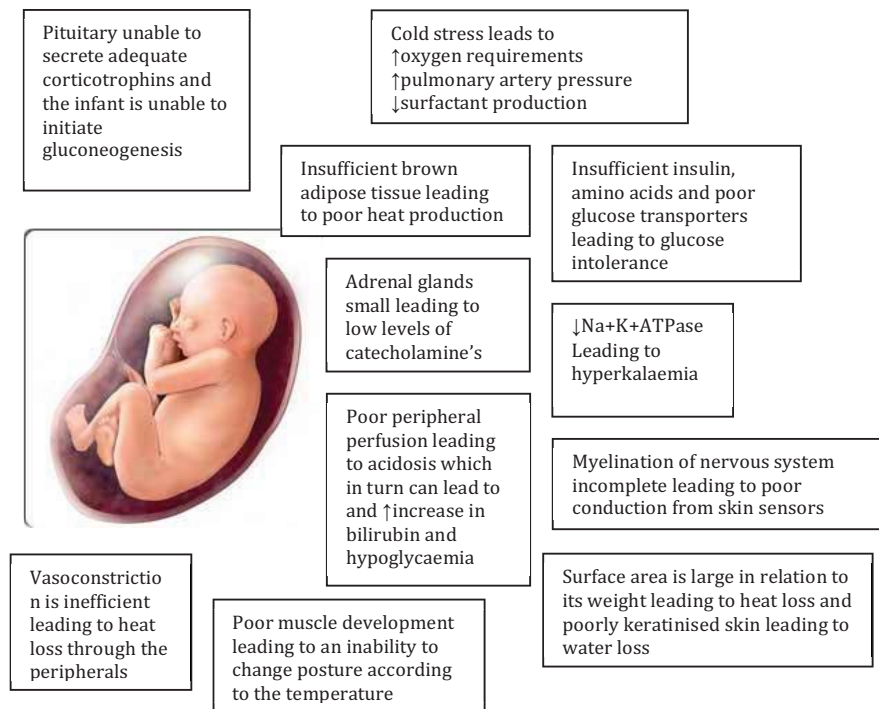


Figure 5: Thermal problems facing vulnerable infants (Fellows, 2011, p.102)

Heat Production

Newborn infants function as endothermic homeotherms, which mean they are capable of maintaining their own body temperature by using a process of internal heat production. As stated above, newborn's can suffer large amounts of heat loss per unit of surface area due to passive heat transfer from the infant's large surface area in relation to their weight ratio and poor insulation (Laburn, 2001). Poor insulation can either be internal or external. Internal insulation includes body tissues that separate the body core (internal organs) from the skin surface (peripherals); including the skin, musculoskeletal structures, and subcutaneous body tissues and more importantly fat, as fat is highly effective insulating material. Thermogenic response begins immediately after birth, and involves two processes: NST and increased metabolic rate (Asakura, 2004). In order to ensure equilibrium between heat loss and heat gain the infant has a high metabolic rate in the first

few days after birth; approximately twice that per kilogram body mass of an adult in resting conditions (Laburn, 2001).

After birth, thermogenesis is initiated which involves cutaneous cooling, oxygenation and separation from the placenta. Separation from the placenta is the pivot that initiates NST (Gunn & Gluckman, 1989) (see Figure 3). To ensure thermogenesis occurs, brown adipose tissue (BAT) is needed. This can be identified as early as 25 weeks gestation (Carter, 2008). Brown fat constitutes approximately 1.4% of the body mass of newborn infant greater than 2kg of body weight. BAT differs morphologically and metabolically from ordinary white adipose tissue; it contains numerous fat vacuoles, stored triglycerides and the presence of abundant sympathetic innervations and blood supply (Cannon & Nedergaard, 2004). Classical NST is entirely BAT dependent (Cannon & Nedergaard, 2004). In particular, BAT is found around the intrascapular region, kidneys and mediastinum (see Figure 4) (Carter & Schucany, 2008), which elevates temperature.

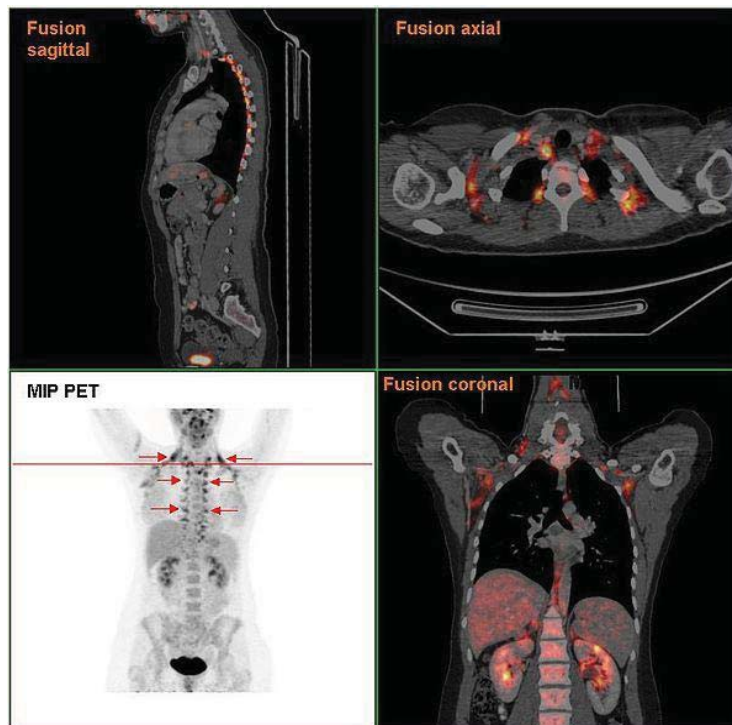


Figure 6: FDG PET/CT: brown fat is highlighted as the patient is cold at the exam November 2010, http://en.wikipedia.org/wiki/File:Brownfat_PETCT.jpg

A signal transmitted via the sympathetic nervous system to the individual brown adipocytes, causes norepinephrine to be released which initiates triglyceride breakdown in the brown adipocytes, mainly by β_3 adrenergic receptor (enhances lipolysis in adipose tissue) (Cannon & Nedergaard, 2004). Triglycerides of free fatty acids (FFA) are released and these are both acute substrates for thermogenesis.

Thermogenin is called the uncoupling protein, which is known as UCP1. It is found in the mitochondria of BAT. By uncoupling ATP synthesis from the oxidative process, heat is produced (Asakura, 2004; Okken & Koch, 1995). BAT uses a large amount of glucose per gram of tissue, therefore, even though brown fat constitutes approximately 1.4% of the body mass of infants who weigh more than 2Kg (Carter, 2008), it can utilise glucose very quickly. According to Cannon and Nedergaard (2004), glucose uptake is stimulated in two opposite body states; during active thermogenesis (stimulated by norepinephrine), and during active anabolic process (stimulated by insulin). In addition to triglycerides and glucose, oxygen is also required for thermogenesis. Again, only a small amount of BAT is laid down in utero, but during peak thermogenesis it practically consumes all of the body's oxygen in the body. Therefore, the premature infant who is cold will use a high percentage of its oxygen (premature infants are usually respiratory compromised at birth needing help with respiratory problems and will have an oxygen requirement soon after birth) as the oxygen will be transferred to BAT to help generate heat (Cannon & Nedergaard, 2004). This inevitably causes a significant increase in metabolic rate and with continued cold stress occurs, the brown fat stores will diminish resulting in hypoglycaemia and hypoxia. This in turn can result in an accumulation of lactic acid causing the cardiovascular system to work harder to compensate for the loss in cardiac output, which results in the infant becoming acidotic (Carter, 2008).

Heat Losses and Transfer

All infants, when born, will lose heat during birth, stabilisation and resuscitation. Reducing heat loss during stabilisation and in the first few days after birth (especially if premature) has been associated with increased survival (Kumar, Shearer, Kumar & Darmstadt, 2009; Acolet et al, 2005; Costeloe, Hennessy, Gibson, Marlow & Wilkinson 2000). Transfer of heat between the environment and the infant occurs by conduction, evaporation, radiation and convection. The amount of heat loss from these four mechanisms can sometimes exceed the infant's metabolic production. This is especially the case where health professionals, unaware of these processes and their detrimental effect on the newborn, leave the infant in a cold environment (Fellows, 2011).

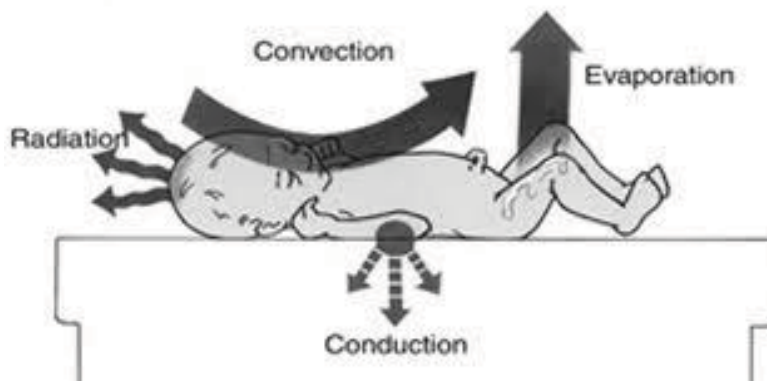


Figure 7: Conduction, Convection, Evaporation and Radiation, (WHO 1997, p.7)

Conduction is the transfer of heat between two solid objects that are in contact. It means that heat flows from the infant's body surface to other solid objects or surfaces and the greater the conductivity, the greater the heat flow. For example, if an infant is placed on an x-ray plate (metal = high conductivity), the infant will have a heat flow towards the cold solid object, and resulting heat loss could be substantial (Fellows, 2011). Loss by conduction can be minimised by the use of warm blankets, hats, pre-warmed incubators, radiant warmers and warm sheets for objects like x-ray plates.

Evaporation

Evaporation is insensible water loss from the skin surface. Heat loss via evaporation is a major route of heat loss as water is lost from the skin. Under normal conditions, in a term baby for example, evaporative heat loss amounts to about a quarter of the resting heat production. Term infants can cope with the initial evaporative losses encountered soon after birth as they have the ability to increase evaporative heat loss in response to a warm environment by sweating (Rutter, 2005). Premature infants however have a high evaporative heat loss when compared to term infants. The loss is due to high transepidermal water loss, which is up to six times higher per unit surface in a 26-week gestational infant than a term baby (Rutter, 2005). High loss is caused by a large body surface area to weight ratio and the infant's immaturity and poorly keratinised skin. Losses due to evaporation can be minimised by wrapping the preterm infant in a plastic wrap soon after birth and placing in a pre-heated humidified incubator.

Radiation

Heat decreases or increases by way of radiation energy and all body surfaces emit heat in the form of electromagnetic waves (Nadel, 2003; Vander et al., 2001). Up to sixty percent of heat can be lost this way. This is proportional to the difference between surface temperatures but independent of the temperature and speed of the intervening air (Rutter, 2005). More heat will be transferred if the surrounding surfaces are cold. Radiation loss can be minimised by ensuring infants are not placed near windows, doors or cold exterior walls.

Convection

Convection is the transfer of heat between a solid surface (the infant) and either air or liquid. Heat is lost due to air movement on the skin surface and heat lost is determined largely by the difference in temperature between the two (Fellows, 2011). Similarly, if the ambient temperature exceeds the surface temperature of the infant; heat will be gained by

convection. Protecting the infant from draughts and wrapping the infant will diminish heat loss from convection.

Hypothermia and Cold Stress

Hypothermia is a condition in which core temperature drops below the required temperature for normal metabolism and body functions, which is defined as below 35°C. If exposed to the cold and the internal mechanisms are unable to replenish the heat loss the heat that is being lost, a drop in core temperature will occur. Hypothermia in infants has been well documented (Vohara et al., 2004; Costeloe et al., 2000; Knobel et al., 2005). Studies undertaken in the 1950's and 1960's, where infants were deliberately left exposed to the cold, linked cold exposure to increased mortality (Buetow & Klein, 1964; Silverman et al., 1958). William Silverman (1958) conducted a series of randomised controlled trials, which showed that keeping infants warm in incubators resulted in a reduction in mortality by 25%. No other single change in practice has had such a dramatic effect on the mortality of the newborn. Despite its recognition, hypothermia remains a significant challenge to health care professionals.

There is general consensus that hypothermia should be avoided in all infants, with the possible exception of term infants suffering from hypoxic ischemic encephalopathy; these infants may need therapeutic cooling to help protect the brain from damage. The adverse effects of hypothermia, particularly in the premature infant, significantly increase the risk of death acidosis and morbidity from infection abnormal coagulation respiratory distress and a delay in foetal transition (Soll, 2008; Kumar, 2009).



Figure 8: One small step

Cold stress occurs when an infant loses more heat than they can produce. As mentioned previously, exposure to the cold can have a significant effect on single or all of the body systems (see Figure 9). A variety of physiological processes lead to mortality including an increase in oxygen consumption because of the energy demands of NST trying to generate heat (Cannon & Nedergaard, 2004). A fall in temperature can also lead to a fall in systemic arterial pressure, decreased plasma volume, decreased cardiac output and an increased in peripheral resistance (Blackburn, 2003). If the infant is mature enough, usually above 32 weeks gestation, there is a high probability that heat production will exceed heat loss and system homeostasis will be maintained; therefore the infant will not experience hypothermia.

Surfactant production also decreases when the infant is cold and its ability to act as a surface tension lowering agent is impaired if the temperature drops below 35°C (Brown & Landers, 2011), causing worsening atelectasis, which in turn will also cause hypoxia. Glucose is utilised by increased metabolism, leading to hypoglycaemia due to a rapid depletion in glycogen storage. This will worsen acidosis and reduce energy. Prolonged hypothermia can also have a detrimental effect on the gastrointestinal system whereby it can cause poor cardiac output and flow to the central nervous system, which in turn has an effect on the intestinal blood flow (reduced). This will cause ischemia to the gut predisposing the infant to a greater risk of necrotising Enterocolitis (Beresford & Boxwell, 2012; Soll, 2008). Hypothermia has also been associated with left ventricular failure, which will cause damage to the pulmonary capillaries, which causes fluid and cells to leak from the alveoli, which can lead to a pulmonary haemorrhage (Filseth, How, Kondratiev, Gamst & Tveita, 2010). As a consequence, if the infant is not re-warmed these conditions can lead to tissue damage, brain damage and ultimately death.

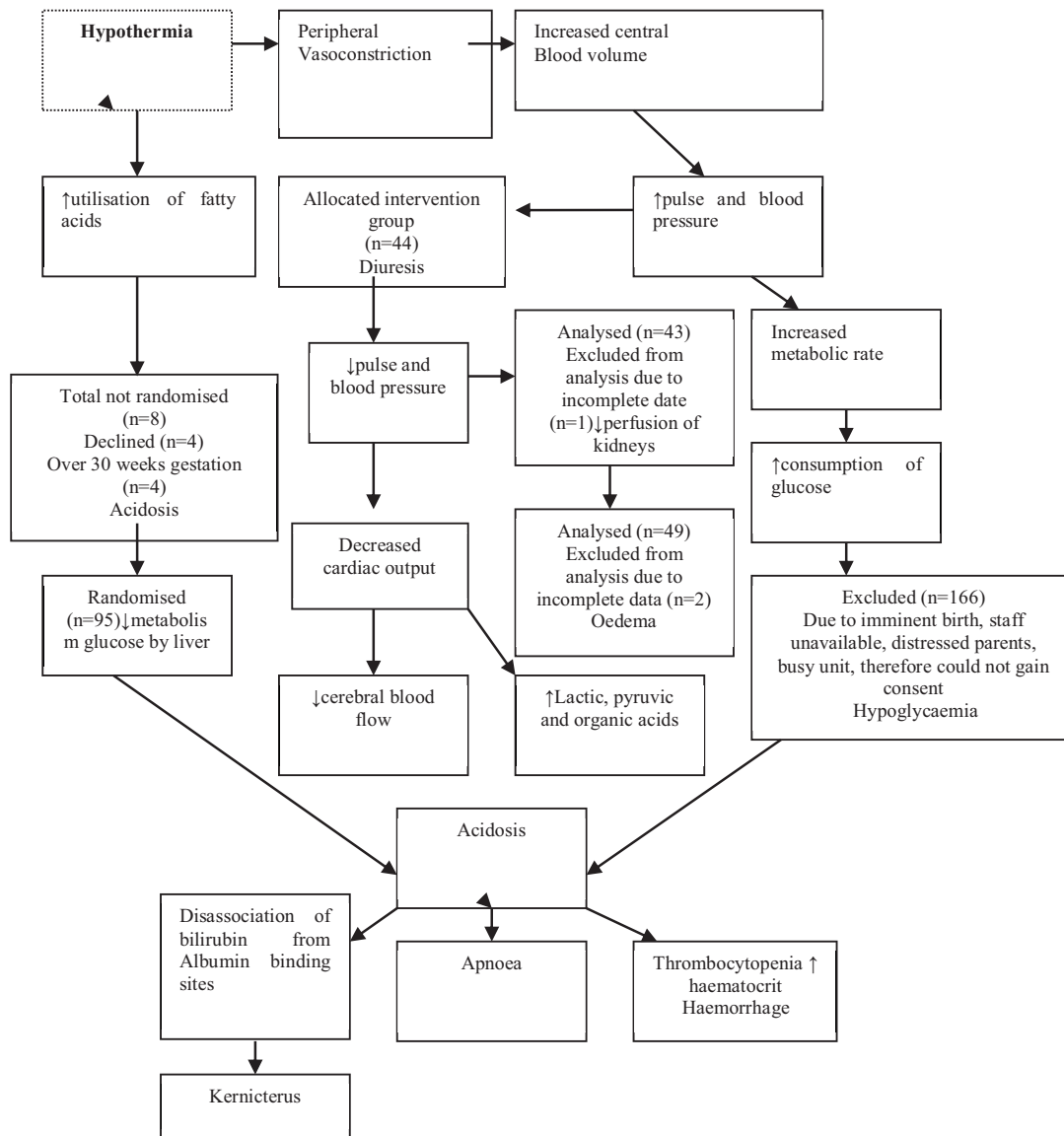


Figure 9: Effects of cold stress on neonates (Fellows, 2011, p.98)

Hyperthermia

An infant with a body temperature of $>37.5^{\circ}\text{C}$ is said to be hyperthermic (WHO, 1997). The premature infant is also at risk of becoming hyperthermic due to the immature thermoregulation system, large body surface area to weight ratio and immature, thin skin. If the environment is not closely monitored and the infant obtains too much heat they can become hyperthermic quite quickly. These infants also have the reduced ability to sweat and limited insulation (Bissinger & Annibale, 2010). Sweating can occur in term and late

preterm infants (35 weeks onwards), therefore they are able to raise their evaporative losses. However, maximal sweating rate is related to gestational age (Knobel, 2007).

Hypothalamic thermo-receptors sense an increase in body temperature, the body notices the temperature has surpassed the 'set body' temperature (hyperthermia), so sends out a signal to activate heat dissipation (Nadel, 2003). Vasodilation will occur as temperature increases; this will increase the rate of heat transfer to the environment. Premature infants have a limited ability to vaso-constrict, so it is highly probable that the premature infant may also have problems when trying to vasodilate when they become too warm (Horns, 2002; Bissinger & Annibale, 2010). However, hypotension can occur secondary to vasodilation and dehydration will follow as increase in insensible water loss (Blake & Murray, 2006). Hyperthermia can be attributed to infection, but according to Weisman, Stoll, Cruess, Merenstein, Heming & Fischer (1992), if the infant has early onset sepsis (within 48 hours of birth), temperature is likely to remain within normal limits for term infants but premature infants will most likely become hypothermic. Hyperthermia, in infants, is usually caused by inappropriate environmental situation (Fellows, 2011).

It is evident that thermoregulation is a vital part of neonatal care and it has the potential to have a significant influence on neonatal outcomes if not corrected in a timely manner. Thus it is clear that continued investigation is needed into the best practice for heat regulation and the need to evaluate the most appropriate ways to accurately measure and monitor temperature using available devices.

Achieving Temperature Stability and temperature measurement

Many methods have been utilised over the years in an attempt to achieve temperature stability in the preterm and term newborn. These have included the use of incubators, first designed by a zookeeper in Paris (Silverman, 1958), which showed that by maintaining premature infant's temperature reduced mortality. Premature infants can also suffer from high water losses (as well as heat loss), which was minimised with the use of

various types of heat shields. These were found to effectively reduce heat loss by radiation (Knobel et al., 2005, Simon et al., 2010).

To ensure a constant thermal environment was maintained the use of a thermistor probe placed on the infant's abdomen with set points according to gestational age and weight, this type of temperature monitoring is known as 'Servo Mode'. Air Mode is another type of heat control where the incubator temperature is set and the thermostat in the incubator reaches and maintains the set temperature (Lyon & Freer, 2011). Other measures useful in keeping infants warm include the application of hats, and the use of radiant warmers, heated mattresses, emollients, humidity and skin-to-skin contact. All of these strategies have been effective in maintaining and reducing heat loss in infants. While these interventions are available to aid in the management of a constant temperature/environment for the neonate, the maintenance of required temperature in preterm neonates remains a challenge. This is especially relevant to infants of less than 28 weeks gestation; becoming more common with advanced technologies to support life in younger neonates, for example gestational age 23 weeks and younger (Kumar, Shearer, Kumar, & Darmstadt, 2009; AIHW, 2010; Knobel, 2005; Costelo, Hennessy & Gibson, 2000). In an attempt to eliminate heat loss in premature infants a simple solution was originally tried in the 1970's; the use of a transparent baby bag placed over the infant. This simple strategy initially paved the way for longer controlled trials undertaken using the plastic bag and plastic wrap. These studies confirmed the use of the wrap or bag prevents rather than delays hypothermia (See Chapter four for further details).

As the maintenance of an appropriate temperature for the preterm neonate is pivotal to survival, accurate and effective temperature measurement approaches and devices are essential. Many different approaches and instruments have been used over the past fifty years. The mercury in glass thermometer was hailed as the best instrument, and measurement via the rectal route was considered the 'gold standard' until the early 1970's when complications were noticed (Frank & Brown, 1978). This paved the way for the

introduction of newer devices such as the digital, thermistor and infrared devices (see Chapter 2 for further details).

Overview of professional doctorate

As a neonatal nurse practitioner, my area of interest is neonates, especially those requiring specialised care. As a result, this portfolio is devoted to work that is of relevance to neonates, especially those who have required care in a neonatal intensive care unit (NICU)(see manuscripts included in Chapter 4 and conference and seminar outputs included in the Appendices. However, it was my particular interest in the necessity to maintain the temperature of the preterm neonate and the need for effective and accurate temperature measurement devices that fuelled the program of research contained in this portfolio. In the following chapters there are a number of embedded manuscripts that are either published or currently under review. The manuscript in Chapter two is a literature review undertaken to determine the current level of evidence on temperature measurement approaches and devices. Chapters three and four contain manuscripts that present the results of two research studies: one undertaken to evaluate the best position and method of measuring temperature in preterm neonates; the other undertaken to evaluate the effectiveness of the application of plastic wrap as a means to improve temperature on admission to NICU. A number of case studies of relevance to preterm neonates are presented in Chapter five. Chapter six provides a discussion of the findings from the two research projects and Chapter seven offers the limitations of the research projects and recommendations for education, practice and further research. In addition, the appendices include an overview of the work undertaken for the Doctoral Specialisation subjects of the Professional Doctorate: a summary of a subject written for the Neonatal Intensive Care course-Care of the '*High Risk*' Newborn and *Infant Feeding and Nutrition* -at James Cook University; and a summary of a course written for the College of Nursing, '*Nursing the High Risk Infant and Perinatal Nursing*'. Copies of conference presentations and School

seminars are also represented in the Appendix. Together, these components offer a significant contribution to the available evidence in this specialised area of practice.

Summary

This chapter provides an overview of the relevant information related to thermoregulation in the neonate, especially the issues faced by preterm or unwell term neonates. It also provided an outline of the purpose of the project and identified the content of each chapter of the thesis. The next chapter addresses the literature of relevance to the topic.

CHAPTER 2: TEMPERATURE MEASUREMENT IN THE PRETERM AND TERM NEONATE

Introduction

This chapter is based on the importance of temperature measurement in the neonate; especially the preterm neonate. Included in the chapter is a literature review manuscript accepted for publication. The aim of the manuscript was to review the current evidence relating to temperature measurement sites and appropriate measurement devices for the preterm neonate.

Publication 1: Temperature measurement in the preterm and term neonate: a review of the literature

Declaration and Contribution Table for Thesis Chapter 2

Declaration by candidate

The extent of candidate contribution to the following publication is as follows:

Thesis	Article	Publication Details	Author Contributions	Impact Factor/h Index
Chapter 2:	Temperature measurement in the preterm and term infant: a review of the literature	In press In: <i>Neonatal Network</i>	Author J.Smith (40%) G.Alcock (20%) A.Gardner (10%) K.Usher (30%)	H Index 4.00

Declaration by co-authors

The undersigned hereby certify that:

- The above declaration correctly reflects the extent of the candidate's contribution to the work and the extent of contribution of each co-author;
- They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least part of the publication in their field of expertise;
- They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
- There are no other authors of the publication according to these criteria;
- Potential conflicts of interest have been disclosed to (a) grant bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
- The original data are stored at the following location and will be held for at least five years from the date indicated below:

Location	School of Nursing, Midwifery & Nutrition
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Candidate signature		27 September 2012
K Usher		27 September 2012
G Alcock		27/9/12
A Gardner		Date

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Temperature measurement in the preterm and term neonate: a review of the literature --Manuscript Draft--

Manuscript Number:	11-T-79R3
Full Title:	Temperature measurement in the preterm and term neonate: a review of the literature
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Author Comments:	I have now revised the manuscript according to the Editors comments. Warmest regards Jackie

Questions

1. According to Lee et al (2011) and Duran et al (2009) measuring temperature via the axilla method is:
 - a. Painful
 - b. *Uncomfortable
 - c. Inaccurate
2. A seminal study by Mayfield (1984) concluded that:
 - a. *Axilla temperature was as reliable as rectal temperature
 - b. Axilla temperature was not as reliable as an rectal temperature
 - c. Axilla temperature is not recommended for use in neonates
3. The length of time it takes to obtain an axilla temperature can vary from:
 - a. > 5 minutes
 - b. < 2 minutes
 - c. *Up to 3 minutes
4. Brown and associates (2000) found that infrared and mercury in glass thermometer, used in the axilla:
 - a. Didn't correlate well
 - b. Was in agreement
 - c. *Correlated well
5. The WHO (1997) guidelines, define an ideal newborn temperature as:
 - a. 36.5°C – 37.5°C
 - b. *36.5°C – 37°C
 - c. 36°C – 37.5°C
6. For the purpose of this review hyperthermia was defined as a temperature greater than:
 - a. > 37°C
 - b. 37.3°C
 - c. *>37.5°C
5. Which of the following is not a concern about rectal temperature measurement:
 - a. Infection
 - b. Perforation
 - c. Time
 - d. *environment
7. According to Smiddy (1969) rectal temperatures can be different to the core temperature, they can be:
 - a. Lower
 - b. Higher
 - c. *Lower or higher
8. The introduction of this thermometer has helped pave the way for a more rapid response in axillary measurement:
 - a. Tympanic
 - b. *Digital
 - c. Mercury in glass
9. Duran et al (2009) and Lee et al (2011) showed that the use of IR temporal artery thermometry:
 - a. Is similar to tympanic measurement
 - b. Is similar to rectal measurement
 - c. *Is similar to axilla measurement

10. At present the most common route for temperature taking in a neonate is:
 - a. *Axilla
 - b. Tympanic
 - c. Temporal artery
11. The main disadvantage of axilla temperature taking in the neonate is:
 - a. Length of time it takes to obtain a reading
 - b. *Length of time the infant is Disturbed
 - c. Inaccuracy
12. BAT, when oxidised produces:
 - a. Phosphate bonds
 - b. *Heat
 - c. Glucose
13. Variations in gestational age and weight may have an effect on:
 - a. Accuracy
 - b. *Data analysis
 - c. Tympanic temperature taking
14. The 'gold standard' method of temperature measurement is usually considered as:
 - a. Axilla
 - b. *Rectal
 - c. Tympanic
 - d. IR
15. Which of the following is a reason why not to use the mouth as a site for temperature taking:
 - a. Poor compliance
 - b. Intubation
 - c. Nasal oxygen
 - d. *All of the above
16. Problems associated with the use of tympanic temperature taking in the neonate is:
 - a. Size of the ear canal
 - b. Size of the probe
 - c. Incorrect placement of the probe
 - d. *All of the above

Temperature measurement in the preterm and term neonate: a review of the literature

Abstract

The maintenance of a constant body temperature is important to all humans but even more so for newborn babies (neonates), especially those born pre-term. As accurate measurement of body temperature is an important component of thermoregulation management in the neonate, a review of the literature was undertaken to determine the most appropriate method and site of temperature measurement in both the preterm and term neonate. The available evidence indicates that the axilla remains the most common place for temperature measurement.

Key words: preterm neonate; term neonate; temperature; measurement; tympanic; rectal

Temperature measurement in the preterm and term neonate: a review of the literature

Introduction

The maintenance of constant body temperature is important to all humans but even more so for newborn babies (neonates), especially those born pre-term. Environmental regulation is essential for the neonate, as, unlike adults and older children, they have limited ability to regulate their own temperature. Furthermore, neonates are extremely sensitive to temperature changes associated with illnesses (Sahni & Schulze, 2004). Detection of temperature change enables early intervention as changes in body temperature may indicate the presence of infection and can impact physiologic responses that can include metabolic reactions, hypoglycaemia and hypoxia. Accurate measurement of body temperature is an important component of maintaining normal temperature in the neonate (Hissink Muller, van Berkel & Beaufort, 2008).

This review examines the literature associated with temperature measurement in the neonate. It aims to establish the most appropriate method and site of temperature measurement in both the preterm and term neonate.

Background

For the purpose of this review, hyperthermia was defined as any temperature greater than 37.5°C (WHO, 1997).

Measuring temperature in the neonate should be simple and as non-invasive as possible (Hissink Muller et al. 2008). In the past, temperature in neonates was measured via the axilla or rectum, using mercury in glass or digital thermometers. The rectal method using mercury glass thermometers or digital thermometers was generally considered the 'gold standard' (Bailey & Rose 2001; Martin & Kline 2004). Historically, a number of issues were raised about the use of glass thermometers (Smiddy & Benson, 1969; Frenah et al, 1981; Horwitz et al, 1976), which resulted in their replacement with newer devices.

Digital devices, which are placed in the axilla, remain a common option for use in neonatal units (Haddock et al, 1988; Rekha et al, 1993; Weiss & Richards, 1994a; Hicks, 1996; Leick-Rude & Bloom, 1998; Fallis & Christianni, 1999; Jirapet & Jiratpet, 2000; Smith, 2004). The main disadvantage of these devices is the time it takes to obtain an accurate reading: up to 3 minutes, depending on the device (Torrence, 1968; Haddock et al, 1988). More recently the thermistor device has been used for both axilla and tympanic measurement. It has been found to be a quick (within 10 seconds) and accurate way of measuring temperature in both the adult and paediatric population (Barber, 1989; Rosenthal & Leslie, 2000; WelchAllyn, 2007.). However, despite the introduction and use of, electronic, thermistor and infrared thermometers, their efficacy in preterm and term neonates has not been clearly established.

METHODS OF LITERATURE REVIEW

SEARCH STRATEGY

The data bases used for the review were CINHAL, MEDLINE, The Cochrane Library, PubMed and Ovid. The search spanned 26 years beginning with the 1984 report by Mayfield and colleagues. These authors compared axillary temperature measurement with core (deep rectal) temperature in 99 term infants and 24 preterm infants; this was considered a pivotal study in regard to this review.

KEYWORDS

The key search words used were: infant; neonate; axilla temperature; tympanic temperature; neonatal nursing; neonatal temperature; neonatal thermoregulation; electronic thermometer; digital thermometer; tympanic thermometer; preterm temperature.

INCLUSION/EXCLUSION CRITERIA

Papers were selected for the review that met the following criteria:

1. Research papers in peer reviewed journals, which included the neonatal population.
2. Papers published in English
3. Papers published between 1984 and 2011.

Papers that did not meet the above criteria were excluded from the review.

RESULTS

Fifty-two studies were identified. Twenty-one of these studies were not

included in the review as they focused only on the paediatric population. Of the thirty-two studies eligible for review, all included the axilla and/or tympanic body sites (see Table one). Although the axillary method is currently preferred in the neonate because of its safety and accuracy (Torrance, 1968; Haddock et al, 1988; Davis, 1993; Yetman, et al. 1993; Weiss, 1994; Sheeran, 1996; Brown et al, 2000; Bailey & Rose, 2001; Jirapet & Jirapet, 2000; Rosenthal & Leslie, 2006), there are other approaches in use, as well as a variety of devices being used to measure temperature in the neonate. Therefore, it was deemed necessary to review the current research related to the efficacy of approaches and devices for temperature measurement in neonates.

Routes used in Temperature Measurement in the neonate

In general, any site near a major artery is suitable for assessing body temperature (Smith,1998). Invasive techniques such as pulmonary artery temperature measurement (Lefrant et al, 2003) are impractical for use in neonates. In clinical practice, the most convenient sites for measuring temperature are sub-lingual, rectum axilla and ear canal. However, the mouth should not be used in the neonate or pediatric patient because of factors such as poor compliance, intubation, continuous positive airway pressure (CPAP) and the use of nasal oxygen; both the axilla and rectum are accepted sites for measuring temperature. The most commonly used site for monitoring temperature in the neonate is the skin. Incubators and radiant warmers are designed to work using a set skin temperature. Continuous monitoring of the abdomen skin temperature is non-invasive method that has shown good

correlation with rectal temperatures (Knobel & Holditch-Davis, 2007).

The axillary method of temperature measurement has been shown to correlate closely with rectal temperature (Smith 1998, Jirapet & Jirapet 2000, Brown et al. 2000, Bailey & Rose 2000, Sheeran 1996) it is also shown to be accurate, causes fewer disturbances to the neonate ease of access, and is considered a relatively safe option (Browne et al, 2000; American Academy of Pediatrics, 1988). However, axillary temperature measurement can be an issue in neonates causing stress related events such as desaturations or bradycardia as a result of over- handling. In a study by Roll, Horsch and Husing (2000), they looked at 21 infants and assessed whether infants tolerate axillary temperature measurement better than rectal. They found that mean heart rate increased, saturations decreased in 20% of infants and also shown a decrease in cerebral oxygenation.

The length of time it takes to obtain an accurate temperature reading via digital thermometer is not clearly defined in the literature, especially when so many different thermometers are now being used in the neonatal population. However, rapid response thermometers can now give a temperature reading in less than ten seconds.

Two recent studies, Lee et al. (2011) and Duran, et al. (2009), measured infant discomfort associated with temperature measurement by using a pain scale adapted for neonates. Both studies confirmed that temperature measurement via the axilla method increases discomfort levels. Lee et al (2011) studied a total of 34 infants and showed discomfort using the temporal

artery was 3(9%), compared with 14 (41%) after axillary temperature measurement. Duran et al (2009), using the premature infant pain profile (PIPP) concluded that the mean PIPP score of axillary temperature measurements were significantly higher than mid-forehead and temporal artery measurements. Therefore, temperature measure via the axilla site needs to be quick yet accurate.

In a seminal study on temperature measurement routes in the neonate, Mayfield (1984) studied premature and term neonates to determine the relationship between the accuracy of axillary temperatures and deep rectal temperature. They concluded that axillary temperature was as reliable as the rectal temperature when using glass/mercury thermometer. Interestingly, studies by Khan et al. (1990) and Haddock and colleagues (1988), identified rectal temperatures to be significantly different from axillary temperatures. They also reported that infants took from 2-11 minutes to reach their maximum axillary temperature while rectal temperatures took from 1-5 minutes when taken with a mercury in glass thermometer (electronic thermometers can produce an axilla temperature in less than ten seconds while others the digital thermometer can take up to three minutes if used in monitor mode).

The difference between rectal and axillary temperatures in the newborn may be influenced by the presence or absence of brown adipose fat (BAT). BAT is found within the neck, back, mediastinum, abdomen and axillae. Mayfield et al (1984) noted that premature infants took a shorter time to reach their axilla temperature when compared to the term infant. This could be attributed to the brown fat, which is in the axilla area, whereby it can generate heat. Dodman

(1987), concluded that the close proximity of the BAT could give a false high axilla temperature recording. The difference in a premature neonate's temperature could also be attributed to the environment in which they are cared for, mainly incubator care, which can sometimes involve up to 90% humidity (depending on the gestational age of the infant) where a constant temperature is set according to gestational age (Cusson et al, 1997; Leick-Rude & Bloom, 1998; Seguin et al, 1999).

The sensitivity of the axilla method is reported in some trials to be poor, between 27.8% to 33% (Haddock et al, 1996; Kresch, 1984). As study done by Morley et al (1992) also found that the axilla method has a sensitivity of 73%, with a post predictive value of 69% and a false negative rate of 27%. This does show that although some studies identified the axilla method as correlating well with other measurement devices, this may not be true with all thermometers.

Rectal Temperature

Many clinicians continue to consider rectal temperature measurement as the 'gold standard' because it closely approximates the neonate's core temperature and is not influenced by ambient temperature or age (Craig et al. 2000; Rutter 1992; Robertson 1996). Problems with the rectal approach include trauma to the rectum as well as the potential for infection secondary to perforation with subsequent sepsis haemorrhage and rectal temperature measurement is contraindicated if there is bowel disease especially necrotising enterocolitis, cool blood returning from the lower limbs. (Van den

Berg, 2000; Mackowiak, 2000), and trauma to the rectum (Frank & Brown, 1978; DeCurtis, et al, 2008). It has also been suggested that in a shocked state, e.g. overwhelming sepsis, perfusion of the rectum can be impaired, which may cause a lag in changes of core body temperature (Holtzclaw, 1993; Carrol, 2000; Mackowiak, 2000). It is also contraindicated in conditions such as thrombocytopenia due to the risk of perianal abscess and also the use of hypothermia during surgery (Holtzclaw, 1993). Frank and Brown (1978), discussed 2 cases of where infants suffered rectal perforation, which was probably caused by a thermometer. A further 26 cases of neonatal rectal perforation caused by thermometers was reported by Horwitz and Bennet, 1976, Lynch et al, (1983) and Tan et al, (1989).

Dodman (1987) questions the accuracy of rectal thermometry arguing that the core temperature decreases after the skin temperature drops, but Schuman (1993) claims that there is a good correlation between rectal and axillary temperature in neonates. As a result, it has been argued that rectal temperatures can be lower or higher than the core temperature. A more recent study conducted to determine the efficacy of the axilla and rectal method in neonates found a wide variation between the two methods with rectal temperature being the most reliable indicator of core body temperature (Hissink Muller, van Berkel & de Beaufort 2008). This study evaluated the difference between axillary temperature and rectal temperature measurement in neonates using a single brand of digital thermometer. The study enrolled 33 neonates with gestational age between 25 and 42 weeks. They concluded that axillary temperature was significantly lower than rectal temperature (mean \pm SD $0.27 \pm 0.20^{\circ}\text{C}$, $p < 0.05$). Variations in temperature could be

attributed to several factors, including operator technique, positioning of the thermometer in the axilla, measurements taken after a clinical procedure such as a chest x-ray, environment, and skin maturity.

Rectal temperature, because of the related problems, is not used regularly in the neonate, however in infants suffering from hypoxic ischaemic encephalopathy (HIE) whole body cooling and head cooling is administered. The core body temperature needs to be reduced to 34°C and it is necessary to reduce systemic temperature to that degree to achieve deep brain cooling (Van Leeuwe, 2000); this has been shown to prevent further neuronal loss. An important finding from therapeutic hypothermia is that cooling decreases mortality, without increasing major neurodevelopmental disability in survivors. A target core temperature of 33.5°C to 34.5°C is maintained for 72 hours. The goal during this phase is to avoid large fluctuations in the core temperature. To achieve this the use of the rectal core thermistor temperature probe is used with a skin temperature probe fixed to the abdomen (Dual temperature measurement). The core temperature is then measured continuously and avoids fluctuations (Chakkarapru & Thoresen, 2010).

Skin

Continuous monitoring of the abdominal skin temperature is a widely used and accepted practice in neonatal units. It is a non-invasive method and research has shown it correlates well with rectal temperatures (Knobel & Holditch-Davis, 2007). However more research is needed, as skin temperature and core temperature are different and servo-controlled

incubators act on changes in skin temperature not on core temperature (Brown & Landers, 2012). The incubator is set to the desired skin temperature and an insulated patch is placed over the thermistor, which then gives a continuous temperature read out. The incubator will adjust accordingly in response to signals from the thermistor attached to the skin (Blake & Murray, 2006).

Oesophageal

Oesophageal temperatures are considered central temperatures because of the large central vasculature and close proximity to the heart. Oesophageal temperatures are not used in the neonatal population and are mainly used in anaesthesia (Brown & Landers, 2012). When oesophageal temperatures are monitored it will measure the core temperature when placed in the lower third of the oesophagus (Mitchell, Brimacombe and Keller, 2003). It has been noted that neonates have minimal thermal insulation between the oesophagus and the tracheobronchial tree therefore temperature measurements may not be accurate (Holtzclaw, 1993; Fallis, 2002) when measured from this site.

Mode of measurement	Advantages	Disadvantages	Factors influencing measurement
Axillary	Safe Easily accessible Reasonably comfortable As accurate as rectal temperature Recommended as the standard (AAP) Cost effective Minimal cross	Can take longer to achieved depending on thermometer used Affects sweat evaporation which can cause temperature to be lower than core temperature	Environment Placement of thermometer Time of placement

	infection		
Rectal	Gold standard Closely approx. core temp Not affected by ambient temp Not limited by age	Time consuming Unhygienic Risk of perforation Risk of sepsis? Lags in core temperature change	Presence of faeces Local blood flow Bowel organisms Cool blood from lower extremities How deep the thermometer is inserted
Skin	Comfortable Steady and continuous Easy to use Automatic response to temperature changes	Fragile skin	Placemen of probe Humidity If probe is loose If probe is placed between body and mattress
Oesophageal	For surgical patients Central temperatures	Invasive Not practical for use	Minimal thermal insulation between oesophagus & tracheobronchial tree
Ear	Fast Easy to use Minimal cross infection Cost effective Tympanic membrane shares blood flow with hypothalamus via carotid artery	Large probe for premature infants Difficult to place the probe correctly Can record surface temperature Inaccuracies in the neonatal population	Different operating modes Operator technique Environment

Measurement Devices

Temperature measurement is a commonly used assessment tool, used when caring for the term and preterm infant. There are many different types of measurement devices, which are appearing frequently and are being utilised in neonatal units. These devices include mercury in glass, digital, electronic, chemical and infrared thermometers. The introduction of the digital thermometer has helped pave the way for a more rapid response in axillary measurement in the neonate. This means that many new measurement devices are being compared with other better known or more commonly used devices to ascertain their accuracy, reliability and speed of use (Uslu et al, 2011; De Curtis et al, 2008; Lee et al, 2011; Duran, Vataner & Acunas, 2009;

Hutton et al, 2009;, 2009; Duru, Akinbami & Orimadegun, 2012).

Mercury in glass and Digital Thermometers

Mercury in glass and digital thermometers has obviously been studied more frequently than other devices. The use of mercury in glass and digital thermometers when used in the axilla are said to be comparable (Browne et al, 2000). Leick, Rude and Bloom, (1998), confirmed that the digital thermometer used in the axilla had the highest correlation with mercury in glass. However Hissink Muller et al (2008) noted that the digital thermometer when used in the axilla and rectal site, the axilla temperatures were significantly lower than rectal temperatures. A more recent study by Uslu et al (2011) demonstrated, at the axilla site, using a digital thermometer and mercury in glass thermometer a good correlation. The mean difference was statistically significant, but not clinically significant.

Electronic Thermometer

Electronic thermometers have also been widely used and tested in the neonatal population (Weiss et al, 1991; Weiss et al, 1994b; Weiss et al, 1994a; Hicks et al, 1996; Cusson et al, 1997; Leick-Rude & Bloom, 1998; Fallis, 1999; Rosenthal et al, 1996). All authors agree that there was good correlation when compared to other devices, which included infrared, mercury in glass and digital. They supported the use of the electronic thermometer (SureTemp, FirsTemp and IVAC) in the neonatal population. All electronic thermometers are portable thermistor thermometers. The use of the SureTemp electronic thermometer (which can be used to take oral, axilla or

rectal temperatures) still needs to be assessed for accuracy in the neonatal population in the preterm and term neonate. However a study conducted by Rosenthal and Leslie (2006), comparing electronic, infrared and mercury in glass thermometers, found the SureTemp thermometer to be a reliable method for temperature measurement. In a sample size of 34 infants in a NICU setting the mean difference between the reading from the SureTemp and mercury in glass thermometer is 0.1, on average the SureTemp read 0.1 °C higher than the mercury in glass. Data from the WelchAllyn trial (2007) consisting of newborns from 1 hour old to 3 days old, showed the average error was 0.044°C with an SD of 0.199°C. Therefore, the SureTemp thermometer is quick (on average an axilla temperature could be reached in 10.2 seconds), accurate and easy to use.

Tympanic

The use and accuracy of tympanic thermometry in neonates is still unclear. The main problem is has been related to the size of the probe, which is thought to be too large for the small neonatal ear. If the probe is not placed in the ear canal, it is reported that it records surface temperature rather than tympanic. Davis (1993) who studied tympanic temperature measurement in children argued that because of the infrared signal, probe size does not affect accuracy. However other studies have found some differences when using the probe in very small ears (Yetman et al. 1992, Cusson et al. 1997, Leick-rude & Bloom 1998, Bailey & Rose 2001). In 2009, a smaller probe has been designed so more research could be carried out into the efficiency, accuracy

and reliability of tympanic thermometry in small infants using the smaller probes.

Tympanic thermometry is quick and would cause minimal disturbance. However, its use on sick and premature neonates is not yet validated. More research is needed into the use of the tympanic measuring device in preterm and term neonates.

Infrared Thermometers

Temporal artery thermometers, also known as Infrared thermometers (IR), have been recently introduced over the past ten years. None-contact IR thermometers use infrared technology to quickly and conveniently measure a surface temperature. You can obtain a fast temperature reading without touching the infant. IR thermometers are able to capture the invisible infrared energy (invisible heat) naturally omitted via radiation (El-Radhi et al, 2009). These devices reduce the need to handle the infant and therefore cause minimal disturbance. It is reputed to be quick, easy to use and causes no discomfort to the infant.

In a comparative study of 57 neonates (term and preterm), Brown and associates (2000) found that infrared axilla and glass/mercury thermometer correlated well. They concluded that both thermometers used in the axilla site showed a good correlation when compared with the standard rectal temperature measurement using a glass mercury thermometer.

There are very few published research trials on the use of IR thermometry,

especially in preterm infants and different environments. A study by De Curtis et al. (2008) compared rectal and IR skin temperature using the mercury in glass (rectal) and a No Touch sensor (No Touch Sensor Diagnostic, Chicco, Italy), placed 0.5cm from the skin on the forehead in 107 newborns, with gestational age between 25-41 weeks. The IR device tended to provide lower readings than the mercury thermometer. These authors concluded that IR skin measurement cannot act as a substitute for rectal measurement, but the difference between the two measurements was modest. However, there is no mention of the environments the infants were nursed in and whether the temperatures were affected by environmental conditions. Two further studies, Duran et al. (2009) and Lee et al. (2011), investigated temporal artery thermometry. Both studies found axilla and temporal artery temperatures were similar and advocated for the use of the thermometer in neonates. More research needs to be undertaken in larger trials in both preterm and term infants on the accuracy between axilla and IR skin temperatures in different environments.

LIMITATIONS OF THE CURRENT LITERATURE

Whilst reviewing the literature it became apparent that there were a number of methodological issues, which need to be taken into consideration before any conclusion can be made regarding final results. Some of these limitations are;

- The studies reviewed included samples of infants from a variety of settings, which showed a wide difference in gestational age and weight (Mayfield 1984, Khan 1990, Rekha 1993, Yetman 1993, Hicks 1996).

- Research to date has been primarily conducted on healthy neonates (Torrance 1968, Eoff 1974, Johnson et al 1991, Yetman et al 1993, Cusson 1997, Fallis 1999, Leick Rude and Bloom 1998, Seguin & Terry 1999, Bailey & Rose 2001, Rosenthal & Leslie 2006, Browne 2000, Smith 2004). Only one study investigated temperature measurement on un-well neonates (Moen et al 1987).
- Large differences in sample sizes, ranging from 34 to 300, and the inclusion of both preterm and term neonates (Weiss et al 1993, Brerstrom et al 2004), with few adequately powered studies.
- Different environmental factors such as open cots (Eoff et al 1974, Yetman 1993, Smith 2004), radiant warmers (Haddock et al 1998), and incubators were used in studies; some used all three (Mayfield et al 1984, Rekah et al 1993, Weiss & Richards 1994, Seguin & Terry 1999, Jirapet & Jirapet 2000, Bailey & Rose 2001, Browne et al 2000).

Future studies need to be rigorously designed with:

- Targeted population.
- Adequate sample size.
- Controlled environmental conditions.
- Defined procedures for temperature recording – site duration etc.
- Calibration of devices.
- Appropriate statistical analysis.
- Inclusion of healthy and sick premature and term neonates.

Discussion

At present, it seems the axilla method is the most common route to measure a neonate's temperature using digital and electronic thermometers. As new temperature measurement devices become available, research is needed to assess the different methods of temperature taking in the preterm, well term and sick term neonates. Consideration should be given to whether to use axilla; skin or infrared temperature monitoring and whatever is chosen must be used constantly as measurement error will be increased if the mode of temperature taking is not consistent, therefore nurses need to be aware of the various temperature taking methods and the factors influencing neonatal temperature readings. Consideration must also be given to the environment the infant is being nursed in, gestational age, weight and clinical condition of the infant.

Many new temperature devices are appearing on the market and it is evident from this review that agreement and reliability needs to be established before use in the neonatal population can be recommended.

Conclusion

It is important that research continues into the comparison and contrast of both new and old devices and methods and the choice of thermometer used in the neonatal population should be influenced by safety accuracy and the risk of cross infection.

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Table 1: Studies, Temperature taking in the Term and Preterm Infant

Study	Site	Apparatus	Key Findings	Limitations
Eoff et al (1974).	Axilla Rectal	Mercury in Glass Telethermo meter	Significant difference between axillary and rectal temperatures ($p < 0.01$). Axilla temperatures is recommended	Healthy infants Small sample size N=30 Open cot
Mayfield et al (1984)	Rectal Axilla Skin	Glass mercury thermometer	Close agreement between rectal and axillary temperatures	Wide gestational age and weight
Moen et al (1987)	Axilla Rectal	Glass mercury thermometer	Axillary measurement can be substituted for rectal measurement	Small sample size N=25 Preterm infants
Haddock et al (1988)	Axilla Rectal	Glass mercury thermometer	99% of preterm infants reached their optimum axillary temperature in 3 minutes. The difference between rectal and axilla showed a wider range than Mayfield et al (1984)	Small sample size N=30 Preterm infants
Bliss-Holtz (1989)	Rectal Axilla Inguinal	Glass mercury thermometer	At least 99% of the subjects reached temperature stabilisation by 5 and half minutes. It was found that the inguinal site temperatures are more reflective of rectal temperatures and may be less sensitive to the effects of BAT heat generation.	Term infants
Johnson et al (1991)	Axilla Rectal Tympanic	FirsTemp Glass mercury	No difference in temperature in the protected and unprotected ear. No significant differences in axillary readings between tympanic and mercury in glass	Tympanic thermometer underestimated in 2 modes and overestimated in 1 Wide gestational age and weight Health infants Small sample size N=31
Weiss et al (1991)	Axilla Rectal Tympanic	Thermoscan IVAC electronic	No significant difference between tympanic and axillary. Correlations between left and right ear moderate	May be variations in technique and/or ambient temperature Small sample size N=34
Hunter et al (1991)	Axilla	Glass mercury IVAC electronic	3 minute axillary temperature is a clinically appropriate length of time to measure newborn temperatures	Term infants Small sample size N=40
Yetman et al (1992)	Rectal Axilla Oral	Glass mercury Aural tympanic	Temperatures axillary and rectal were similar Tympanic thermometer in oral and rectal mode did not reflect rectal or axillary temperature	Wide gestational age and weight Study conducted on healthy infants Open cots only

Study	Site	Apparatus	Key Findings	Limitations
Rekha et al (1993)	Rectal Axilla	Not stated	Difference between rectal and axillary temperature was 0.3F. Correlation was good. Axillary temperature can be used as an alternative	Wide gestational age and weight Small sample size N=55
Weiss et al (1994)	Axilla Rectal Tympanic	IVAC electronic	No significant differences between tympanic and axillary temperatures. Right ear (exposed) best approximation of axillary measurement. Protected ear, (nearest the mattress) is best approximation of rectal temperature	Term infants Small sample size N=34
Weiss et al (1994b)	Axilla	IVAC electronic in P and M mode	Support axillary temperature measurement via the P mode.	
Hicks et al (1996)	Axilla Tympanic	FirsTemp Glass mercury	There was a difference of 1.2C between axillary and tympanic for the overall sample	Wide gestational age and weight Small sample size N=40
Cusson et al (1997)	Tympanic Inguinal Axillary	IVAC electronic FirsTemp	No significant differences right and left ear. Correlations between tympanic and rectal were weak. Significant interaction was found between site and environment. Tympanic should be used with caution in newborns.	Healthy term infants
Leick-Rude & Bloom (1998)	Axilla Tympanic Tempa-dot Digital	IVAC electronic BD Digital Tempa-dot Glass Mercury	The BD thermometer has the highest correlation with the mercury in glass. Skin temperatures were influenced by swaddling. Tympanic was inappropriate for hospitalized neonates.	Tympanic thermometer was awkward to handle and position. Infants objected to ear tug. Study conducted on infants only <1500g
Fallis (1999)	Axilla	IVAC Temp Plus in M and P modes	The P mode is reliable for axillary measurement	Healthy term infants
Seguin et al (1999)	Axilla Rectal	LighTouch Thermistor 400	Axillary temperatures via IR approximate rectal temperatures.	Healthy term infants Small sample size N=28
Browne et al (2000)	Axilla Tympanic	Glass Mercury LighTouch Genius	Glass mercury axilla correlated well with standard rectal glass mercury. The use of IR axillary thermometer is recommended	Study conducted on healthy term infants

Study	Site	Apparatus	Key Findings	Limitations
Jirapet et al (2000)	Tympanic Skin Axilla Rectal	FirsTemp Glass mercury Electronic	Mean axillary temperatures were the least different from the rectal. Tympanic temps in the rectal mode showed significantly higher mean temperatures than rectal temperatures. The protected ear has a significantly higher temperature than the exposed ear	
Sganga et al (2000)	Axilla Tympanic	Digital disposable Electronic Glass Mercury	Tympanic were the most "cost worthy" but lack of correlation with the glass mercury makes them a poor choice for newborns	Term newborns
Bailey et al (2001)	Tympanic Axillary	Glass Mercury FirsTemp	Statistically significant difference between tympanic and axilla, however the mean temperature differences are only small and not clinically significant. Temperature from the protected ear is higher in 82% of cases	Difficulty placing the probe in the ear Preterm infants Small sample size N=22
Bergstrum et al (2004)	Tympanic Rectal	Braun Thermoscan Digital	Correlation between tympanic and rectal is satisfactory	Healthy term infants
Smith et al (2004)	Groin Axilla Rectal	DataTherm Glass Mercury	Axilla site performed better than the groin skin site.	Healthy term infants Small sample size N=44 Open cots only
Rosenthal et al (2006)	Axilla	SureTemp Glass Mercury Light Touch IR	93% of readings by the SureTemp and 96% by the Light Touch thermometers were within 0.5C of the paired glass mercury readings demonstrating good positive correlation	
WelchAllyn (2007)	Axilla	SureTemp Axilla in P and M mode	Excellent correlation and not clinically significant Difference between 5 minute monitor mode and predicted axilla temperatures (average error was 0.044C)	Term newborns Small sample size N=20
Muller et al (2008)	Axilla Rectal	Digital thermometer	Axilla temperatures significantly lower than rectal temperatures. Mean difference of 0.27C, 95% limits of agreement, ranged from 0.13C to 0.67C.	Small sample size N=33
DeCurtis et al (2008)	Rectal IR Skin	Glass Mercury IR skin	The IR device provided lower readings than the mercury rectal thermometer, with the difference being negative in 61%	
Hutton et al (2009)	Axilla Rectal	Alaris Temp Plus SureTemp Tempa-Dot	Statistically significant temperature difference between axillary and rectal temperatures	Term infants Small sample size N=36

Study	Site	Apparatus	Key Findings	Limitations
Duran et al (2009)	Temporal Artery Axilla IR Skin	Glass Mercury PlusMed IR	No statistically significant difference was noted between the means of the mid forehead and axilla. Temporal artery thermometer was statistically higher than the forehead and axilla.	Preterm infants <1500g Small sample size N=34
Lee et al (2011)	Temporal Artery Axilla Rectal	Rectal probe IR TAT 500 SureTemp	Significant difference between temporal artery and axilla when compared to rectal temperatures ($p>0.01$)	Small sample size N=34
Uslu et al (2011)	Digital Rectal Tympanic Forehead	Digital Mercury IR	Tympanic, good correlation with mercury thermometer	
Duru et al (2012)	Rectal Tympanic	Mercury Braun	Good correlation between rectal and tympanic but sensitivity in the tympanic method was relatively low	Term infants Different wards

Limitations of the current literature

Whilst reviewing the literature it became apparent that there were a number of methodological issues with the studies reviewed, which need to be taken into consideration before any conclusion can be made regarding final results. Some of these limitations are:

- The studies reviewed included samples of infants from a variety of settings, which showed a wide difference in gestational age and weight (Mayfield, 1984; Khan, 1990; Johnson, 1991; Rekha, 1993; Yetman, 1993; Hicks, 1996).
- Research to date has been primarily conducted on healthy neonates (Torrance, 1968; Eoff, 1974; Schiffman, 1982; Kunnel et al., 1988; Bliss & Holtz, 1991; Johnson et al., 1991; Yetman et al., 1993; Cusson, 1997; Fallis, 1999; Leick Rude & Bloom, 1998; Seguin & Terry, 1999; Bailey & Rose, 2001; Brergstrom et al., 2004; Rosenthal & Leslie, 2006; Browne, 2000; Smith, 1998). Only one study investigated temperature measurement on sick neonates (Moen et al., 1987).
- Large differences in sample sizes, ranging from 34 to 300, and the inclusion of both preterm and term neonates (Weiss et al., 1994; Bergstrom et al., 2004), with few adequately powered studies, were noticed.
- Different environmental factors such as open cots (Eoff et al., 1974; Kunnel et al., 1988; Yetman et al., 1993; Smith, 2004), radiant warmers (Haddock et al., 1996), and incubators (Schiffman, 1982; Fleming et al., 1983) were used in reviewed studies; some contained all three environmental factors (Mayfield et al., 1984; Johnson et al., 1991; Rekah et al., 1993; Weiss & Richards, 1994; Seguin & Terry, 1999; Jirapet & Jirapet, 2000; Bailey & Rose, 2001; Brergstrom et al., 2004; Rosenthal & Leslie, 2006; Browne et al., 2000).

Future studies need to be rigorously designed with:

- Targeted population.
- Adequate sample size.
- Controlled environmental conditions.

- Defined procedures for temperature recording – site duration etc.
- Calibration of devices.
- Appropriate statistical analysis.
- Inclusion of healthy and sick premature and term neonates.

Discussion

There are numerous articles relating to temperature measurement and temperature site in the literature. Many articles that are relevant to this review go back to the 1980's but could still be relevant today in helping the clinician understand the concept of temperature measurement in the neonatal specialty. However, it was not possible to include all potential articles in this review.

Neonates, both term and preterm, have widely contrasting needs and any new clinical procedure adapted for use in this population, must take into account their physiological difference. Variations in gestational age and birth weight, may lead to differences in temperature recordings, which can affect data analysis. At present, the axilla is the most common route for measurement of both term and preterm neonate temperature. However, the temperature measurement device that is the quickest and most accurate remains unclear. As new temperature measurement devices become available further research is needed to assess the efficacy of the different methods in preterm and term neonates. Consideration must also be given to the environment in which the infant is nursed, gestational age, and the clinical condition of the infant.

Summary

There are a number of electronic and infrared temperature measurement devices available for use in the axilla, tympanic and temporal region. However, agreement about the effectiveness of the various types of thermometers in the neonatal population remains unclear; especially in regard to the use of tympanic and infrared no touch thermometers. However, it is important to establish the most effective and accurate devices and sites available for use with preterm and term neonates; especially those who are unwell. The

literature review indicates that the axilla method continues to be the site of choice for term and preterm neonates as concordance with rectal temperature has been observed. However, very little work has been done on the sensitivity and specificity of each method of temperature measurement making it difficult to identify any negative or positive results in relation to measuring temperature at the axilla, rectal, skin, IR and tympanic sites. Despite new developments in temperature measurement methods, the axilla approach continues to be the preferred method compared to the modern.

Nurses need to be aware of the various temperature measurement methods, devices and factors influencing neonatal temperature recordings. New thermometers should be rigorously tested for suitability in the neonatal population, whether preterm or term neonates, prior to introduction to practice. Evidence based practice is important and studies need to continue into the accuracy and reliability of different temperature measurement equipment and approaches.

Summary of manuscript

In summary, rectal temperature remains the ‘gold standard’ for temperature measurement in neonates. While there are a number of electronic and infrared devices available for use in the axilla, tympanic and temporal region, agreement about the effectiveness of the various types of thermometers in the neonatal population remains unclear; especially tympanic and infrared non-touch thermometers. It is clear, however, that the axillary method, which continues to be the site of choice for most neonatal units, offers concordance with rectal temperature measurements.

Chapter summary

This chapter has provided an overview of the relevant literature related to the different devices used and different methods for temperature measurement in the preterm and term neonate. Essentially, the chapter consists of a manuscript currently ‘in press’ with the *Neonatal Network* journal. The next chapter is the first of two chapters that outline research studies undertaken as part of the Professional Doctorate degree.

CHAPTER 3: CONCORDANCE OF TEMPERATURE MEASUREMENTS IN THE PRETERM AND TERM NEONATE USING THREE THERMOMETERS

Introduction

This chapter includes a study that has added to the body of knowledge about temperature measurement devices in the preterm and term infant. There are many different thermometers released every year; all claiming to be accurate, quick and effective. However, most clinical trials on new thermometer devices are undertaken on the adult or paediatric population. When taking into consideration which thermometer to use in the preterm and term infant, it is also important to consider the method to be used; axilla, tympanic, skin or rectal. This research study was undertaken to determine the most accurate, effective and easy to use device for temperature measurement with a vulnerable population.

Publication 2: Concordance of temperature measurements in the preterm and term neonates using three thermometers

Declaration by candidate

The extent of candidate contribution to the following publication is as follows:

Thesis	Article	Publication Details	Author Contributions	Impact Factor/h Index
Chapter 3:	Concordance of temperature measurements in the preterm and term neonate using three thermometers	Under review in: <i>Collegian</i>	Author J.Smith (40%) G.Alcock (20%) K.Usher (20%) P.Buettner (20%)	IF 0.898

Declaration by co-authors

The undersigned hereby certify that:

- The above declaration correctly reflects the extent of the candidate's contribution to the work and the extent of contribution of each co-author;
- They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least part of the publication in their field of expertise;
- They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
- There are no other authors of the publication according to these criteria;
- Potential conflicts of interest have been disclosed to (a) grant bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
- The original data are stored at the following location and will be held for at least five years from the date indicated below:

Location	School of Nursing, Midwifery & Nutrition
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P Buettner		27 September 2012

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Abstract: Background: Measuring temperature is an essential part of nursing care. It has been widely accepted as an indication of a patients' clinical condition. Often this enables early intervention and/or treatment as a change in body temperature can indicate the presence of infection or disorders of the thermoregulatory system.

Objective: The purpose to this study was to investigate agreement between the BD digital thermometer, the Genius 2™ tympanic thermometer and the SureTemp®Plus 692 thermometer.

Method: A comparative design was used to evaluate the level of agreement between each thermometer in preterm and term infants, ranging from 24 weeks gestation to post term.

Results: A total of 238 infants were enrolled in the study, 52 infants with less than 28 weeks gestation, 112 with 29 to 36 weeks, 69 infants with more than 36 weeks. In general, BD digital and SureTemp®Plus 692 measurements were in closer agreement than the BD digital and the Genius2™ tympanic thermometer. The mean difference between the BD digital and the SureTemp®Plus692 measurements was -0.185 (\pm 2SD: -0.561 to 0.91). The mean difference between the BD digital and Genius2™ was -0.368 (\pm 2SD: -1.078 to 0.342). The BD digital and SureTemp®Plsu692 showed a negative but non-significant ($r = -0.07$; $p = 0.273$) correlation between the differences and the averages of the measurements. The correlation of the differences and the averages of the BD digital and Genius2™ measurements was also negative and significant ($r = -0.53$; $p < 0.001$).

Conclusion: The results of the study suggested that the SureTemp®Plus 692 thermometer can be used as a reasonable alternative to the BD Digital thermometer in the neonatal population.

Concordance of temperature measurements in the preterm and term neonate using three thermometers

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Key words: Thermometer, Preterm, Term, Agreement

Introduction

One of the precepts of neonatal care, especially of preterm neonates, is the practice of minimal handling to reduce stress in this vulnerable population. The necessity for regular observations such as temperature measurement does however require prolonged handling and disturbance. In order to reduce handling time in preterm neonates this study was conducted to assess the concordance of two alternative thermometers to the “gold standard” Beckton Dickinson digital thermometer (BD). The BD thermometer usually takes more than one minute to record a temperature measurement. In contrast, the Genius 2™ tympanic thermometer and the WelchAllyn SureTemp®Plus 692 thermometers take both less than 10 seconds to obtain a reading. However, these latter thermometers are not current practice because there is insufficient data on their use on preterm and term infants.

The present study was undertaken in a neonatal unit in a regional hospital in Queensland, Australia, to investigate the agreement between the BD thermometer (which is currently the thermometer of choice on the unit at present), the Genius 2™ tympanic thermometer and the SureTemp®Plus 692.

Background and preliminary studies

Measuring body temperature is widely accepted as an important part of nursing assessment (Purcell, While & Coomber, 2009). Maintenance of a stable body temperature is especially important for the term and preterm neonate after leaving the warmth of the uterus where heat exchange is

regulated (Marshall, 1997). Temperature control plays a significant role in preterm neonate morbidity and mortality (WHO, 1997); these neonates are particularly vulnerable to thermal stress due to their inability to make the necessary physiological or behavioral adjustments to conserve or produce heat (Bailey & Rose, 2001).

The most convenient sites for measuring body temperature are the sublingual, rectum and axillary regions. However, while the mouth is not considered an acceptable site for temperature measurement in the neonate or paediatric patient, both the axilla and rectum are acceptable. On the other hand, invasive techniques such as pulmonary artery temperature measurement (Lefrant et al, 2003) are impractical for use in neonates.

Rectal temperature measurement has been supported as the “gold standard” approach to temperature measurement for neonates because of its close approximation to the neonate’s core temperature and is not influenced by the environment. (Craig et al, 2000; Rutter, 1992; Rennie & Robertson, 2001). However, rectal temperature measurement can be time consuming, unhygienic, and carries the risk of rectal perforation and infection (Frank & Brown, 1978). In addition, many factors adversely affect the efficacy of rectal temperature measurement such as the presence of faeces in the rectum, the placement of the thermometer, the presence of infection, the use of hypothermia during surgery, and local blood flow (Holtzclaw, 1993). It is also contraindicated if there is evidence of bowel disease, example NEC (van de Berg, 2000) and trauma to the rectum (De-Curtis et al, 2008).

The axillary method of temperature measurement is accurate, causes fewer disturbances to the neonate than the rectal method, and is considered a relatively safe alternative option (Brown et al, 2000; AAP, 1998). The length of time needed to record an accurate axillary temperature has been reported to cause stress related events such as desaturations or bradycardia in neonates, especially in preterm neonates (Roll, Horsch and Husing, 2000; Lee et al, 2011). In addition, the actual length of time required to stabilise a temperature reading via the axillary method seems to be unclear, especially when different types of thermometers are used in the neonatal population (Shankar et al, 2009). Two recent studies (Lee et al, 2011; Duran et al, 2009) measured infant discomfort during axillary temperature measurement using a pain scale adapted for neonates. Both studies confirmed that temperature measurement via the axilla increases discomfort levels.

The axillary method of temperature measurement has shown to correlate closely with rectal temperatures (Bailey & Rose, 2001; Browne et al, 2000; Smith, 1998; Jirapet & Jirapet, 2000) and is capable of detecting cold stress sooner than rectal temperature measurement. As with rectal temperature measurement, axillary measurement can potentially cause excessive handling and disturbance of the preterm neonate. Nevertheless, the axillary method is the preferred choice as it is deemed safe and accurate (Bailey & Rose, 2001; Browne et al, 2000; Haddock, Merrow & Vincent, 1988; Davis, 1993; Yetman et al, 1993; Wiess & Richards, 1994; Erickson, 1980).

A variety of electronic thermometers have replaced the early glass mercury thermometers and are now readily available. The digital BD is an electronic temperature measurement device utilizing a liquid crystal display (LCD) to indicate the temperature recording. The SureTemp®Plus 692 is a thermistor thermometer which can take up to 10 seconds and is used to measure temperature by oral, axilla and rectal sites. Tympanic thermometers, introduced in the 1980s (Erickson, 1980), are capable of registering temperature readings at much greater speed than the older digital thermometers (approximately 10 seconds compared to more than 1 minute). However, the use and accuracy of tympanic thermometry remains unclear (Molton et al, 2001). The main problem encountered when the tympanic thermometer was used in neonates in the past was inaccurate readings due to the size of the probe. Previous studies using tympanic thermometers with neonates used adult probes not tailored for use with neonates, which resulted in the measurement of surface rather than core temperature. Neonates, especially preterm neonates, have very small ear canals (Molton et al, 2001). Recently Tyco Healthcare Ptd.Ltd has developed a small probe suitable for use in neonates.

In summary, while the rectal approach has been in the past seen as the “gold standard” for temperature measurement in neonates, other approaches are often used due to the risk of perforation and infection, secondary to perforation (Horwitz and Bennet, 1976; Lynch et al, 1983; Tan et al, 1989).. A number of electronic devices are now available for measurement of the neonate temperature in the axillary or tympanic region, however the

agreement of the different types remains unclear. Therefore, this study aimed to compare the agreement of the Welch Allyn SureTemp®Plus 692 axillary measurement and the Genius 2™ tympanic measurement in term and preterm neonates with the measurement achieved with the BD digital in the same neonatal population.

Methods

Study design

A comparative design was used to evaluate the level of agreement between three thermometers in preterm and term infants. The infants ranged from 24 weeks gestation to post term.

Setting

The study was conducted at a neonatal tertiary referral centre of the Townsville General Hospital in North Queensland, Australia, from April 2008 to June 2011. Neonates were nursed in a variety of thermal environments including incubators with or without humidity, radiant warmers, and heated water mattresses, as well as open cots. The bed types were noted in the neonates' charts where each measurement was recorded.

Sample

A convenience sample was used. Neonates were selected because they were available and eligible for inclusion during the period of data collection. Inclusion criteria were: all neonates admitted to the level three neonatal

intensive care and special care unit. Exclusion criteria included: any infant with a poor prognosis and those with ear abnormalities.

Ethical Considerations

The Human Research Ethics Committee (HREC) of The Townsville Health Service Division approved the study. Before enrolment into the study, a written informed consent was obtained from each neonate's parents. Parents were given a full explanation of the purpose of the study and the different methods of temperature measurement being used in the study. They were also made aware of the voluntary nature of participation. The signed consent forms were filed in the neonates' charts and a copy given to each parent. All data were stored in accordance with the accepted guidelines and the data will be held for 10 years after publication of the results.

Procedure

Prior to data collection all thermometers were calibrated according to the manufacturer's instructions by hospital biomedical engineering staff. Before the study commenced and throughout the trial, the nurses and doctors were fully educated and aware on how to use each of the three thermometers correctly. Representatives from Welch Allyn (SureTemp® Plus 692) and Tyco Healthcare (Genius 2™ tympanic thermometer) came to the unit and gave in-services to all staff on the use of each thermometer. PowerPoint presentations were given throughout the day and night to ensure all staff was covered. The education presentations provided information on the background to the study objectives, procedures, information to be collected,

benefits, risks, participants, recruitment, parental consent and parental information sheet, and use of each type of thermometer. A plastic box was placed at each cot side at the start of the study and each box and thermometer was numbered. Each box contained one each of the thermometers, spare probe covers and shields, explanation leaflets, observation forms, parents leaflet and consent forms for parents. All boxes were checked everyday to ensure all boxes were intact.

Temperature measurements

Temperature recordings from the axillary and tympanic membrane were recorded at each usual 'care time', which ensured minimal disturbance to the neonates. Each neonate was enrolled in the study for a period of 24 hours. This enabled the researchers to have at least three sets of data per neonate. Temperature measurement was undertaken using the BD digital thermometer (the thermometer which was in current use in the unit), the Genius 2™ tympanic thermometer, and the WelchAllyn SureTemp®Plus 692 model. The tympanic temperature was taken first. Taking tympanic temperature only takes up to two seconds and causes minimal disturbance to the neonate. The infants' head was gently moved to expose the ear. The probe tip was introduced into the outer third of the auditory canal and a reading obtained. The environment in which the infant was nursed and the manufacturer's instructions were used to determine which ear was used (that is, the protected or exposed ear). For example, according to the manufacturer of the Genius 2™ thermometer, any neonate nursed in a warmed, humidified incubator should have their tympanic temperature taken using the protected ear (Tyco

Healthcare 2004) as the exposed ear may not give a true temperature due to environmental influences.

The axillary temperature was measured next by placing the BD digital thermometer, in predictive mode, in the axilla on the same side as the exposed ear to reduce the amount of disturbance to the neonate. The arm was held at the neonate's side until the predictor mode alarmed (this was the method used in the unit). The WelchAllyn SureTemp®Plus 692 electronic thermometer was then used to measure the temperature in the axillary area, which generally takes less than 10 seconds. All three readings were recorded in the neonate's chart.

Standard demographic information was also collected including the neonates age, gestational age at birth, gender, and weight at time of admission to the neonatal unit. In addition, type of environment the infant was nursed in, and date and time of temperature recordings were also noted.

Outcome measures

The primary outcome measures were the recordings of the digital, SureTemp model 690 and tympanic thermometers used to measure the neonates' temperatures.

Statistical analysis

Numerical data was described using mean and standard deviation (SD) or median and inter-quartile range (IQR) depending on the distribution.

The Bland and Altman (1986) approach for comparing measurement devices were utilized for individual comparison of each trial thermometer with the BD digital thermometer used as the reference thermometer. This method allows for comparison of new measurement techniques with established ones to determine whether they agree sufficiently to support replacement of the original device. The Bland-Altman method for assessing agreement rather than merely association accounts for both accuracy and precision of one measurement compared to another (Szaflarski & Slaughter, 1996). The Bland and Altman analyses are displayed in a scatter plot, which correlates the averages of the measurements on the X-axis against the differences of the measurements on the Y-axis. In an ideal situation of agreement one would expect the differences to be normally distributed around the zero line. Differences of measurements are expected to be in a band of mean difference ± 2 SD (Bland & Altman). The linear regression between differences and averages were calculated. Pearson's correlation coefficient (r) of the regression between differences and averages is expected to be close to zero. In addition, concordance correlation coefficients (CCC) (Lin, 1986) were calculated together with 95% confidence intervals to assess the strength of agreement. Statistical analysis was conducted using SPSS (IBM SPSS, Chicago, Illinois) version 18.

Results

A total of 238 infants were enrolled in the study, 52 (22.3%) in the group less than 28 weeks gestation, 112 (48.1%) with 29 to 36 weeks and 69 (29.6%)

with more than 36 weeks gestation. There were 106 (54.9%) male and 87 (45.1%) female babies (Table 1).

Scatter plots presented in Figures 1a and 1b show that the BD digital thermometer temperature measurement (mean 36.8°C, SD 0.234) was generally lower than the SureTemp®Plus 692 measurement (mean 37.0°C, SD 0.246), which was again lower than the Genius 2™ tympanic measurement (mean 37.2°C, SD 0.395). Agreement between the BD digital and SureTemp®Plus 692 measurements seemed closer than the BD digital and Genius 2™ tympanic measurements. The concordance correlation coefficient between BD digital and SureTemp®Plus 692 was 0.53 (95%-CI: 0.45 to 0.61) showing moderate agreement. The CCC between BD digital and tympanic Genius2™ was 0.25 (95%-CI: 0.17 to 0.31) showing poor agreement.

The Bland and Altman plot (Figures 2a) shows that the mean difference between the BD digital and the SureTemp®Plus692 measurements was -0.185 (± 2 SD: -0.561 to 0.191). There was a negative but non-significant correlation between the average and the difference of sure and digital measurements ($r = -0.071$; $p = 0.273$).

The mean of the differences between the BD digital and tympanic Genius2™ measurements was -0.368 (± 2 SD: -1.078 to 0.342). There was a significant negative correlation between the averages and the differences of tympanic and digital measurements ($r = -0.527$; $p < 0.001$) highlighting that differences

between the two thermometer measurements got bigger as the temperature increased.

Discussion

The study was undertaken to determine whether a less intrusive method of temperature measurement in the preterm neonate was a reliable alternative to the BD digital thermometer, which was in clinical use in a regional facility in Australia. We compared the Welch Allyn SureTemp®Plus model 692 and the Genius 2™ tympanic with the BD digital thermometer. The results of this study showed that only the BD digital and the SureTemp®Plus 692 measurements showed moderately good agreement. A similar result was reported in the study by Rosenthal & Leslie (2006). Our results confirm that the SureTemp®Plus model 692 thermometers can be used safely instead of the BD digital thermometer in term and preterm neonates.

On the other hand, concordance between Genius2™ tympanic and BD digital was poor. The findings showed further that differences between Genius2™ tympanic and BD digital increased with increasing temperature. Previous studies had also found poor agreement between digital axillary and tympanic measurements (Cussan et al, 1997; Yetman et al, 1992; Leick-Rude & Bloom, 1998; Jirapet & Jirapet, 2000). However a recent study by Bergstrom et al (2004), found that tympanic and rectal method correlated reasonably satisfactory.

Preterm neonates have special requirements for temperature regulation so being able to replace the BD digital device on our neonatal unit, with one that is equally efficient yet much faster and less disruptive to the neonate has important implications in clinical practice.

No adverse events were noted throughout this study when using each thermometer on three consecutive occasions. The nurses were asked to observe for any increase in heart rate, oxygen, agitation, and facial expression when monitoring the infant. However, the nurses did comment they perceived the tympanic thermometer was difficult to handle at times, especially when infants were nursed in an incubator, which necessitated negotiating the thermometer through the portholes. Some of the staff commented that the infants, particularly the preterm neonates, did not like the probe in the ear, an observation which confirmed results from a previous study (Bailey & Rose, 2004). The tympanic thermometer was hard to manoeuvre and sometimes hard to insert on the first attempt.

The study is limited by a number of factors. Temperature measurements were not limited to a particular person or group of people and inter-rater reliability was not assessed. Although education and instruction was provided to all staff, it is possible that different people may have undertaken the measurements in a slightly different manner. This may have altered the outcomes of the study.

Variations in temperature taken from either the axilla or tympanic area could be attributed to several factors, which could include operator technique,

positioning of the thermometer either in the ear or axilla, also different sites can yield different temperature measurements.

Conclusion

Based on the findings of this study we conclude that the SureTemp®Plus model 692 thermometer can be used as a reasonable alternative to the BD digital thermometer in the neonatal population. This is an important finding as any opportunity to reduce handling time is an advantage with preterm neonates. Despite new developments in temperature measurement devices, it appears that the axilla remains the preferred site, as this time, for temperature assessment, rather than the tympanic or rectal approach in neonates. A number of different electronic and IR devices which are now available for use in the neonatal population, but agreement the concordance of these various types of thermometers, from different sites, is still unclear. However temperature data obtained from the axilla, tympanic, rectal and skin, will it ever correlate?

It is important that further research be undertaken to ensure that current practice continues to be based on sound evidence.

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Table 1: Descriptive statistics of participating neonates (n=238).

Characteristic	Descriptive statistics
Gestation	
28 weeks or less	52 (22.3%)
29 to 36 weeks	112 (48.1%)
> 36 weeks	69 (29.6%)
Median age (IQR*), range [days]	3 (1, 6), range 0 to 50 days
Median weight (IQR), range [kg]	1.69 (1.08, 2.70), range 0.65 to 5.11 kg
Gender	
Male	106 (54.9%)
Female	87 (45.1%)
Type of bed	
Incubator	143 (60.3%)
Radiant warmer	16 (6.8%)
Open cot	67 (28.3%)
Waterbed	11 (4.6%)
Relative humidity	
Not under artificial humidity	157 (67.7%)
Median humidity (IQR), range [%]	80% (65, 83), range 38 to 90; n=75 (32.3%)
Phototherapy	44 (18.7%)
Skin temperature	
Not required	92 (46.5%)
Median skin temperature (IQR), range [°C]	36.60 (36.50, 36.725), range 28.0 to 37.2 °C; n=106 (53.5%)
Clothes	
Nappy	131 (71.6%)
Shirt	18 (9.8%)
Singlet and jumper	26 (14.2%)
Singlet, jumper, hat and boots	7 (3.8%)
Singles, jumpsuit, boots and socks	1 (0.5%)
Ethnicity	
Caucasian	126 (72.8%)
Aboriginal	41 (23.7%)
Maori	3 (1.7%)
Asian	1 (0.6%)
African	2 (1.2%)
Blanket	

None	111 (58.4%)
One blanket	38 (20.0%)
Two blankets	35 (18.4%)
Three blankets	6 (3.2%)
Mean temperature (digital) (SD**), range [°C]	36.825 (0.234), range 35.85 to 37.95 °C
Mean temperature (sure) (SD), range [°C]	37.010 (0.246), range 36.3 to 38.075 °C
Mean temperature (tympanic) (SD), range [°C]	37.193 (0.395), range 36.267 to 38.575 °C

*IQR = inter-quartile range; **SD= standard deviation

Figure 1: Agreement between BD Digital and SureTemp®Plus 692 (a) and Genius2™ (b) thermometers. Results were based on temperature measurements of 238 neonates in a neonatal tertiary referral centre in North Queensland, Australia.

Figure 1a:

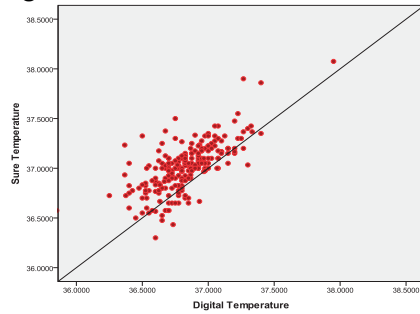


Figure 1b:

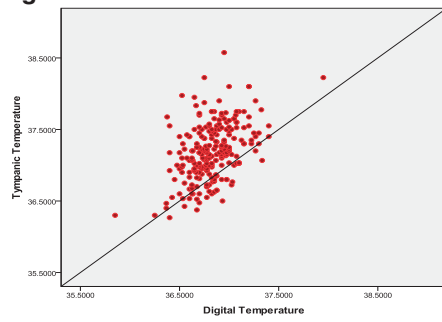


Figure 2: Bland and Altman plots of agreement between BD Digital and SureTemp®Plus 692 (a) and Genius2™ (b) thermometers. Results were based on temperature measurements of 238 neonates in a neonatal tertiary referral centre in North Queensland, Australia. The middle dotted straight lines represent the mean differences and the outer dotted straight lines represent mean differences ± 2 standard deviations. The bold dotted line is the regression line between differences and averages of measurements.

Figure 2a:

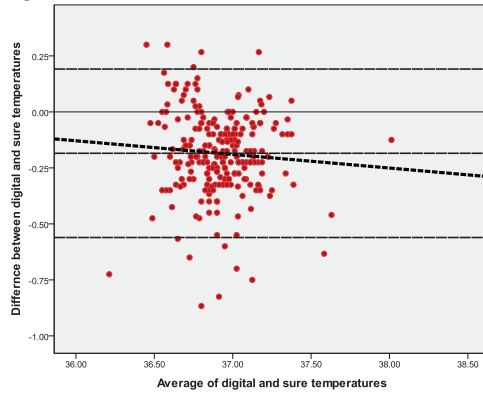
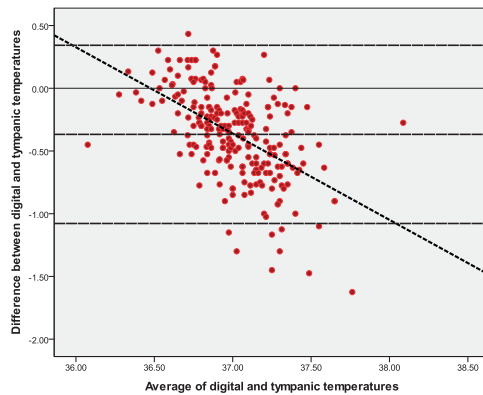


Figure 2b:



Summary of manuscript

The study described in the manuscript took three years to complete. There were many reasons the study was conducted over that time period. For example, high staff turnover meant that new staff had to be educated on the use of each thermometer and be familiar with the data collection forms. However, conducting the study for a longer period of time ensured a larger sample size. A sample size of (n=238) was achieved which included infants from 24 to 40 weeks gestation. The infants were enrolled after parental consent and remained in the study for a maximum of 24 hours. The Bland and Altman shows the mean difference between the BD digital and SureTemp®Plus 692 was 0.185 (\pm 2SD: -0.561 to 0.191) and the BD digital and Genius 2™ was -0.368 (\pm 2SD -1.078-0.342). The study results indicate that the SureTemp®plus 692 can be used as a replacement for the BD digital thermometer in the neonatal population.

Chapter conclusion

This chapter presented a manuscript under review with Collegian. The manuscript presents the results of a study undertaken to determine if the SureTemp®plus 692 and the Genius 2™ could be used as a safe and accurate replacement for the BD digital. The results indicate that the SureTemp®plus 692 can in fact be used as a replacement for the BD digital thermometer in the neonatal population.

The next chapter offers a manuscript that reports the findings of a study undertaken to determine whether the application of plastic wrap applied to preterm neonates at time of birth could improve admission temperatures to the NICU.

CHAPTER 4: THE APPLICATION OF A PLASTIC WRAP TO IMPROVE NICU ADMISSION TEMPERATURES IN INFANTS BORN LESS THAN 30 WEEKS GESTATION: A RANDOMISED CONTROLLED TRIAL

Introduction

Hypothermia in the preterm infant, especially after a prolonged resuscitation, is a common issue in many neonatal units, even though conventional practice is adhered to in most resuscitation situations. Many studies have shown that hypothermia is an independent risk factor for neonatal morbidity and mortality.

The need for prevention and limitation of hypothermia during resuscitation and stabilisation, and also when transferring to the neonatal unit, is of paramount importance. The most innovative approach to preventing hypothermia in the preterm infants is by use of a plastic wrap or bag after birth. Therefore, a randomised control trial (RCT) was conducted in infants born less than 30 weeks gestation to determine if wrapping the infant in plastic improved admission temperature to the NICU in a regional area.

Publication 3: The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial.

Declaration by candidate

The extent of candidate contribution to the following publication is as follows:

Thesis	Article	Publication Details	Author Contributions	Impact Factor/h Index
Chapter 4	The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial.	In press in: <i>Neonatal Network</i>	Author J.Smith(40%) G.Alcock (20%) K.Usher (20%) P.Buettner (20%)	H Index 4.00

Declaration by co-authors

The undersigned hereby certify that:

- The above declaration correctly reflects the extent of the candidate's contribution to the work and the extent of contribution of each co-author;
- They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least part of the publication in their field of expertise;
- They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
- There are no other authors of the publication according to these criteria;
- Potential conflicts of interest have been disclosed to (a) grant bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
- The original data are stored at the following location and will be held for at least five years from the date indicated below:

Location	School of Nursing, Midwifery & Nutrition
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Candidate signature		27 September 2012
K Usher		27 September 2012
G Alcock		27/9/12
P Buettner		27 September 2012

Neonatal Network®: The Journal of Neonatal Nursing

The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial --Manuscript Draft--

Manuscript Number:	11-T-144R1
Full Title:	The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial
Article Type:	Original Research
Corresponding Author:	jacqueline smith, MNSc The Townsville Hospital Magnetic Island, Queensland AUSTRALIA
Corresponding Author Secondary Information:	
Corresponding Author's Institution:	The Townsville Hospital
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First Author Secondary Information:	
Order of Authors:	jacqueline smith, MNSc Kim Usher, Professor of Nursing Gary Alcock, Neonatologist Petra Buettner, Associate Professor
Order of Authors Secondary Information:	
Abstract:	<p>Background: Hypothermia is a significant contributor to poor outcomes in neonates, especially preterm neonates, yet hypothermia is a common finding in preterm infants admitted to neonatal intensive care.</p> <p>Objectives: To determine if the application of a plastic wrap immediately after birth is more effective than the conventional method of temperature management for improving admission temperatures in infants <30 weeks gestation admitted to the neonatal intensive care unit.</p> <p>Method: A randomised controlled trial was conducted. The study enrolled 92 infants < 30 weeks gestation.</p> <p>Results: The mean first temperature was 36.15°C (standard deviation = SD 0.85) for intervention and 35.81°C (SD 0.91) for control infants (p=0.074); while the respective admission temperatures were 36.26°C (SD 0.68; n=42) and 35.79°C (SD 0.77; n=44)(p=0.004).</p> <p>Conclusion: The application of plastic wrap and hat is an effective method of increasing NICU admission temperature in infants less than 30 weeks gestation.</p> <p>Keywords: hypothermia, hyperthermia, plastic wrap, preterm.</p>
Author Comments:	<p>Hi Deb and Megan</p> <p>I have revised the plastic wrap manuscript according to the editor and reviewers comments.</p> <p>Warmest regards</p> <p>Jackie</p>

The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial.

Abstract

Background: Hypothermia is a significant contributor to poor outcomes in neonates, especially preterm neonates, yet hypothermia is a common finding in preterm infants admitted to neonatal intensive care.

Objectives: To determine if the application of a plastic wrap immediately after birth is more effective than the conventional method of temperature management for improving admission temperatures in infants <30 weeks gestation admitted to the neonatal intensive care unit.

Method: A randomised controlled trial was conducted. The study enrolled 92 infants < 30 weeks gestation. Randomisation concealment was by the use of sealed opaque envelopes. The infants' temperatures were assessed for two hours following admission.

Results: Of the 92 infants, 43 (51.2% <27 weeks and 48.8% <30 weeks) were randomized to the experimental group and 49 (53.1% <27 weeks and 46.9% <30 weeks) to the control group. The mean first temperature was 36.15°C (standard deviation = SD 0.85) for intervention and 35.81°C (SD 0.91) for control infants (p=0.074); while the respective admission temperatures were 36.26°C (SD 0.68; n=42) and 35.79°C (SD 0.77; n=44)(p=0.004). The mean temperature of the infants rose steadily from the time of birth to 2 hours follow-up in both the intervention (36.15 to 37.03°C; SD 0.49; n=40) and control groups (35.81 to 36.75°C; SD 0.70; n=47)(p<0.001, respectively).

Conclusion: The application of a plastic wrap and hat is an effective method of increasing NICU admission temperature in infants less than 30 weeks gestation.

Keywords: hypothermia, hyperthermia, plastic wrap, preterm.

Acknowledgments

We would like to acknowledge the dedication of Janelle Creedy and Ruth Oldfield, senior neonatal nurses at The Townsville Hospital, Townsville, Australia, for their support and assistance with education of nursing and medical staff as well as data collection.

Introduction

Heat loss is greatest in the first few minutes of life as infants are born wet into a relatively cool environment compared to the uterus (Cramer et al, 2005; Soll, 2008). Therefore, maintenance of a normal body temperature is one of the key challenges a newborn faces after delivery (Soll, 2008). Preterm infants are at significant risk of hypothermia immediately after birth (Soll, 2008; Watkinson, 2006). Hypothermia is a significant contributor to neonatal morbidity and mortality, particularly in low resource settings such as developing countries where there are a higher incidence of low birth weight babies, less qualified staff and poorer health services available (Kumar et al, 2009). An in house audit of admission temperatures in the neonatal intensive care unit (NICU) in a regional hospital in Australia in 2005 revealed the need for an intervention to reduce the rate of hypothermia in preterm neonates at admission. Given that the particular unit is set in a regional, tropical area that includes a high proportion of Indigenous Australians who are prone to premature birth, and as prematurity and low birth weight are more likely in rural and regional areas than in urban environments (AIHW, 2010), the need for an intervention to improve the clinical situation was regarded as important. In an attempt to decrease hypothermia the use of a plastic wrap in infants less than 30 weeks gestation was trialed, as previous studies using this intervention reported positive results (Vohra et al, 1999; Lyon & Stenson, 2004; Meyer, 2003). Instead of the usual drying after birth, in the plastic wrap method the neonate is immediately wrapped from the shoulders down with a transparent plastic wrap and placed under a warmer. The baby's head is also

dried and a hat applied (Cramer et al, 2005; Vohra et al, 2004); as per neonatal resuscitation guidelines (2010) and NeoResus guidelines (2012). This paper presents the results of a study undertaken to determine if the application of the plastic wrap to preterm infants prior to admission to the NICU improved admission temperatures compared to the conventional method where the infant is dried, wet towels removed and warm towels applied (NRP, 2010: NeoResus, 2012).

Background and preliminary studies

Neonatal hypothermia is when a baby's temperature drops below 36.5°C (Kumar et al, 2009). For this trial we used the World Health Organization (WHO) guidelines (1997) for normal newborn temperature which is defined as between 36.5° and 37.5°C. The WHO (WHO, 1997) defines hypothermia as a temperature less than 36.5°C; mild hypothermia as a temperature between 36° – 36.5°C; moderate hypothermia is classed as a temperature between 32° - 36°C and severe hypothermia as less than 32°C. Hyperthermia was defined as any temperature greater than 37.5°C.

Heat loss in the neonate immediately after birth is mainly due to evaporation of amniotic fluid (Soll, 2008; Kumar et al, 2009). However, babies also lose heat rapidly if placed on cold surfaces, if exposed to cold environments, or if placed where they are affected by drafts (Kumar et al, 2009). Premature neonates have an immature thermoregulatory system and are especially susceptible to heat loss and thus require help with temperature control from the moment of birth (Soll, 2008; Lyon & Stenson, 2004). Premature infants also have limited subcutaneous fats and glycogen, particularly brown fat

(which diminishes quickly during cold stress (Soll, 2008). Further, preterm infants are also not capable of effective shivering when cold, therefore their main source of heat production is non shivering thermogenesis. This places the premature infant at a disadvantage because fats and glycogen are required to produce heat by non-shivering thermogenesis (Soll, 2008; Kumar et al, 2009; Carter & Schucany, 2008)

Hypothermia (temperature $<36.5^{\circ}\text{C}$) is thus a common finding in premature infants following delivery, resuscitation and stabilisation in the NICU.

Hypothermia can cause complications such as an increase in oxygen requirements, difficult resuscitation, disseminated intravascular coagulation, post delivery acidosis, delayed adjustment from fetal to newborn circulation, worsening respiratory distress syndrome, necrotising enterocolitis and increased morbidity from infection (Soll, 2008; Evans & Utter, 1986).

Prevention of hypothermia is one of the basic tenets of good neonatal care.

Conventional practice for prevention of heat loss after birth is to dry the infant, apply a hat and place under a radiant heater (WHO, 1997; McCall et al, 2010). Although this is an effective way of maintaining temperature in term infants, hypothermia remains a common problem in preterm infants. Evidence suggests that application of a plastic wrap or bag is a more effective method of preventing heat loss, especially in preterm babies (Cramer et al, 2005; Vohra et al 2004; McCall et al, 2010).

In 2003, infants born at less than 30 weeks gestation at a regional hospital in Queensland, Australia, had a mean temperature on admission to the NICU of 36.1°C ; 66% of infants had an admission temperature of less than 36.5°C . Despite the application of recommended policy mild to moderate hypothermia

was common on admission to NICU. A decision was made to investigate the efficacy of applying a plastic wrap (NeoWrap TM) immediately after birth. It was hypothesised that the application of the plastic wrap soon after birth would be more effective than the conventional drying approach and thus improve NICU admission temperatures in infants less than 30 weeks gestation.

Methods

The Townsville Health Service District Human Research Ethics Committee (HREC) approved the study and a prospective randomised controlled trial was conducted in the tertiary neonatal referral center at The Townsville Hospital in regional Queensland, Australia, from January 2006 to July 2011.

Setting

The Townsville hospital neonatal unit, comprising of the neonatal intensive care unit (NICU) and special care nursery (SCN), is the only level six tertiary referral centre for newborns north of Brisbane, the capital city, in Queensland. The unit is currently in the process of redevelopment, which will lead to 50 cot spaces across NICU and SCN. The neonatal unit provides care for preterm infants, infant's requiring surgery and infants requiring various types of ventilation. It also has a dedicated neonatal retrieval team which covers an area one and half times the size of France. The study took place in the NICU, which caters for all infants from 24 weeks gestation.

Sample

It was calculated that a sample size of 86 (43 in each treatment group) infants was required to provide a power of 0.9 to detect an difference in mean admission temperature from 36.1°C to 36.5°C using a 2 sided t-test with a statistical significance level of 0.05. All neonates less than 30 weeks gestation were eligible for inclusion in the study. Parental consent was sought. Infants were excluded if they had any congenital abnormalities with open lesions, or if considered not viable. The intervention posed minimal risks to the neonate but hyperthermia was identified as a possible complication of the wrapping procedure. Therefore, particular emphasis was made to ensure that neonates did not become hyperthermic during the study via continuous monitoring of skin temperature by placement of a skin probe. The probe was placed in the upper right quadrant of the abdomen or back, depending on which position the infant was lying, as the infant should never lie on the skin probe as this will give a false skin temperature reading. No other sources of heat generation were used in any group throughout the study (e.g. thermal mattress). Infants in both groups were placed in humidified incubators as per unit guidelines (see Table 1). Both the intervention and control groups had their skin temperature monitored as per unit guidelines (see Table 2).

The first temperature was recorded when an infant had been dried, wet towels, removed and warm towels applied, or when the wrap had been secured from the neck down around the infant. Admission temperature was recorded when infants in both the control and intervention group arrived in the NICU and were

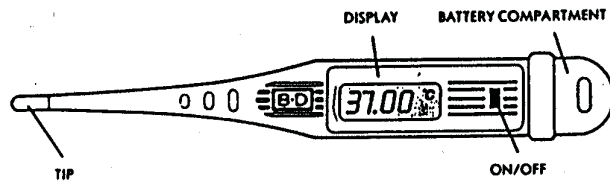
placed in the incubator. When infants were transferred to the NICU, both groups were transported using the radiant warmer.

Instruments

The NeoWrap™ used in the study was biocompatibility tested by the manufacturer; this process included cytotoxic testing; no cytotoxic effects were observed, and intra-cutaneous reactivity, which determines if there is any irritation effect from the material. The NeoWrap™ scored zero on the irritation scale. Each NeoWrap™ comes in its own individual packet and measures 60cm by 60cm (see Figure 1 below). The NeoWrap™ helps reduce evaporative heat loss and allows radiant heat penetration.



The axilla method was used for temperature measurement using the BD digital thermometer device. The BD Digital Thermometer is an electronic temperature measurement device utilising a liquid crystal display (LCD) to indicate the temperature reading. The thermometer is powered by a replaceable alkaline battery (see Figure 2 below).



The hats used were of soft woven fabric; all hats were the same for each infant in the control and intervention group. Towels used were pre-warmed under the radiant warmer on full power prior to the birth. No set temperature was recorded for towel warming and there was no variance between the groups for towel warming.

Procedure

Randomisation was achieved by use of a computer generated randomisation list. The list was stratified by gestation into two groups, group 1, infants <27 weeks gestation and group 2, infant's 27-29⁺⁶ weeks gestation.

Randomisation concealment was adhered to by the use of a sealed opaque envelope. When a mother was at risk of a premature birth, a nurse or doctor would fully discuss the trial with the parents, gained consent and left an information leaflet. If parents consented, the infant was included in the trial. At the time of birth, the nurse would take the appropriate envelope according to gestation and then gather any required equipment needed for the birth.

Delivery room procedures

Control Group

The infant was transferred to the pre-warmed resuscitaire immediately after birth, and dried. The infant was lifted; wet towels removed and warm towels and hat applied. The first temperature was taken, via the axilla, as soon as

the infant was wrapped in warm towels and resuscitation, if needed was completed. If resuscitation was required, resuscitation was performed as per guidelines of the American Academy of Pediatrics Neonatal Resuscitation Program (WHO, 1997; Kattwinkel et al, 2010).

Experimental (plastic wrap) group

A clean wrap was placed under a pre-heated radiant warmer. The infant was transferred to the resuscitaire immediately after birth and without being dried, was wrapped with the NeoWrap™ from the neck down. The infant's head was dried with a pre-warmed towel and a hat was placed immediately on the infant's head. A first temperature was taken as soon as the infant was placed on the resuscitaire and wrapped. Resuscitation was performed as per guidelines of American Academy of Pediatrics Neonatal Resuscitation Programme (NRP) (Kattwinkel et al, 2010). Heart rate could be easily auscultated through the transparent wrap: the airway remained accessible for any resuscitative measures.

NICU Procedures

Control group

Infants who were in the control group were weighed and placed in a pre-warmed incubator (temperature and humidity set as per unit guidelines). A nappy was placed on the infant. A NICU admission temperature was taken, via the axilla, as soon as the infant was placed in the incubator, then every 30 minutes using a digital thermometer placed under the axilla, until the infant reached 120 minutes post admission. The incubator also measured a continuous skin temperature with a skin probe.

Experimental group

The infant remained wrapped whilst weighed and measured and placed in a pre-warmed incubator (temperature and humidity set as per unit guidelines). Any further clinical procedures were carried out whilst trying to keep the opening of the plastic wrap to a minimum, for example, radiological investigation, insertion of lines (umbilical and peripheral), and pathology investigations. Axillary temperature was recorded every 30 minutes using the same type of digital thermometer as used in the control group; the recordings continued from admission until the infant reached 120 minutes. To keep airflow to a minimum when measuring the infant's temperature, the wrap was pulled down just so the axilla temperature could be taken. A continuous skin temperature was also recorded. After two hours the wrap was removed. Infants underwent routine and necessary care for the remainder of their stay.

Analysis of data

The primary outcome was temperature at admission to NICU. Secondary outcomes were temperatures at 30, 60, 90, and 120 minutes after admission, blood glucose level, intraventricular hemorrhage, and pH on first blood gas, early and late sepsis and death.

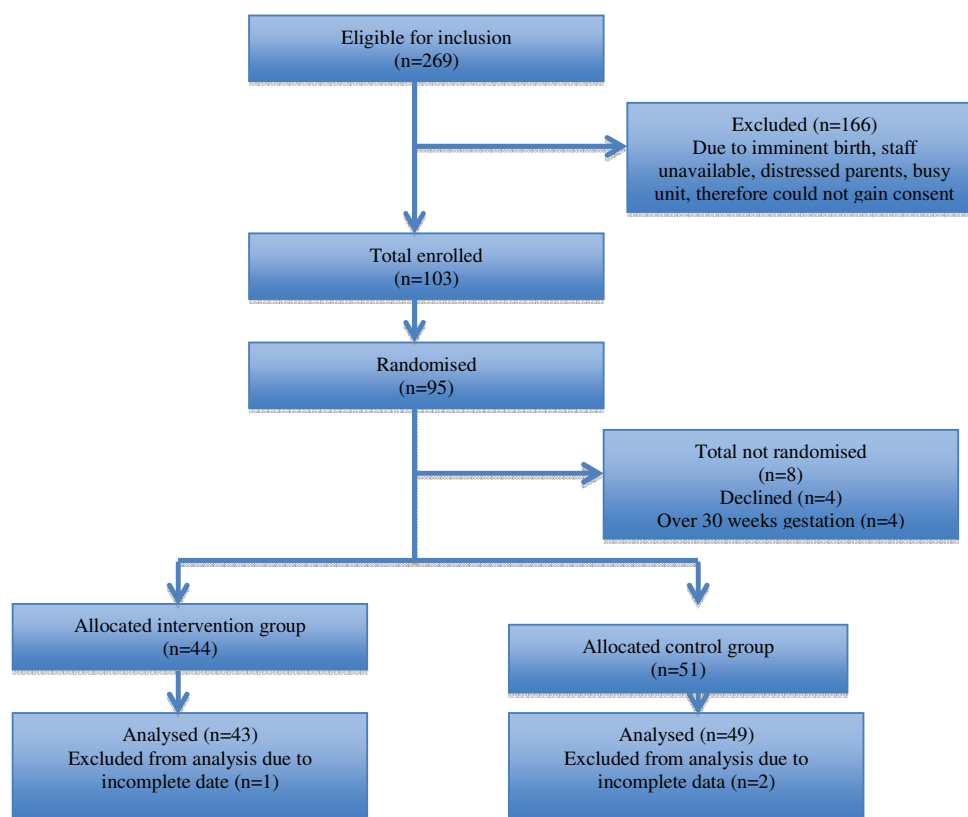
Data were analysed using the Statistical Package for Social Sciences (IBM SPSS, Chicago, Illinois) version 19 (SPSS). Numerical data were checked for approximate normality and were described using mean values and standard deviations (SD). Categorical data were described using percentages. Mean temperatures as well as differences in temperatures were compared between intervention and control groups using independent samples t-test. Categorical

data were analysed using the Chi-square test and Fisher's exact test as appropriate. Changes in temperature over time were assessed using Analysis of Variance for repeated measures.

Results

Overall a total of 269 infants were eligible for inclusion into the study. A total of 103 infants were enrolled in the trial, but only 95 were actually randomised into the trial. This was due to four parents who declined to participate at the time of birth and four infants who were no longer eligible as they were born above 29+6 weeks. The remaining 163 potential participants were not enrolled due to various reasons including imminent birth, distressed parents, language barrier, busy unit, or lack of available staff to discuss the trial with the parents. Multiple births (n=3) enrolled in the trial were randomised separately, which ensured both had an equal chance of being placed in the control or intervention group

Figure 3: Participant Flow Diagram



A total of 95 infants were randomised but only 92 were analysed because three subjects had temperature data missing which included first temperature, temperature up to 2 hours and admission temperature. A total of 92 neonates were analysed; 49 in the control group and 43 in the intervention group; 48 (52.2%) were less than 27 weeks gestation and 44 (47.8%) were <30 weeks gestation (Table 3).

Mean temperatures initially fell slightly from the first temperature recorded to temperature at admission but then steadily rose during follow-up in both intervention and control groups ($p < 0.001$, respectively) (Table 3).

The analysis showed a significant difference in NICU admission temperatures between the intervention and control group ($p = 0.004$, Table 3), however the mean differences in temperatures to the first temperature recorded were always higher for the intervention group (Table 3; Figure 4). The results of ANOVA for repeated measures showed that temperatures in the wrap group ($F = 8.531$; $df = 4$; $p < 0.001$) as well as in the intervention group ($F = 13.813$, $df = 4$; $p < 0.001$) were rising steadily from admission to 120 minutes follow-up.

Temperatures taken at 30, 60, 90, and 120 minutes of age were significantly higher in the intervention group when compared to the control group. No significant differences were noted between control and intervention groups in the sample descriptors which measured, blood glucose level, intraventricular hemorrhage, intubation and mortality and also in baseline characteristics (Table 3). The first temperature after birth was slightly higher in the intervention group ($p = 0.074$, Table 3). Eleven infants were hyperthermic, 6 in

the intervention group and 5 in the control group; hyperthermia was classed as an axilla temperature above 37.5°C as defined by WHO (Table 2) (Watkinson, 2006). Although hyperthermia was not deemed significant in either the control or intervention groups ($p=0.180$), vigilance is still required when using the plastic wrap. The highest axilla temperature recorded was 38.4°C; recorded at two hours of age in an infant in the intervention group. The wrap was removed immediately.

There were 17 infants with admission temperatures less than 36.5°C, four infants had an admission temperature <36°C and 13 infants had an admission temperature >36°C, nine in the control group and four in the intervention group. In addition, because theatre environments are usually cooler than birth suite consideration of the impact of caesarean section (CS) versus spontaneous vaginal delivery (SVB) was included. The wrap group had 57.1% ($n=28$) born by CS compared to the control group (60.5%; $n=26$) therefore clearly demonstrating there was little difference in mode of birth between the two groups (Table 4).

Discussion

The study was undertaken to determine whether the application of plastic wrap to neonates born less than 30 weeks gestation was an effective method of improving admission temperatures to NICU when compared to the conventional method. It is the first attempt to determine if this intervention is effective in a regional, tropical location. The application of plastic wrap or plastic bag at the time of birth has been previously reported to increase admission temperature to NICU in premature infants as the wrap permits heat

gain through radiation; it has also been found to reduce evaporative insensible water loss by 70% (Besh et al, 1970). The efficacy of this method has been established in previous randomised controlled trials (RCT) involving over 300 infants (Vohra et al, 1999; Vohra et al, 2004; Knobel, Wimmer & Holbert, 2005; Simon et al, 2010; Bosch et al, 1996; Dunman, et al, 2006; Rohana et al, 2011). A further thirteen studies, (retrospective and analysis of case series) were completed from 2002-2011 (Meyer, 2003; Bjorkland, 2000; Lenclen & Mazraani, 2002; Newton & Watkinson, 2003; Newton & Watkinson, 2003; Matthew et al, 2007; Kent & Williams, 2008; Ibrahim & Yoxhall, 2008; Patrick et al, 2010; Carroll et al, 2010). The majority of these studies have concluded that the plastic wrap or bag prevents rather than delays hypothermia. Of these studies, 10 used the plastic wrap, of which 9 had an increase of admission temperature and 1 did not show an increase (see Table 4).

The results of this trial indicate a significant difference in admission temperature between the intervention and control (36.26 versus 35.79°C) group, confirming that the application of the plastic wrap at birth increased NICU admission temperature in the preterm infants born in a tropical setting. The initial first temperature in the intervention group was higher than the control group. This may have occurred in response to the study procedure where the control group infants were dried, stimulated, hat applied, resuscitated if needed, wet towels removed, warm towels placed under the infant, compared to the intervention group, who were immediately placed on the wrap, wrapped, hat applied and first temperature recorded. In this way the

procedure used for the control group may have improved the initial temperature of the control group infants.

The risk of over heating has been identified as a problem in a number of previous studies using the plastic wrap intervention (Matthew et al, 2007; Ibrahime & Yoxhall, 2008; Singh et al, 2010). In this study hyperthermia was recorded in 11 infants; 6 (12.2%) in the experimental group, and 5 (11.6%) in the control group (Table 2). Although not significant, there has to be strict vigilance regarding hyperthermia in the newborn, as long-term effects of hyperthermia are still not known. Effects of hyperthermia may cause an increase in neurological damage, especially in hypoxic infants (Gunn & Gluckman, 2000; Gunn & Bennet, 2001). Interestingly a total of eight infants who were hyperthermic were above 1kg in weight. Some studies have shown that size at birth is a significant determinant of NICU admission temperature (Vohra et al, 2004; Singh et al, 2010; Laptok, Salhab & Bhaskar, 2003). This may indicate that very low birth weight infants will benefit more from the plastic wrap than more mature infants.

A fall in body temperature in newborn infants may delay transition to extra uterine life, and increase morbidity and mortality (Kumar et al, 2009; Costeloe, Hennessy & Gibson, 2000). Hypothermia can also be linked to infection. Laptok and colleagues (2003) found that 23.3% of low birth weight infants had late onset sepsis and the odds of late onset sepsis were increased by 11% for every 1°C decrease in admission temperature. Even though this trial did not find any significance between groups and late onset sepsis, it is still important to ensure larger studies continue in this field, as they may be able to

determine the effects of improved survival or other long-term benefits and effects associated with using the plastic wrap at birth.

Four infants were still hypothermic at two hours post delivery despite being wrapped. Other studies have also recorded hypothermia in infants who were wrapped (Simon et al, 2010). This could be due to a number of factors including the infant lying in a cold pool of water, environmental factors, and the process of applying the wrap. Therefore, while the application of the plastic wrap is an effective way to reduce hypothermia, it has its failings and further studies are needed to determine the most effective ways to prevent hypothermia in neonates. For example, Arjan et al (2010) examined the use of humidified and heated air during stabilisation and concluded that the use of heated and humidified air during respiratory support in very preterm infants did help prevent hypothermia. A larger RCT needs to be conducted to evaluate the effects of this method.

Limitations

A few limitations were noted within this RCT. The plastic wrap did prove to have some problems when used which may have had an impact on the analysis. Staff found it difficult to place the saturation probe or temperature probe with the wrap in place. When an attempt was made to site the probes from the bottom of the wrap this also proved difficult and the wrap was difficult to keep closed. If there was a prolonged resuscitation then the wrap was more than likely moved away or dislodged for a number of seconds whilst resuscitation was performed. Incidents such as these could have contributed

to loss of heat. Placement of a nappy also dislodged the wrap in some cases and umbilical lines (as the wrap was in place for two hours) made it near impossible to keep the wrap closed due to the close proximity of the umbilical tie. Timing of the first temperature and time it takes to arrive to NICU from birth suite may have made a difference in the results recorded.

Conclusion

The use of plastic wrap in infants less than 30 weeks gestation did improve admission temperatures to NICU in a regional hospital in a tropical location. Further studies to compare the effectiveness of plastic wrap and bag are needed to confirm the benefits and disadvantages of these and other potential interventions in the premature infant.

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Figure 4: Mean temperatures and 95% confidence intervals (95% CI) at base, admission, 30, 60, 90 and 120 minutes of follow-up (order of bars in diagram) stratified for intervention and control groups.

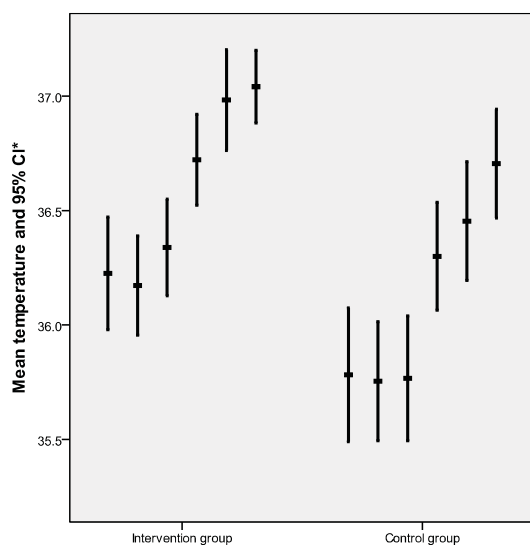


Table 1: skin temperature guidelines used on the TSV neonatal unit

DAY	HUMIDITY	GESTATION	DAY	HUMIDITY	GESTATION
1-3	90%	24 - 26	1 - 4	80%	27-30 weeks
4 - 5	85%	24 - 26	5	75%	27-30 weeks
6	75%	24 - 26	6	70%	27-30 weeks
7	70%	24 - 26	7 - 8	65%	27-30 weeks
8	65%	24 - 26	9 - 13	60%	27-30 weeks
9 - 13	60%	24 - 26	14	50%	27-30 weeks
14 - 28	50%	24 - 26			

Table 2: set skin temperature guidelines used at the TSV neonatal unit

NEUTRAL THERMAL ENVIRONMENTAL for INFANTS DAY 1 - 5

Birth weight and Temperature Range (°C)				
Age	1000 – 1200g	1200 – 1500g	1500 – 2500g	>2500g and >36weeks gestation
0 – 12 hrs	35.0 +/- 0.5	34.0 +/- 0.5	33.3 +/- 1.0	32.8
12 – 24 hrs	34.5 +/- 0.5	33.8 +/- 0.5	32.8 +/- 1.0	32.4
24 – 96 hrs	34.5 +/- 0.5	33.5 +/- 0.5	32.3 +/- 1.0	32.0

NEUTRAL THERMAL ENVIRONMENTAL for INFANTS > 5 DAYS of Age

Age	< 1500g	1500 – 2500g	>2500g and > 36 weeks gestation
5 – 14 days	33.5	32.1	32.0
2 – 3 weeks	33.1	31.7	30.0
3 – 4 weeks	32.6	31.4	
4 – 5 weeks	32.0	30.9	
5 – 6 weeks	31.4	30.4	

Table 3: Differences in temperatures to first temperature taken compared between intervention and control groups.

Mean difference in temperature between	Control group (n=49)	Intervention group (n=43)	p-value
Admission and first (SD); range [°C]	0.0146 (0.569); -1.10 to 2.60	0.0600 (0.820); -1.80 to 2.60	P=0.773
30 minutes and first (SD); range [°C]	-0.0200 (0.489); -1.10 to 1.30	0.12 (0.701); -1.80 to 1.70	P=0.285
60 minutes and first (SD); range [°C]	0.4756 (0.741); -1.00 to 2.60	0.5707 (1.031); -1.30 to 3.00	P=0.627
90 minutes and first (SD); range [°C]	0.6311 (1.002); -1.20 to 3.90	0.8171 (1.035); -1.10 to 3.00	P=0.400
120 minutes and first (SD); range [°C]	0.9186 (1.087); -1.50 to 4.30	0.8500 (0.935); -0.60 to 3.10	P=0.763

Table 3: Basic characteristics of 92 neonates and stratified analysis by intervention and control status.

Characteristic	Overall (n=92)	Intervention group (n=43)	Control group (n=49)	p-value
<i>Gestation</i>				p=0.856
<27 weeks	48 (52.8%)	22 (51.2%)	26 (53.1%)	
27-29+6 weeks	44 (47.8%)	21 (48.8%)	23 (46.9%)	
<i>Mean birth weight (SD)*: range [kg]</i>	0.985 (0.262); 0.46 to 1.89	0.991 (0.299); 0.46 to 1.89	0.982 (0.233); 0.51 to 1.61	p=0.874
<i>Mean first temperature taken (SD): range [°C]</i>	35.99(0.84); 32.90 to 37.60	36.15 (0.85); 34.00 to 37.50	35.81 (0.91); 32.90 to 37.60	p=0.074
<i>Mean temperature at admission (SD); range [°C]</i>	36.02(0.76); 34.20 to 37.40	36.26 (0.68); 34.50 to 37.40	35.79 (0.77); 34.20 to 37.00	p=0.004
<i>Mean temperature at 30 minutes (SD); range [°C]</i>	36.03(0.79); 34.10 to 37.60	36.34 (0.65); 35.00 to 37.60	35.77 (0.82); 34.10 to 37.40	p<0.001
<i>Mean temperature at one hour (SD); range [°C]</i>	36.47(0.71); 34.50 to 38.30	36.73 (0.61); 35.30 to 38.30	36.26 (0.73); 34.50 to 37.70	p=0.001
<i>Mean temperature at 90 minutes (SD); range [°C]</i>	36.68(0.75); 34.20 to 38.40	37.00 (0.66); 35.30 to 38.80	36.44 (0.78); 34.20 to 37.60	p<0.001
<i>Mean temperature at 2 hours (SD); range [°C]</i>	36.87(0.62); 34.50 to 38.40	37.03 (0.49); 36.00 to 38.40	36.75 (0.70); 34.50 to 38.00	p=0.035
<i>BCPAP</i>				p=0.774
Yes	76 (82.6%)	35 (81.4%)	41 (83.7%)	
No	16 (17.4%)	8 (18.6%)	8 (16.3%)	
<i>Ventilated</i>				p=0.526
Yes	65 (70.7%)	29 (67.4%)	36 (73.5%)	
No	27 (27.3%)	14 (32.6%)	13 (26.5%)	
<i>Blood glucose level</i>				p=0.556
<2.6 mmol/L	21 (24.7%)	8 (19.5%)	13 (29.5%)	
Normal range	58 (68.2%)	30 (73.2%)	28 (63.6%)	
>6 mmol/L	6 (7.1%)	3 (7.3%)	3 (6.8%)	
<i>IVH** or PVL***</i>				p=0.288
Yes	11 (12%)	3 (7.5%)	8 (17.0%)	
No	72 (78.3%)	36 (90.0%)	36 (76.6%)	
PVL	4 (4.3%)	1 (2.5%)	3 (6.4%)	
<i>Early sepsis</i>				p=1.0
Yes	1 (1.1%)	0 (0%)	1 (2.1%)	
No	87 (94.6%)	41 (100%)	46 (97.7%)	
<i>Late sepsis</i>				p=0.701
Yes	41 (51.1%)	20 (48.8%)	21 (44.7%)	
No	47 (44.6%)	21 (51.2%)	26 (55.3%)	
<i>pH</i>				p=0.295
<7.25	47 (56.0%)	20 (50.0%)	27 (61.4%)	
>=7.25	37 (44.0%)	20 (50.0%)	17 (38.6%)	
<i>Death</i>				p=0.123
Yes	4 (4.3%)	0 (0%)	4 (8.2%)	
No	86 (93.5%)	41 (100%)	45 (91.8%)	
<i>Mode of Delivery</i>				
SVB		9 (21%)	13 (26.5%)	
LSCS		26 (60.5%)	28 (57.29%)	
Vacuum		1 (2.2%)	0	
Forceps		0	1 (2%)	
Not recorded		7 (16.3%)	7 (14.3%)	

*SD= standard deviation; ** IVH = intraventricular haemorrhage; *** PVL=periventricular leucomalacia

Table 4: Studies on the use of plastic wrap and bags in premature infants

Author	Year	Design	Type	N=	Age	Temp	Result
Besh et al	1970	RCT	Plastic wrap	85	> 2kg	Rectal	Increase in temperature in infants in the plastic wrap.
Bosch et al	1996	RCT	Plastic wrap	65	>35 weeks		Showed a reduction in hypothermia in infants placed in the wrap.
Vohra et al	1999	RCT	Plastic wrap vs. traditional	59	<32 weeks	Rectal	Increase in admission temperature in infants <28 weeks, no significant difference in temperatures 28-31 weeks
Bjorklund et al	2000	Observational pre and post audit	Plastic bag vs. traditional	77	<28 weeks	Axilla	Body temperature was increased to 36.5°C in 73% of infants in the bag, but only 23% of infants in the traditional method
Lenclen et al	2002	Matched pair analysis	Plastic bag	120	<33 weeks	Rectal	A significant higher rectal temperature was less frequent in the infants enclosed in the plastic wrap.
Lyon et al	2004	Pre and post audit	Plastic bag vs. traditional		23-28 weeks	Axilla	Mean admission temperature in infants in the plastic bag is 37°C
Newton & Watkinson	2003	Pre and post audit	Plastic bag vs. traditional	278	<30 weeks	Not known	Increase in admission temperature by 0.35°C, which resulted in a significant decrease in hypothermia in bagged infants.
Vohra et al	2004	RCT	Plastic wrap vs. traditional	59	<28 weeks	Rectal	Mean rectal temperature was significantly higher in the wrap group.
Knobel et al	2005	RCT	Plastic bag vs. traditional	88	<29 weeks	Rectal	Infants in bags have a higher mean admission temperature 36.5°C compared with 36.0°C.
Bredemeyer et al	2005	Pre and post audit	Plastic wrap vs. traditional	141	<30 weeks <1000g /25	Axilla	Use of the wrap improved admission temperatures for infants <27 weeks. No statistically

							improvement in admission temperatures for 27-29 week infants.
Dunamn et al	2006	RCT	Plastic wrap vs. traditional	30	Infants <1500g	Axilla	Infants in the wrap group reached a normal axillary temperature faster than the non-wrap group and required lower incubator temperatures.
Matthew et al	2007	Pre and post audit	Plastic ViDrape bag vs Traditional	27	<28 weeks	Axilla	Difference of 1.0°C between average admission temperatures between both groups. Better admission temperature in the bag group.
Ibrahim et al	2009	Retrospective pre and post audit	Plastic bag	253	<30 weeks	Axilla	Mean admission temperature was significantly higher in the bag group, especially in infants >28 weeks. No significant effect in infants 28-30 weeks.
Kent et al	2008	Retrospective pre and post audit	Plastic wrap & ↑ in ambient temperature	299	<28 28-31 weeks	Not stated	Wrapping and increasing ambient temperature improves admission temperatures, particularly those infants <28 weeks.
Singh et al	2010	Analysis of three case series	Plastic bag Exothermic mattress Traditional	375	<30 weeks	Axilla	Incidence of hypothermia significantly lower in bag and mattress compared with bag only & traditional group. A significantly greater proportion of babies in the bag and mattress group were hyperthermic when compared to the bag only and traditional group.
Carroll et al	2010	Retrospective cohort	Plastic bag vs. Traditional	140	ELBW	Axilla	Axilla temperature on admission was greater in the wrap group
Simon et al	2011	RCT	Plastic wrap vs. exothermic mattress	36	24-28 weeks <1250g	Axilla	41% in mattress group and 68% in the wrap group had admission hypothermia.
McCarthy et al	2011	Prospective	Plastic bag	43	<31	Axilla	The mean admission

			exothermic mattress		weeks		temperatures were similar in both groups, however both high and low temperatures frequently occurred in infants with bag and mattress.
Lewis et al	2011	Quasi experimental design	Plastic wrap, chemical mattress and room temperature	428	1500 <32 2 grps (<1000 g 1000-15000g	Axilla	For each of the three interventions, the percentage having a normal NICU Admission temperature in each intervention group exceeded the control group percentage.
Rohana et al	2011	RCT	Plastic wrap	110	24-34 weeks		Wrapping infants with a gestational age <34 weeks in plastic immediately after birth is associated with lower incidence of hypothermia.

Summary of manuscript

Occlusive plastic wrap or bag applied immediately after birth to reduce heat loss and increase admission temperature has been proven effective in preterm infants. This study aimed to determine the effectiveness of the plastic wrap applied after birth on admission temperature to a regional NICU. All staff was educated prior to the trial commencing and education of staff was on going until the trial was complete. A total of 95 infants were randomised n= 51 in the control group and n=44 in the intervention group. Ninety-two were analysed, 52.2% were less than 27 weeks gestation and 47.8% less than 30 weeks gestation. It was evident the wrap was difficult to handle at times as the wrap was large in size and when the infant was wrapped there was always a large excess to manage. However, the trial did show a significant improvement in admission temperatures in neonates who were in the intervention group (wrapped) versus the control group (conventional care).

Chapter summary

In summary, the use of the plastic wrap soon after birth was shown to minimise heat loss and increase temperature on admission to a regional NICU in infants <30 weeks gestation. The next chapter provides a number of case studies including one that identifies an additional advantage to the use of plastic wrap.

CHAPTER 5: EXSANGUINATION, SAVED IN A TIMELY MANNER BY THE PLASTIC WRAP: A CASE REVIEW

Introduction

This chapter presents a number of case studies published during the period of candidature on issues of relevance to the neonatal specialty area.

Case study 1

Although the use of plastic wrap as a means of preventing heat loss in preterm infants has proven advantageous in many ways, there have been some disadvantages to its use. The disadvantages include hyperthermia, the difficulty of managing the wrap and keeping it closed, the issues involved when the wrap is a secondary consideration during a prolonged resuscitation, and the difficulties that arise when a procedure such as the re-siting of a saturation probe involves the displacement of the wrap. Despite these disadvantages the author and team found an added advantage (apart from increasing admission temperature) when using the plastic wrap; the ability to have full visualisation of the infants without fully compromising heat loss.

Publication 4: Saved in a timely manner by the plastic wrap: A case review

Declaration by candidate

The extent of candidate contribution to the following publication is as follows:

Thesis	Article	Publication Details	Author Contributions	Impact Factor/h Index
Chapter 5	Exsanguination: saved by the plastic wrap: A case review.	Under review in: <i>Journal of Neonatal Nursing</i>	Author J.Smith (50%) K.Usher (50%)	

Declaration by co-authors

The undersigned hereby certify that:

- The above declaration correctly reflects the extent of the candidate's contribution to the work and the extent of contribution of each co-author;
- They meet the criteria for authorship in that they have participated in the conception, execution, or interpretation, of at least part of the publication in their field of expertise;
- They take public responsibility for their part of the publication, except for the responsible author who accepts overall responsibility for the publication;
- There are no other authors of the publication according to these criteria;
- Potential conflicts of interest have been disclosed to (a) grant bodies, (b) the editor or publisher of journals or other publications, and (c) the head of the responsible academic unit; and
- The original data are stored at the following location and will be held for at least five years from the date indicated below:

Location	School of Nursing, Midwifery & Nutrition
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Candidate signature		27 September 2012
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Exsanguination, saved in a timely manner by the plastic wrap: A case review.

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Abstract

Introduction: Plastic wrap is an example of an intervention developed to prevent or minimise heat loss in the newborn. Plastic wrap enables clinical staff easy of access and visualisation of the newborn at all times.

Case presentation: A 24-week infant was placed in a plastic wrap as part of a clinical trial. A cord bleed was noticed soon after birth. The rapidness of the problem indicated an additional advantage of the application of plastic wrap.

Introduction

The impact of cold stress in newborns, first recognised by Silverman in 1958, continues to be a significant clinical problem today. Prevention of hypothermia in the newborn is therefore one of the basic tenets of contemporary neonatal nursing. Significant effort has been directed toward decreasing the incidence of hypothermia in neonates, including studies related to temperature measurement, modes of measurement, interventions during delivery, temperature management during stabilisation and transport, aspects of ongoing care in the neonatal unit, and testing of new warming devices (Lyon and Freer, 2011). However, regardless of these attempts to develop strategies for the management of hypothermia in the preterm infant, research indicates that very low birth weight infants continue to have lower than desirable temperatures at time of admission to neonatal intensive care units. While most newborn infants appear to be quite resilient and seem to experience few lasting side effects from the sudden drop in temperature (Fellows, 2011), the risk from cold stress is much greater for preterm infants who have an immature thermoregulatory system (Rutter, 2005; Bissinger and Annibale,

2010; Carter and Schucany, 2008). Hypothermia in the preterm neonate can cause a myriad of physiological changes that can have a potential detrimental effect on the infant if left unchecked; these include a delay in transition from foetal to extra uterine life, an increase in oxygen requirements, difficult resuscitation, increased incidence of disseminated intravascular coagulopathy, post delivery acidosis, worsening respiratory distress syndrome, necrotising enterocolitis and increased morbidity from infection (Soll, 2008).

In order to avoid these problems a number of interventions have been developed in an attempt to prevent or minimise heat loss in the newborn; these include swaddling, hats, skin-to-skin care, kangaroo care, increased environmental temperatures, emollients, humidity, incubators, plastic wraps, and radiant warmers (Meyer, 2003; Pabst, 1999; McCall, 2005; Vohra, 2004; Bauer, 1998). In particular, research on the use of the plastic wrap or bag since the early 1970's has confirmed its usefulness as a warming method in preterm infants (Besh et al., 1970); Knobel, Wimmer and Holbert, 2005; Simon et al., 2010; Rohana et al., 2011; Kent & Williams, 2008; Carrol et al., 2010) (See Table 1 for further trials) and it has now become a common strategy in many neonatal units for the management of hypothermia in preterm infants.

Figure 1: Premature infant placed in a plastic wrap



Adverse Events

Although the use of the plastic wrap or bag has been successful in minimising heat loss in many preterm infants there has been some complications associated with their use. For example, hyperthermia has been linked with the use of the plastic wrap (McCarthy, 2011), and the wrap has been said to be difficult to manage in some cases (Simon et al., 2011).

Presentation and Birth History

Baby H was a male infant born at 24 weeks gestational age to a 21 year old Gravida 1, P0, who had a blood group A+ (antibody negative), rubella immune, Hepatitis B and C negative, HIV negative, was RPR/TPHA non reactive and evidence of group B streptococcus was unknown at the time of delivery. The pregnancy was uncomplicated until 24 weeks gestation when the woman presented to the local hospital with abdominal pain and bleeding. On examination she was established to be 6 cm dilated with bulging membranes. Steroids were administered to speed up the process of lung maturation and Nifedipine was administered in an attempt to suppress labour; however, contractions continued necessitating transfer by helicopter to a tertiary hospital. Soon after admission a live male infant was born weighing

645 grams. He was in a fair condition at birth with Apgar score of 6 @ 1 minute and 6 @ 5 minutes respectively. He was immediately wrapped in the plastic wrap, head dried and hat applied and covered in warm towels. He was provided with intermittent positive pressure ventilation (IPPV) via bag and mask soon after birth, and then nasally intubated with a size 2.5 endotracheal tube. After intubation he quickly stabilised and all observations remained within normal parameters for his gestation. Prior to transfer to the NICU it was decided to undertake a quick assessment to enable mum to see her baby; as he had the plastic wrap for thermal protection, concerns about heat dissipation were minimal. When the towels were removed to assess chest movement and general colour, it was immediately noted he was lying in a pool of blood. On immediate inspection it was obvious that the cord had been cut below the cord clamp. The cord was quickly double clamped which immediately stemmed further blood loss. It was difficult to accurately estimate the volume loss, however it was agreed that the infant had lost about 15-20mls; approximately one third of the infants total blood volume. The infant was immediately transferred to NICU and placed in a pre-warmed, pre-humidified incubator. Umbilical lines (arterial and venous) were inserted. Whilst the lines were inserted it was again noted that there was a leak from around the umbilical artery, which proved difficult to stop. The cord tie was replaced and repeatedly tightened, sutures were used in an attempt to close the leaking artery but adrenaline and Kaltostat were eventually required to stem the bleeding.

One-hour post birth the infant remained pale with a formal haemoglobin (Hb) of 105, haematocrit (Hct) 0.34, red cell count 3.09, platelets 193, white cell count 15.1, neutrophils 6.7, lymphocytes 7.6 with no bands. He was given a packed cell transfusion of 16 ml one hour after birth and had a further 17mls of packed cells with 4ml of fresh frozen plasma over the next eight hours. Final Hb was 160 on day two of life and the infant appeared to have experienced no lasting adverse effects from the incident.

Discussion

This case study highlights one of the advantages of the use of the plastic wrap or bag in this vulnerable population. To assess the infant, any warm towels would have to be removed, therefore exposing the preterm infant to the cool environment, so the resuscitation team would normally be reluctant to open the warm towels once insitu unless there was deterioration in the clinical condition. Because this infant was wrapped in plastic after birth, followed by the application of warm towels, concern about potential heat loss was not an issue. As a result, the blood loss was noted quickly. If the infant had not been placed in the wrap, blood loss may not have been noticed for some time. Once resuscitation is complete and observations remain stable, infants are usually transferred directly to the NICU. Hence the plastic wrap allows the staff to pull back the warm towels to observe the infant more readily and it also offers opportunities for infants to spend some time with their family prior to transfer to the NICU.

If this event had not been detected so quickly then deleterious effects could have ensued. Infants who suffer from large blood loss respond well if

treatment is initiated quickly, as was the case in this situation. If there had been a delay in noticing the blood loss then end-organ hypoperfusion with hypoxia could have resulted in organ failure, which may have led to the death of the infant.

Conclusion

This case identifies an advantage when using the plastic wrap in preterm infants. Not only did the plastic wrap assist with the maintenance of a life sustaining body temperature, but it also allowed for easy access and observation of the infant. In particular, the use of the plastic wrap enabled the medical and nursing team to maintain visual observation of the infant during and immediately after resuscitation enabling the rapid detection of the bleed from the cord.

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Table 1 – Plastic Wrap and Bag Trials

Author	Year	Design	Type	N=	Age	Temp	Result	
Besh et al	1970	RCT	Plastic wrap	85	> 2kg	Rectal	Increase in temperature in infants in the plastic wrap.	
Bosch et al	1996	RCT	Plastic wrap	65	>35 weeks		Showed a reduction in hypothermia in infants placed in the wrap.	
Vohra et al	1999	RCT	Plastic wrap vs. traditional	59	<32 weeks	Rectal	Increase in admission temperature in infants <28 weeks, no significant difference in temperatures 28-31 weeks	
Bjorklund et al	2000	Observational pre and post audit	Plastic bag vs. traditional	77	<28 weeks	Axilla	Body temperature was increased to 36.5°C in 73% of infants in the bag, but only 23% of infants in the traditional method	
Lenclen et al	2002	Matched pair analysis	Plastic bag	120	<33 weeks	Rectal	A significant higher rectal temperature was less frequent in the infants enclosed in the plastic wrap.	
Lyon et al	2004	Pre and post audit	Plastic bag vs. traditional		23-28 weeks	Axilla	Mean admission temperature in infants in the plastic bag is 37°C	
Newton & Watkinson	2003	Pre and post audit	Plastic bag vs. traditional	278	<30 weeks	Not known	Increase in admission temperature by 0.35°C, which resulted in a significant decrease in hypothermia in bagged infants.	
Vohra et al	2004	RCT	Plastic wrap vs. traditional	59	<28 weeks	Rectal	Mean rectal temperature was significantly higher in the wrap group.	
Knobel et al	2005	RCT	Plastic bag vs. traditional	88	<29 weeks	Rectal	Infants in bags has a higher mean admission temperature 36.5°C compared with 36.0°C.	
Bredemeyer et al	2005	Pre and post audit	Plastic wrap vs. traditional	141	<30 weeks <1000g/25	Axilla	Use of the wrap improved admission temperatures for infants <27 weeks. No statistically improvement in admission temperatures for 27-29 week infants.	
Dunamn et al	2006	RCT	Plastic wrap vs. traditional	30	Infants <1500g	Axilla	Infants in the wrap group reached a normal axillary temperature faster than the non-wrap group and required lower incubator temperatures.	
Matthew et al	2007	Pre and post audit	Plastic ViDrape bag vs Traditional	27	<28 weeks	Axilla	Difference of 1.0°C between average admission temperatures between both groups. Better admission temperature in the bag group.	
Ibrahim et al	2009	Retrospective pre and post audit	Plastic bag	253	<30 weeks	Axilla	Mean admission temperature was significantly higher in the bag group, especially in infants >28 weeks. No significant effect in infants 28-30 weeks.	
Kent et al	2008	Retrospective pre and post audit	Plastic wrap & ↑ in ambient temperature	299	<28 28-31 weeks	Not stated	Wrapping and increasing ambient temperature improves admission temperatures, particularly those infants <28 weeks.	
Singh et al	2010	Analysis of three case series	Plastic bag Exothermic mattress Traditional	375	<30 weeks	Axilla	Incidence of hypothermia significantly lower in bag and mattress compared with bag only & traditional group. A significantly greater proportion of babies in the bag and mattress group were hyperthermic when compared to the bag only and traditional group.	
Carroll et al	2010	Retrospective	Plastic bag	140	ELBW	Axilla	Axilla temperature on	

		cohort	vs. Traditional				admission was greater in the wrap group
Simon et al	2011	RCT	Plastic wrap vs. exothermic mattress	36	24-28 weeks <1250g	Axilla	41% in mattress group and 68% in the wrap group had admission hypothermia.
McCarthy et al	2011	Prospective	Plastic bag exothermic mattress	43	<31 weeks	Axilla	The mean admission temperatures were similar in both groups, however both high and low temperatures frequently occurred in infants with bag and mattress.
Lewis et al	2011	Quasi experimental design	Plastic wrap, chemical mattress and room temperature	428	1500 <32 2 grps (<1000g 1000-15000g	Axilla	For each of the three interventions, the percentage having a normal NICU admission temperature in each intervention group exceeded the control group percentage.
Rohana et al	2011	RCT	Plastic wrap	110	24-34 weeks		Wrapping infants with a gestational age <34 weeks in plastic immediately after birth is associated with lower incidence of hypothermia.

RCT - Randomised controlled trial

HCT - Historical controlled trial

ROS – Retrospective observational study

Case study 2: Absence of the ductus venosus: a case report

Absence of the ductus venosus (ADV) have been reported infrequently. ADV can be associated with foetal malformations. Postnatal complications in this group can include pulmonary oedema, hepatic tumours, congestive heart failure and focal nodular hyperplasia. Therefore this case review is important in education as it allows the neonatal nurse to understand the significance of this condition and to be aware of the sometimes-fatal outcomes, which can occur.

Absence of the ductus venosus: a case report

The ductus venosus connects the umbilical vein with the inferior vena cava permitting oxygenated blood to return from the placenta to the fetal heart. Its absence has been recorded infrequently and has been associated with fetal demise. A case in which the umbilical vein joined tributaries of the hepatic vein and was associated with cardiomyopathy and early death from respiratory failure, is presented.

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Keywords

ductus venosus; fetal circulation;
ultrasound; embryonic; agenesis; foramen
ovale; cardiomegaly; anomalies

Key points

Smith J., Whitehall J. Absence of the ductus venosus: a case report. *Infant* 2008; 4(4): 121-23.

1. It was not until a decade ago that the first cases of absent ductus venosus (ADV) were detected *in utero*.
2. The ductus venosus plays a key role in the distribution of the umbilical venous return.
3. In fetuses with ADV umbilical venous occurs either by extrahepatic venous drainage or intrahepatic venous drainage.
4. The prognosis appears to be better in ADV cases with intrahepatic venous drainage.
5. Genetic counselling should be made available to parents of ADV infants in view of the high incidence of associated anomalies.

The ductus venosus (DV) is a blood vessel unique to the fetal circulation. Before birth the DV functions as a direct connection between the umbilical vein and inferior vena cava, bypassing the hepatic circulation and liver and shunting up to 40% of the oxygenated blood to the fetal brain and myocardium. In conjunction with other fetal shunts – the foramen ovale and ductus arteriosus – it plays a critical role in preferentially shunting oxygenated blood to the fetal brain.

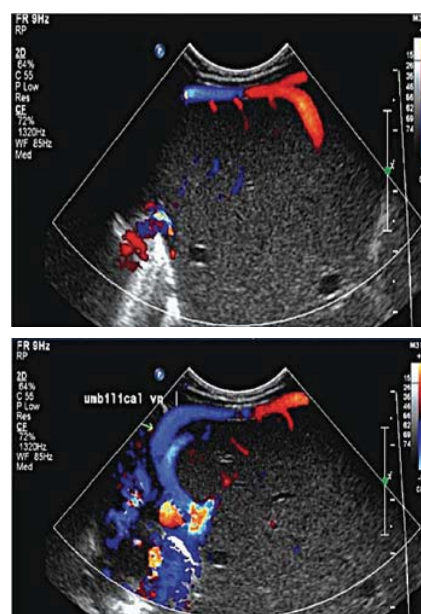
Ultrasound is an invaluable diagnostic tool in maternal-fetal medicine and with modern techniques the DV is easily identified. A case history with a rare finding of the absence of the DV, which was diagnosed during a routine ultrasound examination, is reported.

Case report

Before birth, a male infant was diagnosed with an absent DV, thick myocardium, tricuspid regurgitation and hydrops, together with an absent left kidney and large cysts in the right kidney. The umbilical vein coursed anteriorly over the surface of the liver towards the heart (FIGURE 1).



FIGURE 1 The umbilical vein coursing anteriorly over the surface of the liver towards the heart.



FIGURES 2 and 3 A confluence of veins which lead to the right atrium.

The infant was delivered by caesarean section at 29 weeks and six days for polyhydramnios and worsening hydrops fetalis. After birth he needed prolonged ventilation due to difficulties in oxygenation, associated with pulmonary hypertension as revealed by echocardiography and lung disease by X-ray.

Ultrasonography confirmed the umbilical vein coursing anteriorly to join a confluence of veins inferior to the right atrium. Multiple branches of the portal system were revealed to join the hepatic veins in a porto-systemic shunt which also drained into the confluence. The inferior vena cava was interrupted and though not visualised was concluded to also drain into the confluence (FIGURE 2 and 3). Head ultrasonography initially revealed a grade 3

haemorrhage and subsequently atrophy.

Echocardiography revealed bi-directional shunting through a patent foramen ovale, multiple small ventricular septal defects and a very thick myocardium which may not have compacted. There was also persistent pulmonary hypertension.

The infant remained in need of high concentrations of oxygen delivered under high pressure by various forms of ventilation, did not respond to nitric oxide or sildenafil and was unable to be resuscitated on day 98.

Literature review

Paired umbilical veins appear at the end of the second embryonic week. They enter the cardinal veins (major systemic venous channels), which then join the sinus venosus. The umbilical veins then fuse with the veins of the primitive gut and drain into the sinus venosus. At around the fourth to fifth week of embryonic development the liver bud extends swiftly and integrates the cranial portion of the vitelline vein (which drains blood from the yolk sac) into the hepatic sinusoids. The right umbilical vein regresses, and all the blood then flows through the left umbilical vein. Connections between the left umbilical vein and the intrahepatic sinus venosus are progressively lost. To ensure normal blood flow, the ductus venosus is formed by the coalescence of several hepatic sinusoids. This phase of development has been called critical anastomosis. If this normal development is disturbed, the embryology of the sinus venosus is disorganised and the ductus venosus fails to form. If the ductus venosus is absent other vascular connections must develop to allow proper oxygenation and development of the fetus¹.

It was not until a decade ago that the first cases of absent ductus venosus (ADV) were detected *in utero* using modern ultrasound techniques²⁻⁵.

The fetal DV connects the intra-abdominal umbilical vein to the inferior vena cava (IVC) at its inlet to the heart. The pressure gradient causes well-oxygenated blood in the DV to accelerate towards the left lateral wall of the IVC enabling its preferential streaming through the foramen ovale and ultimately to the cephalic and coronary circulation⁶. However the significance of the absence of the DV with direct communication of the umbilical vein to the heart is still very unclear. A study by Kiserud et al⁶ noted that in normal fetuses the amount of umbilical

venous blood streaming through the DV to the left heart decreased from 30% to less than 20% during the second half of pregnancy, ultimately resulting in an increase in percentage of blood flow to the liver compared to the brain. This data supports the hypothesis that the DV shunt plays less of an important role in supplying well-oxygenated blood to the brain and the myocardium in late gestation⁷.

In the absence of the DV the normal streaming of highly oxygenated umbilical venous blood through the foramen ovale to the left atrium is absent. According to Jaeggi et al⁸ the reason why we do not see any growth restriction in these infants is because the entire oxygenated blood from the placenta returns directly to the heart via the umbilical vein so that fetal arterial blood oxygen concentration may not be affected.

The DV however plays a key role in the distribution of the umbilical venous return, even more so because the fraction of the umbilical blood streaming through the DV increases significantly in hypoxaemia and decreased return^{6,9}.

There are two different routes for umbilical venous return that have been described in fetuses with ADV:

- extrahepatic venous drainage bypassing the liver, where the umbilical vein directly connects to the iliac vein, the IVC, the renal vein, the right atrium or exceptionally the left atrium of the coronary sinus^{8,10-12}
- intrahepatic drainage, without liver bypass, where the umbilical vein connects to the portal sinus in its usual way without giving rise to the DV^{6,11,13}.

In a cohort, studied by Berg et al¹⁴, a total of 63 prenatally diagnosed cases with ADV were reported over the ten year study period. A significant association was demonstrated between extrahepatic umbilical venous drainage, portal vein agenesis and cardiomegaly, which has been linked to severe postnatal complications. In infants with extrahepatic umbilical venous drainage who have no additional fetal anomalies, the prognosis seems to depend on the presence or extent of any fetal congestive heart failure^{8,12}. The prognosis of isolated ADV seems to be more favourable in the presence of intrahepatic venous drainage¹⁴.

Among the fetuses with no or minor associated anomalies the outcome was significantly better in the group without liver bypass. None of the 13 fetuses without

liver bypass died or had long term sequelae attributed to ADV, whereas in the group who were diagnosed with liver bypass, 20 out of 29 died¹⁴.

According to some reviews previous cases of ADV with extrahepatic umbilical venous drainage were associated with fetal malformations which included aneuploidies (varying numbers of chromosomes), high output cardiac failure and significant agenesis of the fetal portal system. Postnatal complications in this group can include pulmonary oedema, hepatic tumours, congestive heart failure and focal nodular hyperplasia^{8,11-13}. It has also been noted that cardiomegaly seems to occur frequently when there is direct drainage of the umbilical vein to the heart, which suggests a high central venous pressure. This can be due to volume overload because of the loss of the DV regulatory mechanism, which may result in high output failure and fetal hydrops^{10,12}.

Conclusion

Absence of the ductus venosus has been reported infrequently. If the umbilical vein joins the portal vein within the liver the prognosis is more favourable but, as in this case, if it courses externally, the outcome is poor. It is often associated with other abnormalities and heart failure. This case appears unique with the widespread abnormalities of systemic and portal vasculature.

Careful evaluation of the DV should be done routinely on fetuses that show evidence of cardiomegaly and polyhydramnios. In view of the limited knowledge of the mechanisms involved in the genesis of this anomaly and its associations with congenital malformations, fetal karyotyping should be considered. Genetic counselling should also be made available to the parents of an ADV fetus in view of the high incidence of associated anomalies.

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Case study 3: Parvovirus B19: a case history and literature review

Human parvovirus B19, has a vertical transmission rate of 33% (PHLS, 1990) and an annual infection rate of 1.5% (Koch & Adler, 1989). Women are especially vulnerable if they care for school age children, particularly within the close family environment (Anderson et al, 1990). Therefore knowledge of this condition is recommended for nurses for working in the neonatal environment.

Human parvovirus B19: a literature review and case study

Human parvovirus is ubiquitous. It affects human erythroid precursors causing their lysis and apoptosis, resulting in varying degrees of interference with red cell production. There is a range of clinical presentation from no obvious abnormalities, to the classic 'slapped cheek' and lacy body rash in a child, to fever and arthropathy in an adult. The level of haemoglobin may fall by 20g/dL or more precipitating anaemia in susceptible people. Amongst the most susceptible are unborn babies who suffer from a high rate of abortion if affected in the first trimester, anaemia that may result in non-immune hydrops in the second trimester, and *in utero* death in the third trimester. An illustrative case study of hydrops in the second trimester treated by *in utero* transfusion is presented, with a review of the literature.

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Parvovirus B19

Human parvovirus is a small (*parvus* in Latin means small) non-enveloped virus with a single strand of DNA, packaged with its three types of proteins into a particle with twenty sides (icosohedral symmetry)¹. Its limited amount of DNA requires it to join a mitotically active cell in order to reproduce and it attaches to several types of cells, but especially the erythroid progenitor cells. Platelet precursors may also be affected. This attachment is by means of a special protein on the surface of certain cells, the P antigen.

Parvovirus was discovered serendipitously in 1974 and is the only member of the family *Parvoviridae* known to be pathogenic in humans. It was identified while evaluating tests for hepatitis B virus surface antigen and named after the location of the laboratory sample in which it was found: number 19 in panel B². It was officially recognised in 1985 as a member of the *Parvoviridae* and given the name B19 by the International Committee on Taxonomy of Viruses³. At first, it was a virus without any obvious disease but an association with transient aplastic crisis in patients with sickle cell anaemia was noted in 1981⁴. Two years later it was linked to the childhood infection, erythema infectiosum (slapped cheek disease)⁵. It was then found to be associated with red cell aplasia and arthropathy in adults, myocarditis, neuropathies and perhaps even auto-

immune disease.

Due to the clinical similarity to rubella it was postulated that infection in pregnancy would result in structural defects in the offspring. However, while defects have not been confirmed, it has become recognised that *in utero* infection may result in abortion, hydrops and intrauterine death.

Case study

On a routine ultrasound at 20 weeks and 3 days of gestation, the fetus of a 32 year old gravida 3, para 2 lady was found to have signs of severe hydrops, including ascites, skin oedema, pericardial effusion, cardiomegaly, tricuspid regurgitation, hepatomegaly and placentomegaly. No other structural anomalies were found but the velocity of blood in systole in the middle cerebral artery was elevated suggesting reduced viscosity due to severe anaemia.

Blood samples from the mother on that day revealed elevated levels of IgM and IgG and the presence of parvovirus B19. It was apparent the baby was at severe risk of death from anaemia, resulting in cardiac failure and hydrops, and an intrauterine transfusion (IUT) of blood was undertaken (FIGURES 1 and 2).

Two cordocentesis and intrauterine blood transfusions plus one platelet transfusion were given to the fetus. Prior to the IUT fetal haemoglobin (Hb) was 3.3g/dL and 3.4g/dL, with a platelet count of 27,000; post IUT the Hb was 13.0g/dL

Keywords

Parvovirus B19; infection; fetal anaemia; hydrops fetalis; *in-utero* transfusion

Key points

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1. Parvovirus B19 is a common infection in humans.
2. It affects erythroid precursors resulting in decreased erythropoiesis.
3. It is usually spread by respiratory means but can pass vertically from mother to fetus.
4. It can lead to miscarriage, hydrops fetalis and intrauterine death.
5. Intrauterine blood transfusions can compensate until the effect of the virus passes.

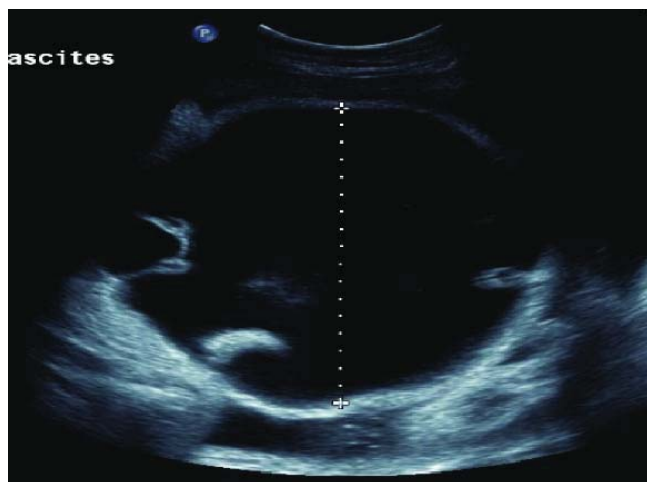


FIGURE 1 Transverse ultrasonography of the abdomen of the fetus revealing a huge amount of free fluid (black) in which a few loops of bowel are floating.



FIGURE 2 Transverse ultrasonography of the fetal chest revealing cardiomegaly and oedematous chest wall.

and 11.7g/dL respectively. The fetus stabilised, but there remained persistent fetal hydrops, gross ascites, scalp oedema and an enlarged heart.

A live female infant was born at 36 weeks' gestation by emergency lower segment caesarean section, for fetal hydrops and previous sections. Apgars were 6 at one minute and 8 at five minutes. She appeared pale and was suffering from respiratory distress complicated by a grossly distended and tense abdomen (**FIGURE 3**). She was intubated, and transferred to the neonatal intensive care unit as the consultant was concerned about diaphragmatic splinting and wanted to ensure that the baby was well oxygenated as soon as possible to avoid going into refractory persistent pulmonary hypertension. Left and right intraperitoneal drains were inserted; 870mL of ascites fluid was drained and sent for microscopy, culture, viral studies and albumin. Bloods were sent for FBC, LFTs, U&E, CRP, Coag, B/C, and virology.

Parvovirus B19 DNA was not detected in the ascitic fluid nor was specific IgM detected in the blood of the baby, although IgG levels were elevated. Echocardiography and ultrasonography of head, liver and kidneys revealed no abnormalities.

Enteral feeds were commenced on day one of life and the infant has tolerated feeds since.

She recovered quickly: was intubated within hours, fed enterally on the first day and discharged breastfeeding on day 5 with no evidence of congenital abnormalities.

She is now 15 months old and is generally well but is exhibiting significant

gross motor delay. She can only sit aided and cannot stand, but has reasonable hand control and is interested in her surroundings and communicates with about eight words. She has a lax abdominal wall.

Discussion

This case illustrates the danger of fetal infection and the value of intrauterine intervention in some babies. This baby must have been close to death.

The effect of parvovirus on the fetus is a result of the attachment and subsequent invasion by the virus of mitotically active cells bearing the specific attachment protein, P antigen, on their surface. Particularly affected are erythroid and megakaryocyte precursors and myocardial cells. The virus causes the erythroid precursors to lyse and to apoptose resulting in anaemia.

The virus spreads vertically from mother to fetus^{6,7} and if the mother is infected in the first trimester, about 10% of pregnancies are miscarried. If infected in the second trimester, there appears to be a 1% chance of developing hydrops and if infected in the third trimester, about a 1% chance of intrauterine death.

The most critical time of infection appears to be the 16th week of gestation⁸⁻¹¹ associated with the hepatic period of haematopoietic activity^{11,12} when the life span of the fetal red blood cell is shortened and red blood cell mass increases three to fourfold to meet the demands of fetal growth¹³. Fetal death usually occurs around 4-6 weeks post infection but has been reported up to 12 weeks after B19 infection¹⁴.

Hydrops fetalis appears to be a result of anaemia due to interruption of rapidly increasing erythropoiesis at that stage of pregnancy. The anaemia may cause high output cardiac failure which, in turn, may reduce the oxygenation of the endothelial cells of blood vessels, while increasing pressure within them, resulting in the characteristic leak of fluids into tissues and body spaces seen with hydrops fetalis. With parvovirus, direct infection of myocardial cells may contribute to the failure. Increased production of blood in the liver may interfere with the function of the hepatocytes, resulting in decreased production of albumin which will reduce the oncotic pressure within blood vessels, worsening the oedema. Hydrops may occur rapidly, usually within 2-4 weeks after maternal B19 infection¹⁵.

Fortunately, the risk of developing hydrops after maternal infection is low: approximately 1%. The sero-prevalence of specific IgG denoting prior infection and life-long immunity increases with age from 2-15% of children from 1-5 years old, to 15-60% of children from 6-19 years of age to 30-60% in adults. Obviously many women are vulnerable, with an annual infection rate of 1.5%¹⁶. In these pregnancies, a vertical transmission rate of at least 33% has been established¹⁷.

Women are especially vulnerable if they care for school-aged children, particularly within the close family environment¹⁸. During outbreaks, transmission rates of 25% in schools and 50% at home have been reported¹⁹. Most pregnant women are asymptomatic though some experience malaise, arthralgia, fever and a rash¹⁵.

There is no correlation between the severity of the mother's illness and that of the fetus.

Whereas it was logical to fear a teratogenic effect of B19, none has been demonstrated in humans, including this case. The virus, however, has been associated with birth defects in animals, causing cerebellar hypoplasia and ataxia in cats, and anencephaly, microcephaly, facial defects and ectopic hearts in hamsters¹⁰.

In this case, the neurodevelopment of the baby is retarded, which may reflect tissue hypoxia but may also be due to infection of the fetal brain by the virus. There have been limited reviews of the outcome of fetal infection, but the rate of neuro-developmental abnormalities appears to be higher in cases of hydrops associated with parvovirus than with those associated with immune causes¹⁹. Neurological complications are being reported with increasing frequency in association with parvovirus B19 but there is uncertainty as to whether they are due to infection *per se*²⁰, or secondary immune responses. Ultrasonography failed to reveal any abnormalities on several occasions in this infant and there was no suggestion of cerebral inflammation at any stage.

The patulous abdomen which will require surgical correction in this case appears similar to that of 'prune belly' syndrome. It is probably due to interference with development of the anterior abdominal wall musculature by sustained distension by ascites. This complication has not been widely reported but has affected another B19 baby treated by *in utero* transfusion in Brisbane. (Dr Glen Gardener, Maternal Fetal Medicine, personal communication. 2008.)

Diagnosis

Diagnosis depends on clinical signs, specific serology and detection of viral DNA by PCR. Acute infection can be detected by the presence of viral DNA and the development of specific IgM which appears about 10 days after exposure, at around the time of the development of symptoms and signs of infection, in more than 90% of immunocompetent patients. Levels begin to fall after two months and may be detectable for six months. IgG antibodies appear soon after the IgM and persist for life.

Thus, if IgG is negative but IgM is positive, recent infection is likely. If both are positive, infection has most likely

occurred within recent months. If IgG is positive but IgM is negative, past infection is likely. If both IgG and IgM are negative, infection is unlikely and the mother is vulnerable. Exceptions to these rules occur, unfortunately, because of the considerable individual variations. For example, the mother may not have detectable IgM at the onset of hydrops fetalis.

Elevated levels of specific IgM in the baby will denote its active infection because this immunoglobulin cannot pass through the placenta. IgG, however, can cross the placenta and elevated levels in the baby will usually denote past maternal infection.

B19 DNA can be detected in amniotic fluid and in fetal blood by PCR, confirming infection²².

Infection in this baby was confirmed by maternal positivity of IgM and IgG and the growth of parvovirus in her blood at 20 weeks' gestation. Virus was not isolated from the amniotic fluid but the baby's IgG was positive, denoting placental transfer. The baby's IgM was negative, consistent with the testing several months after the infection. In retrospect, it would have been wise for us to have looked for the virus in the baby's blood after birth.

Treatment

There is no specific treatment for human parvovirus and there is a need for a vaccine with similar effect to the one that protects dogs from the species of parvovirus that causes distemper. That vaccine is very effective and has been produced because of the relative ease of reproduction of the virus in tissue culture. In contrast, B19 is not easily cultured and, therefore, would be more expensive to produce. According to

the discoverer of B19, Yvonne Cossart (personal communication, 2008) wider studies on the implications of the infection for neurological, cardiac, haematologic and auto-immune disease would permit a better estimate of the overall effect of the virus in developed countries and provide impetus for the development of the vaccine. Studies in developing countries reveal a heavy disease burden, with B19 infection contributing as greatly to the development of severe anaemia as falciparum malaria²³.

There have been as yet unproved suggestions that immuno-globulin might ameliorate infection in pregnant women^{7,24}, otherwise, apart from trying to avoid infected people, there is no specific therapy for the mother. There may also be a role for immunoglobulin for the fetus and baby. (Cossart Y. Personal communication. 2008).

The fetus should be observed for signs of anaemia revealed by increased velocity of blood flowing in systole in the middle cerebral artery (MCA). This velocity increases with the decrease of viscosity as the blood thins in anaemia and has been shown reliably to correlate with the degree of anaemia²⁵. Levels of haemoglobin <5g/dL are considered to warrant *in utero* transfusion of blood, and are usually associated with hydrops. Platelets should be counted on the specimen of blood taken from the fetus and should be transfused if low. The complications of *in utero* transfusion include spontaneous rupture of membranes, bradycardia, immediate delivery, miscarriage, chorioamnionitis and intrauterine death. Velocity in the MCA should be repeated weekly and



FIGURE 3 Grossly distended abdomen at birth.

transfusions repeated as necessary.

This baby required two transfusions, even though the haemoglobin rose from 3.3g/dL to 13g/dL in the first week. It probably fell in the next week in association with restoration of the circulating blood volume and dilution of haemoglobin.

It is not clear why this baby had persistent ascites. Liver function tests were essentially normal after birth and there was no evidence of congestive cardiac failure. The ascites did not return after it was removed and the liver function has remained normal.

Conclusion

Parvovirus B19 is a common virus that usually does not damage the fetus but miscarriage, non-immune hydrops, and death may occur. Fetal demise is greatest in the first 20 weeks of gestation, and most losses will occur 4-6 weeks after exposure. Fetal blood transfusions have been shown to be effective. There is no specific treatment for the viral infection and human beings must await the development of a similar vaccine to that which protects their canine brethren from a cousin of the human parvovirus.

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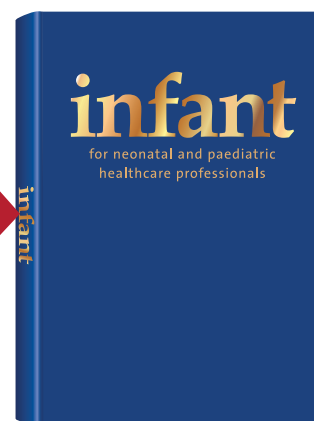
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Case Study 4: Sodium Valproate and the foetus: a case study and a review of the literature.

It is becoming increasingly evident that sodium valproate is widely used for epilepsy, but is becoming increasingly prescribed for such non-epileptic conditions as bipolar disease, migraine, pain relief and sleep disorders (James et al, 2007; Kennedy & Koren, 1998; Yonkers et al, 2004). It is teratogenic in its effect and can cause major abnormalities, therefore nurses need to be aware of the maternal history of pregnant women and understand the complexities of the drug in order to educate and fully inform about the risks of valproate therapy.



Sodium Valproate and the Fetus: A Case Study and Review of the Literature

*Jacqueline Smith, RSCN, MSc, NNP
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SODIUM VALPROATE (VALPROATE) IS WIDELY USED FOR epilepsy, but is increasingly prescribed for such non-epileptic conditions as bipolar disease, migraine, pain relief, and sleep disorders.¹⁻³ Valproate, however, is teratogenic, causing a wide range of abnormalities in offspring of many treated mothers.⁴⁻⁶ A particular facial dysmorphism and spina bifida in combination with other musculoskeletal disorders have been described as “fetal valproate syndrome.” Major abnormalities have been reported in 11 percent of exposed pregnancies in the U.S.,⁷ 6.2–14.4 percent in the U.K.,⁸ and 17.1 percent in Australia by the Australian Pregnancy Register for Women on Anti-Epileptic Medication.⁹

Women of childbearing age taking valproate should be counseled regarding its teratogenic effects, and modification of therapy should be considered. Folic acid supplementation has been shown to reduce the recurrence of myelomeningocele in mothers who have given birth to a previously affected child.¹⁰ Although this effect has not been demonstrated in mothers taking valproate, supplementation in a dose of 4–5 mg/day of folic acid is recommended.¹¹

We present a case of a mother prescribed valproate for bipolar disease in which neither warning of teratogenicity

nor advice on the need for folic acid supplementation was recorded. She produced a child with myelomeningocele.

ABSTRACT

Sodium valproate is a teratogen responsible for a wide range of abnormalities, including neural tube defects. It has traditionally been prescribed for epilepsy, but is increasingly used for such psychiatric conditions as bipolar disease. Women of childbearing age taking valproate should be warned of its teratogenicity and advised to plan pregnancies, take a higher dose of folate, discuss reducing the dose of valproate or changing the medication with their physician, and have antenatal screening. After birth, the infant should be examined for a wide range of reported abnormalities. Neurodevelopmental assessment should continue throughout childhood. We present a case that illustrates the need for better education of mothers taking valproate and the medical staff prescribing it.

CASE REPORT

A female infant weighing 2,870 g was born at term to a 25-year-old, gravida 1, para 0, mother. Diagnosed with bipolar disorder and from a remote town in Queensland, Australia, the mother had been taking valproate 1,500 mg/day. Her care had been shared by a general practitioner and a psychiatrist, who had prescribed the valproate. She had been taking valproate for about four years; it was discontinued because of an improvement in the mother's psychological condition with the fetus at 11 weeks gestation. The

obstetrician had not advised the mother regarding the use of valproate because the pregnancy was unexpected.

An ultrasound examination at 20 weeks gestation revealed a myelomeningocele. Termination of pregnancy was offered but refused. There was no record of discussion about the teratogenic effects of valproate, and the mother could recall no such discussions. There was no record of advice on the value of folate supplementation to reduce the risk of neural tube defects in general or with special relevance to valproate therapy. The mother took no folate or vitamin supplementation

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FIGURE 1 ■ Myomeningocele



until she realized she was pregnant. She then began the usual pregnancy folate supplementation dose of 0.5 mg/day, not the higher dose of 4–5 mg/day recommended for women at high risk for neural tube defects.¹²

The female infant was delivered by cesarean section because of failure to progress, with a brow presentation. She required no resuscitation and was admitted to the neonatal unit for surgical closure of the myelomeningocele (Figure 1).

There were no signs of infant withdrawal from the valproate because it had been discontinued at 11 weeks of gestation, nor were there disturbances in hepatic or glucose homeostasis, which have been reported in infants of mothers taking valproate throughout pregnancy.^{13,14} The half-life of valproate depends on whether the drug is used on its own or in conjunction with another anti-epileptic drug (AED). When used in monotherapy, valproate's half-life is approximately 10–12 hours. When used with other agents, its half-life may be as short as 5–6 hours.¹⁵ The myelomeningocele extended from the second to the fifth lumbar vertebrae and was associated with mild hydrocephalus and prominent Arnold-Chiari (Arnold Type II) malformation. Although the lesion was severe, there was surprising preservation of movement in the legs; the anus, however, was patulous. The kidneys and heart were normal on ultrasound examination, and no other abnormalities were noted. The infant tolerated surgery and recovered well. She was discharged on day of life (DOL) 11, but was readmitted on DOL 42 because of rapidly progressing hydrocephalus that required a ventriculoperitoneal shunt.

At three months of age, this infant had reached her appropriate milestones, though movement of the legs was impaired in accordance with a myelomeningocele at S1–S4. She was smiling, following with her eyes, showing interest in people and her surroundings, and reaching appropriately. Further follow-up for assessment of growth, intellectual and behavioral development, eyesight, and hearing will be done.

DISCUSSION

The teratogenicity of valproate was reported soon after this drug became available for treatment of epilepsy in the late 1970s.¹⁶ In 1982, a significant association with spina bifida was noted.¹⁷ In 1984, fetal valproate syndrome was described.¹⁸ Our case emphasizes the teratogenic effect of certain drugs that may not be well appreciated by physicians working in subspecialties that are distant from the intricacies of fetal development.

STATISTICS

In major studies in various countries, maternal treatment with valproate has been associated with a collection of major and minor anomalies in the neonate. In the U.S., two studies reported major congenital anomalies in 10.7 and 20.3 percent of exposed pregnancies.^{19,20} In Australia, major and minor anomalies have been described in 17.1 percent, in England, 14 percent, in Finland, 10.7 percent, in Sweden, 9.7 percent, and in the Netherlands, 6 percent.^{9,21–24} The rate of major anomalies in the general population is 1–3 percent.²⁵ There is a slightly higher rate of anomalies in offspring of mothers with epilepsy because of genetic influences.²⁶ Thus, the overall relative risk for major anomalies in offspring of mothers treated with valproate is considered to be 3.77 times higher than the risk in the general population. When compared with offspring of mothers treated with other AEDs, the relative risk is considered to be a factor of 2.59.¹¹ By way of comparison, thalidomide is believed to have been associated with a 20–30 percent rate of anomalies in offspring of treated mothers.²⁷

ANOMALIES

Antenatal screening should be performed for major anomalies. Short-term effects of maternal valproate use that would be of particular concern to neonatal nurses include not only congenital anomalies, but signs of withdrawal, which occur soon after birth. These signs and symptoms include hypoglycemia, irritability, jitteriness, hypotonia or hypertonia, feeding problems, and seizures.¹⁴ One study reported withdrawal symptoms in 20 percent of exposed neonates. These infants require follow-up developmental studies that should continue beyond infancy through childhood to identify late-presenting problems such as joint laxity, connective tissue weakness, otitis media with effusion, and minor malformations of the digits.⁴

A particular facial dysmorphism of thin arched eyebrows with medial deficiency, broad nasal bridge, short anteverted nose, and smooth, long philtrum with thin upper lip has been described.²¹ A wide range of anomalies, including neural tube defects, has also been described (Table 1). A review of 69 cases in the literature from 1978 to 2000 reported consistent facial phenotype and abnormalities in the musculoskeletal system (43 cases), the cardiovascular system (18 cases), the genitourinary tract (15 cases), the skin (21 cases), the respiratory tract (11 cases), and the eyes and ears. Abnormalities in

the neurologic system included neural tube defects (2 cases) and problems in neuronal migration and organization that resulted in intellectual and behavioral difficulties, including autism spectrum disorder, in as many as 20 of the infants.²⁸ Verbal intelligence quotients, in particular, have been reported to be reduced.^{29,30}

Comparison between studies is difficult because of varying methods of reporting, inexact amount of drug exposure, age of the child at examination, mode of evaluation of development, and such confounding influences as cultural differences and social status.³¹ Data from a 20-year study period in India revealed that 8.9 percent of those exposed to valproate *in utero* became autistic.³² In Canada and the U.K., a lengthy review revealed that 28 percent of exposed infants suffered developmental delay, and another 10.9 percent experienced behavioral disorders with normal development.⁴ (See: Pharmacokinetics—Anticonvulsant, Antipsychotic.)

TERATOGENIC EFFECTS

The teratogenic effects of valproate are not well understood and appear to be multifactorial. These include an effect on genes that control the early patterning of the fetus, a direct disruption of cell differentiation and proliferation that could interfere with the development of the neural tube and neuronal development, and an interference with folate metabolism, which is necessary for cell division. Widespread, dose-dependent, neuronal apoptosis has been observed in the rat model exposed to valproate.³³ The therapeutic effect of valproate appears to involve an increase in inhibitory neurotransmitters and alteration in ion channels that may indirectly interfere with neuronal migration and organization in the developing brain.^{34–39} The development of the brain may thus be interrupted by exposure in all trimesters of pregnancy.⁴⁰ The embryopathy has been seen to be repeated in siblings, so there may be a congenital susceptibility in some families.⁴¹

Folic acid is known to reduce the incidence of neural tube defects in the offspring of women not receiving anti-epileptic drugs.²⁵ A dose of 0.5 mg/day is recommended for all women likely to become pregnant. A dose of 5 mg/day is recommended for those at high risk as suggested by a family history of neural tube defect.¹¹ It is recommended that 5 mg be taken daily by women who are receiving valproate for whatever reason and who intend to become pregnant, but there is more hope than evidence for effect.^{2,9,19}

COMMUNICATION

Failure to inform the mother fully about the risks of valproate therapy is not unusual. According to a review of records of women attending a mental health institution in England, 138 women of childbearing age were prescribed mood-stabilizing drugs including valproate, but documented warning of teratogenicity was found in only 29 cases (21 percent). Thirty-three women (24 percent) had been advised about contraception, and 14 (10 percent) conceived while on

Valproate Pharmacokinetics Anticonvulsant, Antipsychotic

Site and mode of action	Not yet fully established. Valproate's anticonvulsant effect is attributed to the blockage of voltage-dependent sodium channels. However, there are some inconsistencies in the data. A combination of mechanisms that involves the excitatory amino acids, sodium flux, and potassium-mediated inhibition may be operative.
Absorption	Rapidly, almost completely absorbed in fasting patients following oral dosing with Epilim plain tablets, syrup, and sugar-free liquid. Absorption is delayed, however, if the medicine is taken with food. Peak blood levels occur within 1–4 hours.
Distribution	Rapidly distributed and most likely restricted to the circulation and rapidly exchangeable extracellular water. Cerebrospinal fluid and breast milk levels were found to be 5–15% and 1–10%, respectively, with 90% bound to plasma proteins, but only 60% bound to albumin.
Excretion	Valproate almost completely metabolized prior to excretion
Use in lactation	Only about 5% of valproate passes through to the breast milk, and even less enters through the baby's bloodstream. How valproate affects the infant is unknown, and most breastfed infants whose mothers are on valproate experience no side effects. The American Academy of Neurology and the American Epilepsy Society both recommend breastfeeding in women with epilepsy, and neurologists have the view that the benefits far outweigh the risk.

Adapted from: www.sanofi-aventis.com.au/products/aus_pi_epilim.pdf

TABLE 1 ■ Major and Minor Malformations Seen with Maternal Valproate Use

Epicanthal folds
Upturned nose/flat nasal bridge
Shallow philtrum
Thin upper vermillion border
Low-set ears
Hypospadias
Neural tube defects
Congenital heart disease
Genitourinary abnormalities
Laxity in joints
Glue ear

the mood-stabilizing drugs. Extrapolating to the whole of the U.K., it was predicted that between 7,000 and 11,000 women of childbearing age would have been prescribed such drugs without documented discussion of risks.¹

In Australia, prescriptions for valproate (presumably for psychiatric reasons) increased by 10 percent in 2004, reaching an approximate total of 660,000 in 2006. If each patient had four prescriptions each over a year, a quarter of women of childbearing age may be using this drug in 2008.⁴²

Warnings of the drug's teratogenic effects should be provided and recorded in the patient's medical record. Ideally, pregnancy should be planned and folate supplementation taken. The health care provider should work with the patient to find an alternate neuropsychiatric medication if possible. Alternative medications for maternal epilepsy include lamotrigine and carbamazepine, and alternative medication for psychological disorders, such as bipolar disorder, include lithium. Adverse effects have been described with these medications also, but at a rate lower than with valproate.⁴³ If an alternative medication cannot be used, the minimum dose of valproate for effect should be given, divided into several daily doses to minimize peak levels. Embryopathy is reported to be unlikely if the mother is receiving less than 1,000 mg/day, but the rate increases with dose, especially beyond 1,400 mg/day, when normal metabolism of the drug might be saturated and breakdown products accumulate.⁴⁴ Risks and benefits, therefore, need careful assessment, and full understanding by the mother and by the whole team of providers is essential. (R. Schwarz, perinatal psychiatrist, personal communication, 2008).

Contrary to other reviews,^{24,30,45,46} Vajda reports that monotherapy is associated with a higher rate of abnormalities in Australia than polytherapy, but considers the higher rate due to higher doses of valproate (Personal communication, 2008). Rat models, however, suggest greater apoptosis with polytherapy because of damaging synergism between various anti-epileptic drugs.³³ Some studies have reported lower developmental quotients in infants of mothers on polytherapy.⁴⁶

CONCLUSION

A major adverse effect in any change of established therapy is destabilization of the mother, and the underlying principle should not be forgotten: The infant needs a healthy mother. It is important to remember that withdrawal of anti-epileptic drugs for the mother may precipitate a catastrophic recurrence of seizures in which the fetus may be damaged from hypoxia. Indeed the overall death rate is higher in epileptic mothers, and uncontrolled seizures are considered a cause.²⁶

There is a need for more study of the effects of anti-epileptic drugs in pregnancy. Health care providers should consider encouraging affected mothers to join national registries. Valproate has been prescribed for epilepsy for almost 30 years, during which time its teratogenic effects have been recognized. Those effects, however, may not be well known by

those who prescribe valproate for psychological conditions. The effects of congenital abnormalities and withdrawal are of immediate concern to neonatal nurses, who are also in the position to advocate for long-term developmental assessment. Awareness of these effects should encourage consideration of alternative or reduced therapy.

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Case Study 5: Staphylococcal Scalded Skin Syndrome (SSSS): A case review.

A neonatal nurse should be able to understand many of the complex and sometimes rare diseases which can present in the neonatal unit. SSSS, although rare in the neonatal population can be a complex disease which encompasses the skin, hydration levels, infection risk, pain, nutrition and family support, therefore education is an important component in case study reviews.



EDUCATION ISSUES

Staphylococcus Scalded Skin Syndrome in the newborn: A case review

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Available online ■ ■ ■

KEYWORDS

Staphylococcus aureus;
SSSS;
Toxins;
Toxic shock syndrome;
Toxic epidermal necrolysis;
Desmoglein-1

Abstract *Introduction:* Staphylococcal Scalded Skin Syndrome (SSSS) is an extensive desquamative erythematous condition that usually affects infants and young children. It is caused by exfoliative toxins, ET-A and ET-B of *Staphylococcus aureus*. The disease generally responds quickly and effectively to antibiotic therapy. *Case presentation:* A term infant, no problems at birth and was discharged home on day four of life, but was admitted to the neonatal unit on day 18 due to SSSS, which affected over 90% of his body.

Introduction

Two main gram positive pathogens, streptococcus and staphylococcus cause many types of infections in the general population. There are less common types of diseases which are caused by Gram-positive rod shaped organisms such as Listeriosis, Diphtheria and Anthrax Mcadam and Sharpe, (2005).

Staphylococcal organisms are non-motile anaerobes. There are 32 known staphylococcal species, 16 of these are usually found in human skin and mucus membranes (Fraser Askin, 2004).

This review will concentrate on the staphylococcal pathogen causing scalded skin syndrome in

a newborn, also known as Ritter von Ritterschein disease (in the newborn), as it's first clinical features were described in 1878 by Baron Gottfield Ritter von Ritterohain (Mockenhaupt et al., 2005).

Staphylococcus scaled skin syndrome (SSSS) is usually seen in infants and children, rarely seen in adults and at birth (Patel and Finlay, 2003; Mockenhaupt et al., 2005). Factors which may be responsible for the high prevalence in infants and children can be due to renal immaturity; which leads to diminished clearance of toxins and lack of specific antibodies against staphylococcal toxins (Haveman et al., 2003). Up to 80% of infants become colonised, usually the skin, umbilicus and nares, with staph. aureus in the first few weeks of life (Fraser Askin, 2004). Although colonisation in infants is high, the incidence of infection is usually

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low. However the organism can be responsible for periodic outbreaks in neonatal units (Shinefield and St Geme, 2001). Transmission of exfoliative toxin-producing staph. aureus appears to be through asymptomatic carriers and is also carried by staff working in neonatal and pediatric units (Patel and Finlay, 2003).

The syndrome is characterised by blistering and epidermal peeling (Duijster et al., 2009), if you apply gentle traction to the bullae it results in the upper epidermis separating and wrinkling, which is known as Nikolsky sign (Uzun and Durdu, 2005).

The epidermis consists of five layers, stratum basale, spinosum, granulosum, lcidum and corneum. It is the stratum granulosum that newborns are susceptible to the dissemination of staph. aureus epidermolytic toxins. Onset is usually quick and will include blanching erythema, which often begins around the mouth. Within a short space of time a paper like wrinkling of the epidermis appears, and then bullae forms in the axilla, groin, abdomen, umbilicus and general distribution (Fig. 1).

Diagnosis of SSSS is based on histological and microbiology findings in collaboration with the overall clinical picture (Mueller, 2009) it has been associated with bullous impetigo in older children (Shi et al., 2011) and clinical symptoms can be similar to Steven Johnson syndrome, Kawasaki disease and Scarlet fever.

The mucus membranes are spared, which distinguishes it from toxic epidermal necrolysis (TEN) and toxic shock syndrome (TSS); these two conditions, are very rarely seen in the neonatal period. It is important to differentiate SSSS from TEN or TSS as SSSS is usually benign but TEN and TSS can be associated with higher morbidity and mortality (Kim et al., 2012). TSS is a multisystem disease manifested by sudden onset of fever, chills, hypotension and rash and is caused by toxin

producing strains of staphylococcal and streptococci.

The blistering is on the upper layer of the skin, caused by the release of exotoxin (ET), which is circulated systemically leading to a general eruption this, caused by a strain of staph. Aureus, as SSSS is usually caused by a phage 11 staph. aureus strain (which emerged in the 1970's).

ET is a bacterial protein that exhibits the hallmark structural and amino acid sequence features of a serine protease; an enzyme that cut some peptide bonds in other proteins. (Hanakawa and Stanley, 2004). Patel and Finlay (2003), state that there appears to be a connection between the scope of the disease, how much toxin is produced and if the toxin is released systemically or locally.

There are two main exotoxins (a toxin secreted by a microorganism) ET-A and ET-B, (Duijsters et al., 2009). ET-A has been found to be the most commonly secreted toxin, it's encoded on the bacterial chromosome and produced by 89% of isolates (Oono et al., 1997). ET-B is produced by 4% of isolates and the remaining 7% are ET-A and ET-B combined and co-secreted (Criber et al., 1994). ET-A and ET-B target the protein of desmoglein-1 (Dsg 1), in the zona granulosa of the epidermis. Dsg 1 is an important cell-to-cell attachment protein found only in the superficial epidermis (Amagai et al., 2002). ET's may fit into Dsg 1 which can specifically bind and activate ET (Hanakawa and Stanley, 2004). This highly specific and efficient cleavage of Dsg 1 allows bacteria to form a blister under the normal barrier of the skin in order to survive and proliferate (Hanakawa and Stanley, 2004) (Fig. 2).

The toxin will then circulate systemically from the site of introduction, for example the umbilicus and even though the toxins circulate through the body it only causes blistering in the epidermis (Simpson, 2003).



Fig. 1 Wrinkling of the epidermis with general distribution.

Postnatal history and presentation

Baby K was born to a 37 year old mother, gravida 4, para 4. She received antenatal care from the first trimester. Maternal serology which included, CMV, rubella, syphilis, toxoplasma were all negative. Parvovirus B19 IgG, Herpes Simplex 1 and EBV were all reactive.

Due to mild pre-eclampsia at 38 weeks and 3 days gestation a caesarean section was performed. A live male infant was born weighing 3.5 kg, good condition at birth and no resuscitation was required.



Fig. 2 Blister formation.

Mother and baby went home on day four; he was bottle feeding well with no concerns. On day 18 of life the mother presented at the emergency department with a referral from her general practitioner, due to skin peeling.

The mother had noticed a slight redness around the umbilicus area which escalated to blistering of the skin on the abdomen and sores around the mouth which were weeping. On closer inspection baby K had blisters on the face and axilla area. He continued to feed well, had wet and dirty nappies but remained a febrile. He was noted to be unsettled at times.

The family were well, but the 8 year old sibling has 'school sores' on the face. Baby K was admitted to the paediatric ward but became very unsettled, he was given paracetamol and codeine but it was evident from his cries and facial expression that the pain was not under control.

Treatment and management

There was more evidence of skin desquamation which was new and very extensive involving most of the body. He had large fluid filled blisters, therefore fluid loss and hydration was a concern.

For further critical care management he was admitted to the neonatal intensive care unit. On admission he was immediately placed in isolation. A peripheral venous line was inserted and Flucloxacillin and Clindomycin and Ciprofloxacin was commenced.

Due to the extensive skin exfoliation, as the skin was red and painful with more than 50% of the total body covered by blisters, morphine was commenced at 10 mcg/kg/hr but was soon increased to 20 mcg as he was very unsettled. It is recommended that if infants have severe SSSS which covers more than 50% of the body then

infants may need to be transferred to a tertiary paediatric, neonatal or burns unit for one to one critical care nursing and treatment (Kim et al., 2012).

Maintenance fluids were commenced at 120 ml/kg/d. Baby K could also demand bottled feed as required as this helped him settle

Extra fluids are encouraged to compensate for fluid loss (Simpson, 2003), drainage from a wound (in this case fluid filled blisters) can be a major source of fluid loss. Dehydration can also reduce tissue perfusion at a wound site because of reduced blood volume, limiting the supply of oxygen and nutrients (Johnstone, 2007). Good nutritional support is vital in the treatment of wounds (Thompson and Furham, 2005) and oral fluids were encouraged.

Blood investigations that were carried out were urea and electrolytes levels, C-reactive protein, full blood count, blood culture; all were within normal parameters. Skin swabs were sent which proved positive for staphylococcus aureus and enterobacter aerogenes which confirmed a clinical diagnosis of SSSS.

Once commenced on antibiotic therapy the lesions ceased to increase and no new areas of blisters or exfoliation occurred after 36 hours. Wound management consisted of ongoing assessment of skin lesions and dressing integrity. Twice daily dressing changes were performed in order to promote healing, prevent further infection and aid comfort. Damaged skin is at risk of contracting a secondary infection (Johnstone, 2007). Infection control practices were adhered to, to prevent further spread of SSSS to other patients but also to prevent secondary infection to Baby K, examples include, strict hand washing, clean dressing application, regular hygiene cares and clean sheets and restricting visitors.

The dressing products used were paraffin, which were applied to the lesions to help reduce fluid loss and help soothe the area. Prior to emollient the skin was cleaned with normal saline and excess emollient removed. Jellonet was applied (see Fig. 3) then bandages were wrapped around limbs and torso to prevent chafing of the skin (Fig. 4).

As the exposed denuded skin dried it developed a crusty, flaky appearance (Fig. 5).

Baby K was nursed on a radiant warmer with just his dressings and nappy on. SSSS can alter the thermoregulatory function of the skin. This can result from an underlying infection, the severity of



Fig. 3 Jellonet was applied.



Fig. 6 Infant prior to discharge.



Fig. 4 Bandages around limbs and torso.

infection and peripheral vasodilation (Patel and Finlay, 2003). Baby K's temperature was monitored by axilla temperature monitoring. Ideally a continuous skin temperature would have been an advantage, but, because the infant suffered from epidermal peeling, this was avoided.



Fig. 5 Crusty, flaky appearance.

Conclusion

Baby K spent a total of 13 days as an inpatient and was discharged home into the care of his parents. Baby K was taking demand bottle feeds, settled and sleeping for periods. His skin completely healed, aside from one area of skin on his right foot that had not fully healed, this was dressed with a dry bandage. He completed a 14 day course of antibiotics. An outpatient review was organised for 2 days later. Fig. 6 shows Baby K a day before discharge home.

Baby K had an uneventful course of treatment. His diagnosis, treatment and management proved to be well co-ordinated and implemented and therefore a positive outcome was achieved. Typical characteristics allow for early recognition and treatment; however it can still be associated with mortality (Patel and Finlay, 2003).

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Chapter summary

Even though research advocates the use of the plastic wrap or bag at birth, no long-term information regarding the use of this method has been studied. It has also been noticed that some infants placed in the wrap or bag soon after birth become hyperthermic, however, this has not been a common finding in the majority of studies. Displacement of the wrap has also proved a problem in some clinical situations especially in prolonged resuscitation. Many research trials have shown clearly that the use of this method immediately after birth can minimise heat loss in the preterm infant and therefore increase admission temperature when admitted to NICU. It has also been shown as an added advantage whereby the security of the infant's temperature offers parents the opportunity to spend time with their baby prior to admission to NICU and where the use of the wrap allows for better visual observation of the infant.

In this chapter these case reviews can add new lessons to be learned, with regards to treatments and outcomes in the neonatal population. In terms of research, the case reports can contribute to better understanding of a new and emerging infectious diseases or other clinical manifestations through a case series review. Publication in this area is highly welcomed by journals and can serve as a future point of reference.

CHAPTER 6: DISCUSSION

Introduction

This thesis concentrates on two main areas: thermoregulation and temperature measurement in preterm and term neonates. Two studies were undertaken during the professional doctorate and the results of these studies are discussed in this chapter.

Study 1: Concordance of temperature measurement in the preterm and term neonate using three thermometers

This study was undertaken to determine the agreement between three different thermometers in the axilla and tympanic region. The study was conceptualised as a result of the literature review and because the researcher works in a unit where the BD digital thermometer is used under the axilla for all neonates for temperature measurement. It has been noted that the BD digital thermometer can take up to one minute to assess a temperature. For the temperature to be as accurate as possible the nurse needs to keep the thermometer in line with the axilla, along the body and make sure the arm is close to the side, which can prove to be difficult at times, especially if you have a vigorous infant or an infant who does not tolerate handling very well. Preterm infants have special requirements for temperature regulation so being able to replace the BD digital device with one that is equally efficient yet much faster and causes less disruption to the infant has important implications for clinical practice.

A decision was made to study the SureTemp®Plus 692, as it was claimed to be quick and easy to use, and the Genius 2 tympanic thermometer, as it was also claimed to be quick, easy to use and as the probe had been redesigned to suit preterm and term neonates. Both of these thermometers had been trialled in paediatrics and adults and received a favourable response. They are also both in current use in Queensland Health adult and paediatric units.

Agreement between the BD digital and SureTemp®Plus 692 measurements were closer than the BD digital and Genius 2™ tympanic measurements. Specifically, the concordance correlation coefficient between BD digital and SureTemp®Plus 692 was 0.53 (95%-CI: 0.45 to 0.61) showing moderate agreement. The CCC between BD digital and tympanic Genius2™ was 0.25 (95%-CI: 0.17 to 0.31), showing poor agreement. The conclusion was that the SureTemp®Plus 692 was in agreement with the BD Digital thermometer, whilst the tympanic thermometer showed poor limits of agreement when compared to the BD digital thermometer. This result is in agreement with previous studies (Hicks et al., 1996; Cusson et al., 1997; Leick Rude & Bloom, 1998; Rosenthal & Leslie, 2006; Hutton et al., 2009; Lee et al., 2011).

It can be argued that the variations seen from the tympanic and axilla temperatures could be due to factors such as inter-rater reliability, operator technique, positioning of the thermometer and the use of different sites (ear and axilla), which may generate different temperature readings. The Genius 2 tympanic thermometer is also awkward to use as it is quite large in diameter (7") centimetres and weighs 160g. Considering a high percentage of our infants are less than 1 kilogram, it is not surprising staff found the thermometer difficult to use and manipulate in the incubator while trying to ensure the probe was placed in the correct site in the auditory canal. The SureTemp®Plus 692 is also quite large (8.46"x3.18"x2.43"centimetres) and weighs 357 grams, however, it has a distinct advantage of providing a retractable cord. The retractable cord can be easily pulled out of the main unit and placed under the axilla, which makes temperature measurement much easier especially when the infants are nursed in the incubator. In view of the positive results of this study the regional neonatal unit will be changing the thermometers currently in use on the unit from the BD digital to the SureTemp®Plus 692, as this thermometer was shown to be quick, causing less disturbance to the preterm neonate, easy to use and read, and in agreement with the current BD digital thermometer. No adverse events were noted throughout this study when using each thermometer.

The importance of accurate temperature measurement in the preterm neonate is an important clinical consideration. Given the untoward outcomes of hypothermia in this population, the clinical specialist must have confidence in the accuracy of the device in use and approach used for temperature measurement. Undertaking studies such as the one described here increases the likelihood that nursing care is based on evidence rather than availability of instruments or current untested practice.

What new knowledge does this study demonstrate? Based on the findings of this study we conclude that the SureTemp®Plus 692 can be used as a reasonable alternative to the BD digital thermometer in the neonatal population. The study also demonstrates that the tympanic thermometer was difficult to use, especially in premature infants when nursed in an incubator. It was felt the device was too large to manipulate into the portholes of the incubator and obtain the accurate positioning for a correct tympanic temperature.

The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial

Prior to the 19th Century the sick or preterm infant was largely ignored. As a result, the infant mortality rate was around 50%. The infant welfare movement (IWM) started in France in 1870 and then proceeded to Europe. The aim of this movement was to decrease mortality rates as infant mortality posed a threat to the strength of the population and long term national security. Two French obstetricians, Tarnier and Budin, endeavoured to prevent high mortality in infants. Coliney, a student of Budin, eventually came to be considered the founder of neonatology (Baker, 2000). Studies of the outcomes of hypothermia in neonates, especially preterm neonates, has shown that chances of survival are considerably reduced, the incidence of illness increased, and the rate of growth diminished (Toubas & Nelson, 2002). Even though these studies were mostly undertaken some time ago, the implication that hypothermia in infants is harmful and should be avoided remains important today; as a result many different methods have been tried over the years in order to diminish heat loss in the preterm infant soon after birth. Immediately

after birth is the most critical time as this is often when preterm infants lose large amounts of heat through conduction, convection, evaporation and radiation as discussed previously.

The use of the plastic wrap or bag is one strategy that has been advocated for minimising heat loss in preterm neonates since the early 1990's. However, the studies upon which the recommendations for this heat reduction strategy were based were small and no RCT was conducted until 1999. In the researcher's place of work it had been recognised that a high percentage of preterm infants had NICU admission temperatures less than 36.5°C, indicating mild hypothermia. As a result, it was decided to trial the application of plastic wrap in all infants born less than 30 weeks gestation to determine if the wrap would reduce heat loss and increase NICU admission temperature.

The trial confirmed the results of previous RCT studies (Vohra et al., 1999; Vohra et al., 2004; Knobel, Wimmer & Holbert, 2005; Simon et al., 2010; Bosch et al., 1996; Dunman, et al., 2006; Rohana et al., 2011), and showed that the application of plastic wrap does minimise heat loss. However, some difficulties with the use of the wrap were experienced. The problems were mainly to do with the size of the wrap, the placement of the saturation probe, displacement of the wrap, nappy placement, placement of peripheral venous lines, umbilical lines, weighing, chest x-ray and axilla temperature measurement. In the researcher's experience, some of the difficulties encountered in the wrap may be avoided by use of the plastic bag and not the wrap. The use of the plastic bag would eliminate many of the displacement issues, the nappy could be placed on the infant as soon as born (laid into the bag ready), however, the use of the saturation probe may remain problematic if the signal is poor. Maybe a saturation probe could be designed where it could be placed over the plastic straight onto the arm or leg therefore it would eliminate any displacement issues.

An important advantage of using the plastic wrap is the ability to have full visualisation of the infant. This can be essential, not only if there is a prolonged resuscitation (the team good easily assess colour, chest movement etc. through the wrap), but also for the accessibility of the infant to the parents. When the preterm infant has been

stabilised the parents would be able to see their infant, not just the head (as previously the infant was wrapped in warm towels and a hat and these towels would stay in place, as long as the infant remained stable, until admission to the neonatal intensive care unit). In addition, the cost of this strategy is low making it a cost effective, easy to use method of keeping infants warm.

While the findings of the study confirmed the use of the plastic wrap was associated with an increase in NICU admission temperature in infants <30 weeks gestation, it has also been suggested that size at birth is a significant determinant of admission temperature. Vohra et al. (2004) found an increase in rectal admission temperature by 0.21 degrees with 100g increases in birth weight. This may have some bearing on our findings as 72.7% (n=8) of our hyperthermic infants were over 1kg. Hyperthermia was recorded in 11 (11.9%) of our infants, which was similar to the rate of hyperthermia in previous studies (Matthew et al., 2007; Ibrahime & Yoxhall, 2008; Singh et al., 2010).

No side effects were noted after the wrap was removed. For example, skin integrity had not been breached, and there was no evidence of skin or systemic infection secondary to our intervention in early sepsis (p 0.849), and late sepsis (p 0.981) noted.

These findings are significant given that as technological advances are made, smaller and more immature neonates are surviving. Therefore, findings ways to support their temperature maintenance in the first few hours of life is essential. It is also important for nurses to be aware of the need for accurate temperature measurement and strategies to maintain heat so that they can deliver relevant care. Further, practice that is based on recent evidence is needed to ensure that all nursing care is evidence based.

CHAPTER 7: LIMITATIONS, RECOMMENDATIONS FOR EDUCATION, PRACTICE AND FURTHER RESEARCH

Introduction

This chapter presents the limitations found in both studies presented in this portfolio. Although the research studies reached their aims, there were some unavoidable limitations, which are discussed below. The following chapter makes some recommendations related to both research studies.

Specialist post registration education training equips nurses with the specialist knowledge to practise effectively in their specialised field. Therefore recommendations have also been made towards the importance of education in neonatal care and relates to some of the work undertaken in the doctoral specialisation subjects (1 and 2).

Study 1: concordance of temperature measurements in the preterm and term neonate using three thermometers

Limitations: Temperature Study and Plastic Wrap Trial

The temperature measurement study reviewed infants from a variety of settings and environments. Gestational age and weight did show a large variation, which may have had some impact on the final data. For example, infants were nursed in different environmental conditions including radiant warmers, incubators, open cots, waterbeds, and humidifiers. Temperature measurements were not limited to a particular person or select research team member, and inter-rater reliability was not assessed during the conduct of the study. However, education and instruction was provided for both day and night staff, although some staff may have missed educational sessions and/or practical demonstrations. In addition, as the temperatures were taken from two different sites, the axilla and tympanic, there may have been a variation in temperature, which could also be due to operator technique and positioning of the thermometer. Some staff found the Genius 2™ tympanic thermometer difficult to handle, especially if an infant was being nursed in an incubator. In that case they found it difficult to place the thermometer through the portholes and then

find the correct position in the ear. Errors are known to occur if the probe is not directed towards the tympanic membrane.

Although the plastic wrap RCT was conducted under strict and vigorous guidelines, there were still a few limitations to the study. In some instances, staff found it difficult to replace the saturation probe without disturbing the wrap. If there was a poor signal the probe would need to be resited, therefore it proved difficult to keep the wrap tightly close, when the probe was replaced. This may have had an impact on the study outcomes. In the case of prolonged resuscitation where the wrap became displaced or moved, the wrap seemed to impede the neonatal team's resuscitation efforts. Placement of a nappy, peripheral venous lines, umbilical line placement or simply weighing prior to going into an incubator, all had the potential to dislodge the plastic wrap and therefore contributes to heat loss. Some of the infants were noted to be hypothermic even though they were placed in the wrap. Any of the above incidents could have attributed to this factor. However, an issue often overlooked relates to the potential for large diuresis soon after birth. When this occurs and the pool of urine becomes cold, the neonate's temperature will drop. This may have been a problem for some infants for whom the plastic wrap was unsuccessful.

Recommendations for Further Research

- Research is required to further establish the validity and reliability of the non-touch IR thermometer in the neonatal population;
- Further research is required into the use of the tympanic thermometer in the preterm neonatal population;
- An RCT is needed to establish the validity and reliability of humidified and heated air, during stabilisation at birth when compared to the plastic wrap or bag in minimising heat loss at birth in preterm infants;

- Future researchers need to take into consideration the many variables encountered in the neonatal intensive care environment when conducting further temperature measurement and maintenance strategies;
- Further research is needed to ascertain if there are any differences when the plastic wrap and plastic bag is used in the preterm population

Recommendations for practice

As the literature states there are many different methods and devices for temperature measurement in the neonatal population; my recommendations are:

- Thermometers have to be quick, safe, accurate, hygienic and easy to use;
- When comparing new devices with an established one, in this case electronic and tympanic thermometers, with the BD digital thermometer, it is necessary to establish agreement prior to the use of the new device;
- Based on the present findings of the data it would seem the SureTemp®Plus 692 is a safe alternative to the BD digital thermometer;
- In using the SureTemp®Plus 692 it has the advantage of being easy to use and quick which decreases handling time and decreases the potential for stressful incidents in this fragile population.

A large influential study conducted at the beginning of 2000, the CESDI project 27/28, studied the outcomes of infants born less than 26 weeks gestation and the effect of the quality of care on the survival of the babies born at 27-28 weeks (Acolet et al., 2005). The studies reported that temperature on admission is an independent variable in predicting death in extreme preterm infants. Much work has therefore been accomplished in trying to minimise heat loss in premature infants at birth. This work mainly consists of the application of a plastic wrap or bag in infants born less than 32 weeks gestation. Evidence now suggests that the use of the plastic wrap or bag after birth is a more effective method of preventing heat loss, which was also confirmed in the RCT reported in this portfolio.

Further, an additional RCT, known as the HELP trial, designed to investigate the effect of the plastic wrap applied immediately after birth to infants born less than 28 weeks gestation, is currently underway. The investigators of this study are investigating the long-term outcomes of infants enrolled in the study up to 18 months of age; therefore some questions may be answered regarding the long term outcomes when using the plastic wrap or bag to prevent hypothermia in preterm neonates. Recommendations from the plastic wrap study include:

- It is recommended that the plastic wrap be used in all infants born less than 30 weeks gestation;
- Given that hypothermia in preterm infants is known as an independent variable in mortality, it is unethical to withhold this device if available in the future;
- Long-term neurological outcomes using this method are not yet available; hyperthermia can be associated with the plastic wrap or bag at birth it is recommended strict vigilance be applied when using this method in all preterm infants.

Recommendations for education

The specialist knowledge needed in the neonatal area relies on partnerships between hospital and higher educational institutions. However, there are currently no agreed standards of neonatal education in Queensland at present. Therefore, it is difficult to ensure consistent educational and practical goals are achieved in neonatal units. Often, under qualified nurses are employed in many neonatal units. Although neonatal units employ clinical facilitators, clinical nurse consultants and educators, they are often too busy to provide the consistent education new nurses need. In Queensland, a nurse can work in a neonatal intensive care environment once they have completed a degree in nursing or midwifery. However, it is advised that new graduates study for a further twelve months to gain a certificate in midwifery. It is further claimed that this further study will help the nurse have a better understanding of the problems that sick neonates will face when

admitted to NICU. However, I argue that although midwifery training helps to educate the midwife in some aspects of neonatal nursing, the problems faced in the critical care environment are unique and specialised and therefore need specialist educational programs. A certificate in neonatal nursing, available via an in-hospital training program, is recommended for all who intend to work in the neonatal intensive care environment. Also, core competencies have to be achieved and maintained throughout employment on the neonatal unit. However, there is still some disagreement about the exact nature of the core set of competencies required by neonatal specialists and the assessment criteria for evaluating these varies between institutions.

The four distance learning modules developed as part of this degree (Doctoral Specialisation subjects 1 and 2) will go some way towards improving the skills of the nurses working in the neonatal environment and provide specialist neonatal nurses with the knowledge required to understand the unique complexity and needs of the preterm and sick term infants. Recommendations for specialised education are:

- Post registration training is essential to allow nurses working in neonatal critical care areas to undertake additional specialist training;
- Fundamental knowledge is needed as a foundation to advance clinical and theoretical knowledge in neonatal care;
- Although there are numerous bodies dedicated and working towards specialised education for nurses, it is vital we work towards a professional consensus about what needs to be offered in this area between hospital and higher education institutions;
- This will ensure clear and concise criteria based-standard matching, both knowledge and skills, which will provide nurses working in this speciality to be competent, confident, evidence based professionals.

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APPENDICES

Appendix 1: Ethical approvals to conduct the study

Townsville Health District Ethical Approval for Thermometer Study

Townsville Health District Ethics Finalisation letter

James Cook University Ethics Consent form

Townsville Health District Ethical Approval form for the PW study

Townsville Health District Ethics final letter for PW study

Appendix 2: Clinical Trials Registration

Appendix 3: Patient Information Sheets

Appendix 4: Patient Consent Forms

Appendix 5: Professional Doctorate of Nursing Science Confirmation presentation - 2008

Appendix 6: Pre-completion seminar - 2012

Appendix 7: Conference presentations, Posters and Publications, since commencing Professional Doctoral Studies

Appendix 8: Doctoral specialisation I

Appendix 9: Doctoral specialisation II

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Participant Information Sheet

PATIENT INFORMATION SHEET

PROTOCOL NAME: **A comparison of Tympanic and Axillary Temperature recording in the preterm and term Neonate.**

INVESTIGATORS: **Jacqueline Smith, Neonatal Nurse Practitioner
Gary Alcock, Consultant Neonatologist
Ruth Temple, Research Assistant, RNC**

My name is Jackie Smith and I work at The Townsville Hospital Neonatal Unit as a Neonatal Nurse Practitioner.

I am interested in the most effective way of temperature taking which causes the least disturbance in the preterm and term baby.

At present in the neonatal unit we take all temperatures via the axilla method, this is where we place the thermometer under the baby's arm and wait for a temperature recording. This can take up to two minutes to obtain an accurate recording. One new method of temperature taking which has been shown to work in children and adults is taking the temperature just inside the ear canal also a new electronic thermometer that takes the temperature under your baby's arm. This is a painless technique and only takes two seconds for the ear temperature and 10 seconds for the new underarm thermometer, and therefore causes fewer disturbances to the baby. We are undertaking this study to find out whether taking the temperature in the ear is as accurate as the underarm method.

Why change the way we take your baby's temperature?

The reason why axilla (underarm) temperature taking is used in the neonatal unit is because it is relatively quick, non-invasive and accurate. However to take your baby's temperature accurately we disturb your baby for around 2 minutes. Some babies need rest to feed, grow and mature, so the less time we disturb your baby the more rest they have. Because tympanic

temperature taking only takes 2 seconds and the new electronic thermometer 10 seconds, it would mean less disturbance to your baby.

The method of temperature taking by the ear canal has not yet been assessed properly in newborn babies. If these new thermometers work well it would be invaluable.

What is the study about?

We are conducting a trial at The Townsville Hospital neonatal unit to see if using the tympanic thermometer and the electronic thermometer is as reliable, accurate and acceptable method of taking temperatures in preterm and term babies compared to the standard axillary method.

What will happen in the trial?

If you have given permission for your baby to be in the trial, at 'care' times your baby will have his/her temperature taken just like they would have normally.

The tympanic temperature will be taken first; a nurse will gently move your baby's head to the side to expose the ear, the probe tip will then be placed snugly over the external ear opening, a button on the machine which will scan your baby's temperature which will take no longer than two seconds. After this has been completed your baby will next have his/her temperature taken via the axilla method, which is normal procedure on the unit. The B.D. digital thermometer and the electronic thermometer will take the axilla temperature. The nurse will place the thermometer under your baby's arm and hold the arm downwards; this is to ensure the tip of the thermometer stays in the correct position. When the thermometer has finished recording it will beep (usually 2 minutes) this will then tell the nurse what your baby's temperature is by the axilla.

How long will my baby need to be on the trial?

If you consent, your baby will be enrolled on the trial. He/she will be on the trial for no longer than 48 hours.

There will be no other changes to the care given to your baby. If your baby does take part in the study they will not need any more blood test, X-rays or medications than babies who are not in the study.

What are the risks?

Temperature taking in neonates using the axilla and tympanic method is a quick, non-invasive method. However there can be certain risk when taking the tympanic temperature, although these are deemed minor we still have to make you aware.

When using the tympanic method care must be taken when pulling the bottom part of the ear when placing the thermometer, to avoid over handling/stimulation of the neonate. Compressing the soft tissue in the ear must also be avoided; only gently pressure should be applied to prevent this occurring.

Please be aware that all staff using these new thermometers are fully trained in the correct operation and the risks mentioned above are minimal.

What if I don't want my baby to be in the study?

Taking part in the study is entirely voluntary. If you don't want your baby to be in the study, take no further action. The care he or she receives will not be compromised in any way.

If you agree to participate in this trial, you have the right to withdraw your baby at any time by notifying me in person, by phone or in writing or just telling one of the nurses on duty. This will not in any way affect your baby's care or treatment during their stay in the neonatal unit.

If you have any queries or questions regarding this trial, please do not hesitate to contact me, by phone, email or in person.

Work Phone: 07 4796 3472

Email address:

jackiesmith3@me.com

Jacqueline_jsmith@health.qld.gov.au

Should you have any complaint concerning the manner in which this research is conducted, please contact the Standing Committee on Ethics in Research Involving Humans @ the following address:

The Townsville Health Service District Institutional Ethics Committee

HREC Administrator: Shannon Campbell

HREC Chair : Dr Andrew Johnson

P.O. Box 670

TSV

QLD 4810

Ph: 07 4796 1003

Fax: 07 4796 1021

INVESTIGATOR CONTACT NAME: Jacqueline Smith

INVESTIGATOR CONTACT TELEPHONE NO. 07-4796-3472

DATED:

SIGNATURE OF CONTACT INVESTIGATOR:

PATIENT INFORMATION SHEET

PROTOCOL NAME: Prevention of hypothermia in the delivery room.

INVESTIGATORS: Jacqueline Smith, Neonatal Nurse Practitioner
Gary Alcock, Consultant Neonatologist

My name is Jackie smith and I work at The Townsville Hospital Neonatal Unit as a Neonatal Nurse Practitioner.

I am very interested in the most effective way of preventing your baby from getting cold after he or she has been delivered.

At present following birth we immediately dry all neonates with warm towels, under a warm radiant heater. Although this has been shown to be effective in most newborns, premature neonates may need more help to prevent them getting cold.

One inventive method that has shown good results for preventing premature neonates from getting cold in the delivery room is by using a polythene wrap. This is placed on the baby immediately after delivery (no drying is needed) and the baby is then still placed under a radiant warmer. There is evidence to suggest that this unique method is more effective in premature neonates than the conventional method we currently use.

Does is matter if a baby gets cold?

It has been known for a long time that becoming cold can have serious harmful effects on a premature baby. Babies who become cold are likely to have worse breathing problems, low blood sugar levels, a higher risk of brain

haemorrhage and problems with increased acidity of the blood. Severe cold may even reduce a neonate's chance of survival.

What is the study about?

I propose to conduct a trial at The Townsville Hospital Neonatal Unit to see if using a plastic wrap is an effective way of keeping a premature neonate warm. At The Townsville Hospital although it is rare for premature babies to get severely cold after delivery, most premature babies are slightly cold by the time the infant is admitted to the nursery.

The trial will consist of two groups, one group using our conventional method and the other group using the plastic wrap. We will not know what group your baby will be in until delivery, but as soon as we are aware, we will tell you.

The decision as to which method are used for each neonate is made by random allocation and not by me or the nurses and doctors caring for your baby.

Conventional group

Following birth we will immediately dry your baby with warm towels, under a warm radiant heater. The infant will then be wrapped in warm blankets and a woollen hat will be placed on his/her head. Once in the neonatal unit baby will be placed in a pre-warmed resuscitaire or humidified incubator.

Plastic bag group

Your baby will be placed into a plastic wrap up to the neck while still wet.

Your baby's head is dried with warm towels and a woollen hat will be placed

on his/her head. No blankets are used, as this will allow the warmth from the heater to gently warm your baby through the wrap. Baby will be transported to the neonatal unit still wrapped in the polythene wrap. Once in the neonatal unit baby will be placed in a pre-warmed resuscitaire or humidified incubator. Once your baby's temperature is normal and all admission procedures have been done, the plastic wrap will be removed.

Plastic wrapping similar to the one used in the trial has been used in other studies with no harmful effects. The potential benefits of the study will be to improve the reduction in heat loss, thus decreasing complications that can arise from hypothermia (when baby gets too cold).

One problem that may occur is your baby may become too warm. Please rest assured your baby's temperature will be monitored continuously, and if baby is becoming too warm we will remove his/her hat, adjust the incubator setting according to your baby's needs and remove the plastic wrap if needed.

There will be no other changes to the care given to your baby. If your baby does take part in the study they will not need any more blood tests, X-rays or medications than babies who are not in the study.

What if I don't want my baby to be in the study?

Taking part in the study is voluntary. If you do not want your baby to be in the study, they will be dried and kept warm in our conventional way. The care he or she receives will not be compromised in any way.

If you agree to participate in this trial, you have the right to withdraw at any time by notifying me in person, by phone or in writing. This will not in any way prejudice your baby's care or treatment during their stay in the neonatal unit.

If you have any queries or questions regarding this trial, please do not hesitate to contact me, by phone, email or in person.

Work Phone: 07 4796 3472

Email address:

smithjackie@me.com

jacquelinej.smith@health.qld.gov.au

Should you have any complaint concerning the manner in which this research is conducted, please contact the Standing Committee on Ethics in Research Involving Humans @ the following address:

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TSV

QLD 4810

Ph: 07 4796 1003

Fax: 07 4796 1021

INVESTIGATOR CONTACT NAME: Jacqueline Smith

INVESTIGATOR CONTACT TELEPHONE NO. 07-4796-3472

DATED:

SIGNATURE OF CONTACT INVESTIGATOR:

PATIENT CONSENT FORM

PROTOCOL NAME: A comparison of Axillary and Tympanic
Temperature Recording in the Preterm
and Term neonate

INVESTIGATORS: Jacqueline Smith, Neonatal Nurse Practitioner
Gary Alcock, Consultant Neonatologist
Ruth Temple, Research Assistant, RNC

The nature and purpose of the research project has been explained to me. I understand it, and agree to take part

1. *I agree to take part in the above research trial being conducted at The Townsville Hospital Neonatal Unit. I have had the project explained to me and I have read the explanatory statement, which I will keep for my records.*
2. *I understand that I may not directly benefit from taking part in the trial.*
3. *I understand that, while information gained during the study may be published, I will not be identified and my personal results will remain confidential.*
4. *I understand that I can withdraw from the study at any stage and that it will not affect my medical care, now or in the future.*
5. *I have had the opportunity to discuss taking part in this investigation with a family member or friend.*
6. *I have fully read and understand the risks and benefits of the thermometers used in this trial*

NAME: _____

SIGNED: _____

DATE: _____

I certify that I have explained the study to the patient/volunteer and consider that he/she understands what is involved

Researcher's Name:.....

Researcher's Signature:.....

Witness Signature:..... Date:.....

APPENDIX B

PATIENT CONSENT FORM

PROTOCOL NAME: Prevention of hypothermia in the delivery room.

INVESTIGATORS: **Jacqueline Smith, Neonatal Nurse Practitioner**
Gary Alcock, Consultant Neonatologist

The nature and purpose of the research project has been explained to me. I understand it, and agree to take part

7. I agree to take part in the above research trial being conducted at The Townsville Hospital Neonatal Unit. I have had the project explained to me and I have read the explanatory statement, which I will keep for my records.
8. I understand that I may not directly benefit from taking part in the trial.
9. I understand that, while information gained during the study may be published, I will not be identified and personal results will remain confidential.
10. I understand that I can withdraw from the study at any stage and it will not affect my medical care, now or in the future.
11. I have had the opportunity to discuss taking part in this investigation with a family member or friend.

NAME: _____

SIGNED: _____

DATE: _____

I certify that I have explained the study to the patient/volunteer and consider that he/she understands what is involved

Researcher's Name:..... Signature.....
Witness Name..... Witness Signature:.....
Date:.....



An invitation is extended to all staff members and research students of the School of Nursing, Midwifery & Nutrition to attend a

Higher Degree Research Seminar by

Ms Jackie Smith

DNSc Confirmation Seminar

Date: 24th November 2008

Time: 11.00 am - 11.50 am

Venues: Townsville - DB25-207
Cairns - A21.002

**Temperature Taking in the
Pre-term and Term Neonate**

<u>Supervisor:</u>	Professor Anne Gardner
<u>Co-Supervisor:</u>	A/Professor David Lindsay
<u>RSM:</u>	Dr Melissa Crowe

*Dr Lea Budden, Postgraduate Liaison Officer
School of Nursing, Midwifery & Nutrition
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research seminar

You are invited to attend the
Pre-Completion Seminar by
Doctor of Nursing Science
candidate

Jackie Smith

RSCN, NeonatalSA19, ENB405, HDipNeolntCare,
MasterNursSc(NP)

When: 11:00 – 12:30 pm
Thursday 20 September 2012

Where: Townsville – DA09-001
Cairns – E1.112 (videolink)

Panel: Professor Kim Usher
| Principal Advisor

A/Prof Petra Buttner
| Associate Advisor

Dr Melissa Crowe
| Research Student Monitor



School of Nursing, Midwifery & Nutrition

Dr Elizabeth Emmanuel, Postgraduate Liaison Officer
(Ph: 4042 1306 or Elizabeth.Emmanuel@jcu.edu.au)

Temperature Measurement and Thermoregulation in the Preterm and Term Neonate

Prevention of hypothermia is one of the basic tenets of effective neonatal care. Concerns about cold stress and its link to increased morbidity and mortality in neonates were first documented in 1907 (Budin 1907), but it was not until 1958 that Silverman et al. (1958) demonstrated the association between more effective temperature regulation and decreased mortality. Cold stress, or hypothermia, is known to result in complications such as an increased need for oxygen, difficult resuscitation, an increased incidence of disseminated intravascular coagulation (DIC), post delivery acidosis, delayed adjustment from foetal to newborn circulation, worsening respiratory distress syndrome, and increase morbidity from infection (Soll, 2008; Knobel, 2007).

Unfortunately, hypothermia (temperature $<36.5^{\circ}\text{C}$) remains a common finding in premature neonates following delivery, resuscitation, stabilisation and admission to the neonatal intensive care unit (NICU). During this period, body temperature is highly dependent on the environmental temperature and its surroundings. Predisposing factors for hypothermia, especially in the premature infant, include a large surface area to body mass ratio, wet at birth, skin immaturity, and prematurity. Evaporation, convection, conduction and radiation all participate in the frequently rapid fall in body temperature. Heat loss is the greatest in the first few minutes of life as infants are born wet into a relatively cool environment when compared to the uterus (Cramer et al, 2005; Soll, 2008). Given that the Townsville Hospital neonatal unit is set in a regional, tropical area that includes a high proportion of Indigenous Australians prone to premature birth, and as prematurity and low birth weight are more likely in rural and regional areas than in urban environments (AIHW, 2010), the need for an intervention to help improve admission temperature to the NICU and decrease heat loss at birth was considered important.

The measurement of temperature is also an important part of the care of the neonate admitted to the NICU. Accurate temperature assessment enables early intervention and/or treatment as a change in body temperature can indicate the presence of infection or disorders of the thermoregulatory system. The necessity for regular observations such as temperature measurement does however require prolonged handling and disturbance. Findings ways to reduce the need to disturb the preterm neonate are essential.

Appendix 7: Conference presentations, Posters and Publications, since commencing Professional Doctoral Studies.

Publications

- Smith, J. (2005). The Nurse Practitioner role comes to North Queensland. *The Infant*, 1(4), 108.
- Smith, J., Whitehall, J. (2008). Absence of the ductus venosus: a case history and literature review. *The Infant*, 4(4), 121-123.
- Smith, J., Whitehall, J. (2008). Parvovirus B19: a case history and literature review. *The Infant*, 4(3), 101-104.
- Whitehall, J., Smith, J. (2008). Valproate and babies. *Australian and New Zealand Journal of Psychiatry*, 42(9), 837-839.
- Smith, J., Whitehall, J. (2009). Sodium Valproate and the foetus: a case study and a review of the literature. *Neonatal Network*, 28(6), 363-367.
- Smith, J., Alcock, G., Gardner, A., Usher, K. (In press). Temperature measurement in the preterm and term neonatal: a review of the literature. *Neonatal Network*, Accepted August 2012.
- Smith, J. & Sandall, M (2012). Staphylococcal Scalded Skin Syndrome: A case review. *The Journal of Neonatal Nursing*, <http://dx.doi.org.elibrary.jcu.edu.au/10.1016/j.jnn.2012.08.004>
- Smith, J., Usher, K., Alcock, G., Buettner, P. (Under review). Concordance of temperature measurements in the preterm and term neonate using three thermometers. *The Collegian*.
- Smith, J., Usher, K., Alcock, G., Buettner, P. (2012). The application of a plastic wrap to improve NICU admission temperatures in infants born less than 30 weeks gestation: A randomised controlled trial. *Neonatal Network*, Accepted September 2012.
- Smith, J. & Usher, K. (2012). (Under Review). Exsanguination, saved in a timely manner by the plastic wrap: A case review. *The Journal of Neonatal Nursing*.

Nursing presentations and lectures given at The Townsville Hospital Neonatal Unit

- Fluid and electrolytes
- Jaundice
- Haematology
- Understanding respiratory problems in the neonate
- Pharmacology in the neonate
- Respiratory distress in the neonate
- Respiratory mechanics
- Hydrops Fetalis
- Meconium Aspiration
- Neonatal infections
- IVH in the premature infant
- The Brainz Monitor

Conference, Presentations & Posters

Perinatal Society of Australia and New Zealand – 2007, Preventing Heat Loss in Preterm Neonate <30 weeks – Poster Presentation

Perinatal Society of Australia and New Zealand – 2008, Usefulness of the Brainz Monitor – Poster Presentation

Neonatal Nurses Association of Queensland – 2008, Pink, Sweet and Warm (or cold If needed) – Oral Presentation

TTH - Grand Round Presentation – 2008, Parvovirus B19 – Oral Presentation TTH
Grand Rounds – 2009, Myelomeningocele: a case study - Oral presentation

Midwifery State Conference – 2009, Temperature taking in the neonate - Poster presentation

Midwifery State Conference – 2009, Preventing Heat Loss in the Premature Infant – Oral Presentation

Midwifery State Conference – 2009, Pink, Sweet and Warm, Cold if needed - Oral Presentation

Cairns Hospital Neonatal Transport Seminar – 2010, Flying with babies – Oral Presentation

Neonatal Nurses Association Queensland – 2011, B19 – Oral Presentation

Perinatal Society of Australia and New Zealand – 2012, Plastic Wrap in infants < 30 weeks – Oral Presentation

Perinatal Society of Australia and New Zealand – 2012, Comparison of temperature taking – Poster Presentation



Introduction

- Hypothermia is a significant contributor to poor outcomes in neonates and remains a problem today
- Evidence suggests that the use of a plastic wrap or bag is a more effective method of preventing heat loss
- A decision was therefore made to investigate the efficacy of applying a plastic wrap (NeoWrap™) immediately after birth

(Lyons et al 2003, Meyer et al 2003, Newton & Watkinson 2003, Vohra et al 2004, Knobel et al 2005, Matthew et al 2006, Ibrahim et al 2008, Patrick et al 2010, Singh et al 2010)

Methods

- Approved by the Townsville Health Service District Institutional Ethics Committee
- Trial conducted at the Townsville Neonatal Unit from January 2006 – July 2011
- Blinded randomized controlled trial stratified by gestation
- Objective is the use of the plastic wrap immediately after birth increases admission temperature

NeoWrap



Sample Size

- Sample size of 86
- This provides a power of 0.9 to detect an increase in mean admission temperature from 36.1C to 36.5C



Procedure

- All infants <30
- Exclusion Criteria
 - Congenital anomalies with open lesions
 - Infants who were not viable
 - Any infant born above 29 weeks and 6 days



Interventions

- Control group
- Intervention group
- Both groups had their first temperature taken within the first few minutes of birth, then admission to NICU and every 30 minutes until 2 hours of age
- The BD Digital thermometer was used throughout the study



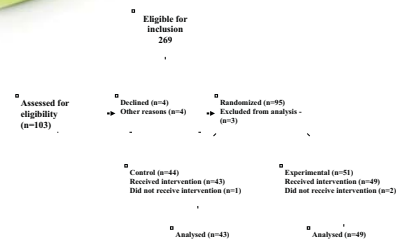
Outcome Measures

- Primary – temperature at admission to NICU
- Secondary outcomes- temperatures at 30, 60, 90, and 120 minutes
- Other characteristics measured were, BGL, IVH, early and late sepsis and death

Statistical Method

- Temperatures were compared between the two groups
- Categorical data described using percentages
- Numerical data were described using mean values and SD
- Changes in temperature over time were assessed using analyses of variance for repeated measures

Participant Flow Diagram

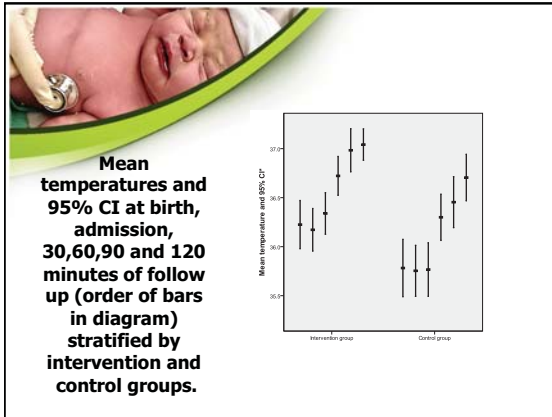


Differences in temperatures stratified by analysis intervention and control

Temperature stratification	Control group (n=43)	Intervention group (n=43)	P-value
Mean temperature at first (SD), range (°C)	35.81 (0.91); 32.90 to 37.60	36.15 (0.85); 34.00 to 37.50	P=0.074
Mean temperature at admission (SD), range (°C)	35.79 (0.77); 34.20 to 37.00	36.26 (0.68); 34.50 to 37.40	P=0.004
Mean temperature at 30 minutes (SD), range (°C)	35.77 (0.82); 34.10 to 37.40	36.34 (0.65); 35.00 to 37.80	P<0.001
Mean temperature at one hour (SD), range (°C)	36.26 (0.73); 34.50 to 37.70	36.73 (0.61); 35.30 to 38.30	P=0.001
Mean temperature at 90 minutes (SD), range (°C)	36.44 (0.78); 34.20 to 37.60	37.00 (0.66); 35.30 to 38.80	P<0.001
Mean temperature at 2 hours (SD), range (°C)	36.75 (0.70); 34.50 to 38.00	37.03 (0.49); 36.00 to 38.40	P=0.035

Temperature stratified by gestation

Mean temperature at...	Control group (n=26)	Intervention group (n=22)	P-value
Gestation < 27 weeks			
Birth (SD)	35.77 (1.03)	36.24 (0.80)	P=0.105
Admission (SD)	35.86 (0.84)	36.33 (0.75)	P=0.063
30 minutes (SD)	35.73 (0.90)	36.28 (0.70)	P=0.027
60 minutes (SD)	36.19 (0.76)	36.67 (0.61)	P=0.021
90 minutes (SD)	36.27 (0.79)	37.04 (0.66)	P=0.001
120 minutes (SD)	36.69 (0.74)	36.97 (0.49)	P=0.155
Gestation 27 to 29+6 weeks			
Birth (SD)	35.81 (0.77)	36.06 (0.88)	P=0.332
Admission (SD)	35.69 (0.71)	36.15 (0.62)	P=0.026
30 minutes (SD)	35.81 (0.73)	36.39 (0.60)	P=0.007
60 minutes (SD)	36.33 (0.70)	36.79 (0.62)	P=0.028
90 minutes (SD)	36.63 (0.75)	36.96 (0.66)	P=0.142
120 minutes (SD)	36.81 (0.67)	37.10 (0.50)	P=0.136



- ### Hyperthermia
- Hyperthermia was recorded in 10 infants
 - 6 in the wrap group (12.2%)
 - 5 in the control group (11.6 %)
 - This however was not significant

- ### Conclusion
- The use of the plastic wrap in infants less than 30 weeks gestation did improve admission temperatures ($p=0.004$)
 - Add to current knowledge?

Whether an improved admission temperature manifests into improved clinical outcomes needs to be determined in follow-up, larger multi-centred trials.



Acknowledgements

I would like to quickly thank a few people for there dedication and help in completing this trial.

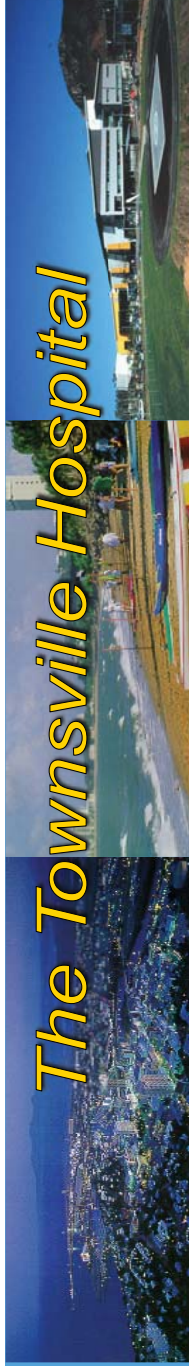
Dr Gary Alcock, my mentor throughout my Doctorate, for his unfailing patience with my numerous questions and emails.

Janelle Creedy who is a senior neonatal nurse on the unit for her help and time in the education of the nursing and medical staff and collecting data.

Ruth Oldfield for her help establishing the data set

All staff of the TTH neonatal unit for there help, patience and understanding throughout this trial.

The Townsville Hospital



PREVENTING HEAT LOSS IN PRETERM NEONATES <30 WEEKS

Department of Neonatology, The Townsville Hospital, Nth Qld

JACKIE SMITH NNP & Dr GARY ALCOCK NEONATOLOGIST

INTRODUCTION

INTRODUCTION

Hypothermia is associated with increased risk of morbidity and mortality (CESDI 2003). Hypothermia is identified as being predictive of oxygen dependence (EPI Cure 2000). Temp on admission to NICU is influenced by severity of illness, amount of handling & quality of thermal care during resuscitation, stabilisation and transfer to NICU (CESDI 2003). Predisposing factors to hypothermia include, large surface area to mass ratio, being wet at birth and skin immaturity. Evaporation, convection, conduction and radiation all play a role in the frequent rapid fall in body temperature. Prevention of hypothermia is one of the basic tenets of good neonatal care.

WHY PREVENT HEAT LOSS?

Hypothermia is identified as being predictive of oxygen dependence. Temperature on admission to NICU is influenced by severity of illness, amount of handling and quality of thermal care during resuscitation, stabilisation and transfer.

HYPOTHERMIA - WHAT CAN IT DO?

- Increase oxygen consumption
- Cause a difficult resuscitation
- Increase incidence of DIC
- Lead to Post delivery acidosis
- Exacerbate Worsening RDS
- Increase morbidity from infection
- Delayed adjustment from fetal to newborn circulation

METHOD

- Subject population – all neonates born @ < 30 weeks.
- The study will aim to enrol 86 neonates, enabling the study to have a statistical power of 0.9 to detect & increase mean admission temperature from 36.1 to 36.5.
- A randomised controlled trial.
- Primary outcome – temperature on admission to NICU
- Secondary outcome – temperature @ 30, 60, 90, 120 minutes, pH & BE & incidence of hypoglycaemia in first 12 hours, incidence of late sepsis, mortality, incidence of IVH, need for inotropes, need for mechanical ventilation.

RANDOMISATION

- Randomisation will be by the use of computer generated randomisation list.
- Stratified by gestation into two groups, neonates <27 weeks & 27-29 weeks gestation.
- Randomisation concealment will be by the use of sealed opaque envelopes.
- Control group – as per conventional method.
- Experimental group – use of plastic wrap.

DATA COLLECTION/ETHICAL CONSIDERATIONS

DATA COLLECTION

- Includes primary and secondary outcomes.
- A list of all neonates eligible for inclusion.
- Possible complications of the intervention.
- Demographic data, gestational age, birth weight, mode of delivery, gender, time of admission.

ETHICAL CONSIDERATIONS

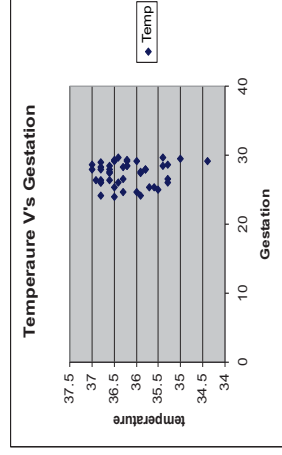
- Signed parental consent will be required before enrolment into the study.
- The intervention is considered by the investigators to be of low risk.
- Hyperthermia is a possible risk which is taken into consideration.

INFORMATION

OTHER HOSPITALS

Many infants are born in North QLD at level 1 and level 2 nurseries. Plastic wrapping can benefit premature neonates born at these smaller hospitals by preventing heat loss to premature infants which will prevent a worsening clinical condition e.g. hypoxia, acidosis. In addition it will be an advantage to those infants born in a large tertiary centre.

It can also be of benefit to neonates who need transferring to tertiary units for ongoing treatment.



All Neonates born at the neonatal unit at TTH in 2003 <30 weeks gestation

CONCLUSIONS

SIMPLE SOLUTION

- POLYTHENE WRAP.
- Prevents evaporative heat loss.
- Minimises convective heat loss.
- Polythene allows transmission of the long wave length energy of radiant heat.
- Cost effective.
- Infant is easily assessed through transparent polythene wrap.
- Easy to use.

WHERE IS THE EVIDENCE?

- Vohra et al (2004) has shown that the polythene wrap is more effective at preventing heat loss at delivery than the conventional method.
- Bjorkland & Hellstrom-Westas (2000), temperature of >36.5 was achieved in 73% of infants in the polythene wrap group compared with 23% in conventional managed group.
- Lyon & Stevenson (2004) achieved a mean temperature of 37°C on admission to NICU.

REFERENCES

REFERENCES

- Bjorklund, LJ & Hellstrom-Westas, L (2000) Reducing heat loss at birth in very preterm infants. Jnl Pediatrics Confidential enquiry into Stillbirth and Deaths in Infancy (CESDI): Project 27/28 (2003) Accessed via website <http://www.cemach.org.uk/publication/sp2728/main>
- Lyon, AJ & Stenson, B (2004) Cold comfort for babies. Archive of Disease in Childhood, Fetal and Neo ed. 89(1)
- Vohra, S et al (2004) Heat loss prevention (HeLP) in the delivery room: A RCT of polythene occlusive skin wrapping in very preterm infants.

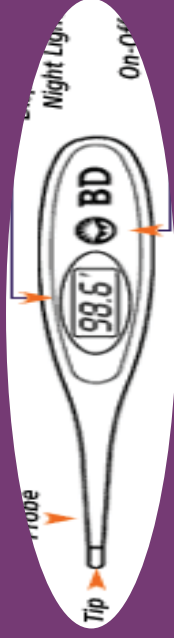


Current digital thermometers are now being compared with new thermometers such as tympanic or electronic.

Research must be accomplished to help determine the reliability of both new and established methods.

STUDY AIM

To investigate the accuracy of the Genius 2 Tympanic and Suretemp thermometers compared with the digital thermometer, when used in preterm and term neonates.



Measuring temperature is an essential part of nursing care.

It has been widely accepted as an indication of a neonates well being.

It can give an early indication of sepsis, which can be fatal in the sick or premature newborn.

Current digital thermometers are being compared with the tympanic and electronic methods.



New
Thermometers
The use and accuracy is still unclear in the neonatal population

Preterm and term neonates in NICU and SCBU
Gestational age from 24 weeks
Commence from birth
Neonates will be classified into 3 groups

- <28 weeks
- 28 – 36 weeks
- >36 weeks



Temperature taking in the preterm and term neonate in the neonatal unit at The Townsville Hospital.



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Parvovirus B19

Dr John Whitehall
Jackie Smith NNP

Key Points

- Parvovirus B19 is a common infection in humans
- It affects erythroid precursors resulting in decreased erythropoiesis
- It is usually spread by respiratory means but can pass vertically from the mother to the foetus

- It can lead to miscarriage, hydrops fetalis and intra-uterine death
- Intrauterine blood transfusions can compensate until the effect of the virus passes

- Amongst the most susceptible are unborn babies who suffer from a high rate of abortion if affected in the 1st trimester, anaemia that may result in non-immune hydrops in the 2nd and in utero death in the 3rd

- We present an illustrative case study of hydrops in the 2nd trimester treated by in-utero transfusion
- Together with our learned colleagues
Professor – Rick Speare
Professor – Yvonne Cossart
Obstetric Consultant -Dr David Watson

Hydrops – led to death



Case Study

- 32 year old
- Her third pregnancy
- 2 healthy daughters
- Viral illness at 8 weeks gestation
- Daughter had 'red cheek'

'slapped cheek'



- Referred to the Maternal Foetal Medicine Facility after routine U/S at 20 weeks and 3 days
- Revealed foetal hydrops and anaemia
- No obvious structural anomaly seen
- Blood was taken on the same day for human parvovirus B19

- The blood sent confirmed:
 - IgG reactive
 - IgM reactive
 - DNA confirmed for parvovirus B19
- This condition is associated with high perinatal death or foetal demise without intrauterine intervention

1st Scan – 20+⁴ weeks

- At the referring centre she was assessed for an IUF
- Middle cerebral artery peak systolic velocity (blood flow to the brain) was elevated 52cm/sec
- Suggesting reduced viscosity due to severe anaemia

- Further evaluation showed:
 - Foetal hydrops with ascites
 - Skin oedema
 - Pericardial effusion
 - Cardiomegaly
 - Tricuspid regurgitation
 - Thickened placenta
- Differential diagnosis, parvovirus B19, Rh isoimmunisation, foetal maternal haemorrhage

Ascites

Transverse U/S of the abdomen revealing a huge amount of fluid (black) in which a few loops of bowel are floating



Foetal Chest

Transverse U/S of the foetal chest revealing cardiomegaly and oedematous chest wall



1st IUT

- 20+⁴ weeks
- Hb 3.4g/dL, platelets 27x10⁹/L
- 20 mls of blood transfused
- 15 mls of platelets transfused
- Post transfusion Hb 13.2
- Parvovirus IgM and parvovirus PCR on foetal blood

Day 2 post IUT

- Baby remained active
- Hydropic features remained the same
- Satisfactory myocardium
- MCA – a significant drop

2nd Ultrasound

- 22+² weeks
- Mild scalp oedema
- Foetal ascites remains the same
- MCA 50cm/sec
- Suggests another IUF

2nd IUF

- 22+3 – for anaemia and infection
- Pre transfusion Hb 3.3g/dL
- 30 mls of blood given
- Post transfusion Hb 11.7
- Post transfusion MCA 33.3cm/sec

Birth

- A live female infant was born at 36 weeks gestation by LSCS
- Good
- On evaluation her abdomen was grossly distended and tense
- She was intubated in theatre
- Intra-peritoneal drains inserted
- 870 mls of ascites fluid was drained

- Umbilical lines were inserted
- Bloods were sent for FBC, LFT's, U&E, CRP, Coag, Blood Cultures and virology
- Ascites fluid was also sent for microscopy culture, viral studies and albumin
- After five days incubation the ascites fluid showed no organism or growth and B19 was not detected
- Blood sent on day one of life showed the presence of B19 IgG but not IgM

CXR soon after birth



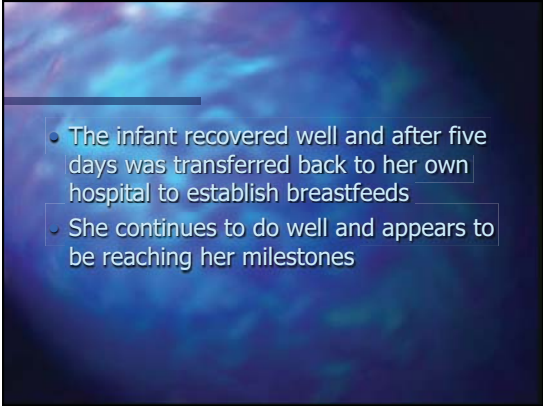
Infant soon after birth



- Infant extubated after one hour of life and has since been self ventilating in room air
- Enteral feeds were commenced on day one of life and she has tolerated feeds since

Ultrasounds

- A cardiac echo showed that the four chambers of the heart appeared normal
- A small PFO
- No VSD
- LV function fair
- No PDA
- Head and kidney U/S showed no obvious abnormality

- 
- The infant recovered well and after five days was transferred back to her own hospital to establish breastfeeds
 - She continues to do well and appears to be reaching her milestones

Myelomeningocele

Case Study

What is Spina Bifida

- ☐ Defects in the closure of the neural tube
- ☐ Can also be known as neural tube defect (NTD)
- ☐ The NT is the tissues of an embryo that become the brain, spinal cord and bones surrounding each

- ☐ During the 3rd or 4th week the NT has developed and spinal column (bones) closes
- ☐ In a foetus with spina bifida the NT does not close completely
- ☐ This leaves a gap through which organs that should be inside the body are left outside

- ☐ Myelomeningocele is the most common form of NTD
- ☐ The sac contains cerebral spinal fluid, meninges and spinal cord
- ☐ There will be neurologic deficits below the level of the defect
- ☐ Can result in loss of feeling or paralysis

Maternal History

- ☐ 2002 diagnosed with bipolar disorder
- ☐ History of alcohol abuse
- ☐ Regular reviews at remote hospital
- ☐ Commenced on Valproate 2002
- ☐ 500mg TDS

- ☐ no record regarding folate supplementation in general or with special relevance to valproate therapy
- ☐ No record of any advice about the teratogenic effects of valproate
- ☐ She could recall no discussions

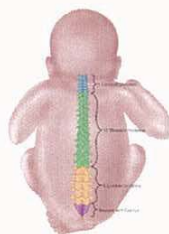
In-Utero

- ☐ No folate supplements during pregnancy
- ☐ Triple test showed increased risk of NTD
- ☐ Ceased valproate at around 11 weeks
- ☐ Routine U/S – myelomeningocele
- ☐ Termination offered but refused

Infant

- ☐ Female infant, weight 2.87kg
- ☐ Born at 38 weeks gestation
- ☐ No resuscitation required at delivery
- ☐ Admitted to NICU for surgical closure
- ☐ Myelomeningocele extended from L5 to S1
- ☐ Cerebellar tonsils were displaced down to C5 level

L5/S1



MRI

- ☐ Mild hydrocephalus
- ☐ Marked inferior herniation of the cerebellar tonsils
- ☐ Cervico/medullary kinking at C2/3 level
- ☐ Failure of fusion of L5/S1 in keeping with spina bifida

MRI

- ☐ Cord is tethered and continuous with the subcutaneous tissues @ approx' L5/S1 where there is a large myelomeningocele
- ☐ Features in keeping with Chiari 11 malformation

Infant

- ☐ Though lesion severe there was preservation of movement of the legs
- ☐ Kidneys and heart were normal on U/S
- ☐ No other abnormalities noted
- ☐ No signs of withdrawal from valproate
- ☐ No disturbance in hepatic or glucose homeostasis

Severe Lesion



After Surgery



Surgical

- ☐ Closure of lesion on day 2
- ☐ Recovered well
- ☐ Discharged on day 11

Recovered Well




Re-Admission

- ☐ Readmitted on day 42
- ☐ Rapidly progressing hydrocephalus
- ☐ Required ventriculo-peritoneal shunt


Up Date

- ☐ At 3 months of age progressing within the limits of myelomeningocele
- ☐ No suggestion of intellectual disability
- ☐ Hearing screen on discharge was normal
- ☐ Further assessment of growth, intellectual & behaviour development, eye sight & hearing will be performed





THERMOREGULATION

KEEPING ME WARM



The premature neonate





PAST AND PRESENT


- 'No foetus coming into the world before the seventh month of pregnancy can be saved'
Hippocrates 460BC




The responsibility for appropriate and accurate monitoring and maintenance of a patient's temperature belongs with the nurses and midwives



- Thermoregulation is a critical function associated with neonatal survival, Thomas 1994
- A neutral thermal environment is the environmental air temperature at which a baby with Normal body temperature has a minimum metabolic rate and minimal oxygen consumption




- The WHO lists hypothermia as a 'top killer' during the neonatal period (WHO 1996)
- Low neonatal body temperature is associated with poor rates of survival, Day et al (1964)




DEFINITION OF HYPOTHERMIA

- The world health organisation classifies a core body temperature for newborns of 36-36.4°C as mild hypothermia or cold stress, 32-35.9°C as moderate hypothermia and <32°C as severe hypothermia (WHO 97)



Background

- Maintaining temperature at the time of birth is one of the primary goals of newborn care
- In the premature infant, body temperature can rapidly fall in the delivery room, and if this occurs it has been associated with high morbidity and mortality



- In the term infant elevated maternal as well as infant temperature is associated with increased neonatal morbidity and mortality. Conversely, induced hypothermia in the post-resuscitation period had been recently utilised as a neuro-protective strategy



HEAT LOSS Infant Thermoregulation

- When the environment is either too warm or too cold:
 - Metabolic processes of the infant are stressed
 - A large amount of energy is expended
 - This leads to exhaustion, instability and ultimately death



- In cold stress
 - Oxygen consumption is increased, there is a switch to anaerobic metabolism with a resulting build up of lactic acid which can lead to metabolic acidosis



Immaturity of the skin at 25 weeks



Heat loss in neonates

- They have limited subcutaneous fat
 - This fat layer serves as an insulator
 - Prevents heat loss to the environment
 - The smaller the infant, the greater the loss of heat
 - Involuntary muscular activity (shivering) – virtually absent in the preterm



- Very low birth weight infants do not have a superficial layer of keratin and consequently water and heat are lost through the permeable skin



- The close proximity of neonatal blood vessels to skin surface allows for rapid cooling of circulating blood
- The relationship of body surface to body weight (mass): Infants have a large surface area for their body weight which results in increased dissipation of heat.



- Neonates use the flexed body position to minimise heat loss diminishing the amount of body surface exposed
- Vasomotor control is less well developed although the ability to constrict subcutaneous and skin vessels is efficient



FACT

- A naked wet term neonate in the delivery room placed on an open table with an ambient temperature of 25°C will lose 4°C in skin temperature and 2°C in core temperature within 30 minutes.



RANGE

- The more preterm the infant, the greater the thermal challenge



Figure 10. The very low birthweight (VLBW) infant has an extremely large body surface area from which to lose heat.



- Predisposing factors include large surface area to mass ratio, wet at birth, and skin immaturity.
- An exposed 1kg neonate will lose heat at a rate of 1°C every 5 minutes.
- Heat loss on transfer to NICU is often significant.



Heat Loss

- Neonates should always be nursed in a neutral thermal zone, where both heat production (thermogenesis) and heat loss are at a minimum
- As the baby increases in body mass, even in the first few days, but particularly beyond that, skin tissue insulation increases, the body to surface mass decreases and so does heat loss



- Prolonged cold stress reduces stores & leads to a cascade of events as low blood sugar levels aggravates metabolic acidosis, which can delay fetal transition
- At birth the neonate passes from 37.7°C to between 21-25°C
- The body is wet with amniotic fluid and therefore can lose heat very rapidly if not dried immediately



HEAT PRODUCTION

- Neonates produce heat by non-shivering thermogenesis.
- The brown fat stores that are used in this process can be rapidly depleted during cold stress.
- This type of heat production is due to increased metabolic activity which is a major stress to the infant



- Heat production and brown adipose tissue (BAT) = thermogenesis
 - After first 24 hours babies can increase their body heat production by 2.5 times as a response to cold by lipolysis of brown adipose tissue (increase heat production by as much as 100%)
 - 2.7% of baby's weight consists of BAT (at term)



- BAT is located around kidney, mediastinum, nape of the neck and scapulae, along the spinal column and around large blood vessels in the neck
- BAT cells begin to proliferate at 26-30 weeks gestation and continue developing until 4 weeks after birth



- Fat cells (adipocytes) are capable of a large heat production
- In response to cold stress the metabolism of the brown fat cells is increased and heat is produced
- This process requires extra oxygen and glucose



- Thermal receptors in the skin
- The hypothalamus detects deviations in temperature (from a set point)
- Mediates a response from autonomic, somatic and endocrine system



- Infants will then respond to cold stress by increasing their oxygen consumption
- This results in oxidative metabolism of glucose and fat protein to produce heat
- Therefore NST is the primary mode of heat production in the neonate



CARE OF THE NEONATE

- Parents and professionals should be aware of the need to keep baby warm
- Adjust clothing and environmental temperature to maximise heat regulation
- Baby should be dried, covered and a hat
- Given to mother to hold if possible (kangaroo care, skin to skin)



- Most heat lost from headhat
- Warm room
- Positioning of baby on mothers abdomen
- Early breast feeding
- Delay procedures (e.g. bathing)



The at risk infant

- **PRETERM**
 - Decreased fat insulation
 - Decreased BAT
 - Large surface area to weight ratio
 - Inadequate calorie intake
 - Ineffective ability to increase oxygen consumption



- Posture (extension)
- Immature thermal regulatory ability
- Increased TEWL
- Higher total body water content
- Immature skin without a well defined stratum corneum



IMMATURE SKIN



Figure 2: The skin of a newborn preterm infant – the stratum corneum is poorly developed and is prone to increased permeability.



Hypothermia and the preterm neonate

- Hypothermia occurs commonly in the LBW neonate following delivery
- It is more severe in the smallest and most immature neonate
- Morbidity associated with hypothermia in the newborn includes hypo/hyperglycaemia, RDS, hypoxia, metabolic acidosis and coagulation defects



OTHER FACTORS AFFECTING HEAT LOSS


- The primary goal is to provide a neutral thermal environment in which heat loss can be prevented and oxygen remains at resting levels



- Hypoglycaemia
 - Less substrate for energy, and metabolic response to cold
- Cardio-respiratory problems
 - Impaired BAT due to hypoxia
 - Inadequate calorie intake
 - Increased risk of metabolic acidosis
- Congenital anomalies
 - Increased surface area
 - Increase evaporative heat losses



- Small for Dates
 - Less fat for insulation
 - Large BSA to MASS ratio
 - Increased metabolic rate
 - Increased energy demands
- Sedated infants
 - Decreased activity
 - Decreased muscle tone



- Limited ability to mobilise norepinephrine and fat for energy production
- Diminished capacity to increase their oxygen consumption
- Decreased glycogen stores
- Poor vasomotor control







Figure 9. Transparent polythene wrap over the infant and the mother's body, particularly preterm neonate, at birth and postnatal age.




So how can we prevent heat loss in the preterm neonate?

- Simple
 - The use of a plastic wrap




THE USE OF THE PLASTIC WRAP


Preventing heat loss – disadvantages & advantages

- Cooling at birth will increase the metabolic stress of the infant, increase oxygen consumption and may, lead to an increase in oxygen requirements
- Conversely, prevention of some degree of cooling may not provide the necessary stimulus needed to initiate breathing and thyroid function




Where is the evidence?

- Vohra et al (2004) heat loss prevention in the delivery room
- Bjorkland et al (2000), temperature > 36.5°C achieved in 73% of infants
- Lyon & Stevenson (2004), mean temperature when admitted to NICU was 37°C
- Knobel et al (2005) wrapped infant less likely to be hypothermic



Infants at TSV <30 weeks in 2003

- In 2003 neonates born at the Townsville Hospital at < 30 weeks gestation, the mean temperature on admission to the NICU was 36.1°C, with 66% of neonates having an admission temperature of <36.5°C.



The use of the wrap

- By wrapping the preterm neonate in the transparent polythene, and more importantly, polythene with a high diathermancy (rate of radiant heat transmission), is that evaporative heat losses are virtually stopped while heat from a radiant source can still penetrate the polythene and warm the baby



How can we avoid hypothermia?

- High transmission rate of energy
- Complements radiant warmers
- Effective for minimising high evaporative and convective heat loss after birth
- Opens easily and does not stick to itself but adheres to the wet and newly born infant



- Clean and individually wrapped
- Permeable to oxygen and carbon dioxide
- Barrier to water vapor
- Cost effective
- Infant is easily assessed through transparent wrap
- Easy to use.



Trial at TSV NICU

- Randomised controlled trial
- Infants born <30 weeks gestation
- Intervention – plastic wrap applied immediately after delivery
- Objective – the use of plastic wrap immediately after delivery prevents hypothermia



Any risks?

- The risks of hyperthermia are not well defined as hypothermia
- If temperature does rise >37°C, the hat will be removed, and/or consideration to change the environmental temperature
- Consideration will also be given to remove the plastic wrap



Study design outline

- A blinded randomised controlled study comparing the effectiveness of wrapping and conventional temperature maintenance methods in neonates in neonates born <30 weeks.

Delivery



Place the infant wet (DO NOT DRY) into the wrap. One member of the team dries the head and places the hat. Whilst another member of the team places the saturation probe on the foot.



Umbilical cord

- As you close the wrap leave the umbilical cord outside and continue with care



Other hospitals

- Many infants are born in North QLD at level 1 and level 2 nurseries
- Plastic wrapping can benefit these smaller hospitals by preventing heat loss to premature infants
- In addition it is also an advantage to those infants born in large tertiary centers



- Hypothermia is a common finding in premature neonates following delivery, resuscitation and stabilization.
- During this period, body temperature is highly dependant on the environmental temperature.
- "No intervention is more important for preterm neonates in terms of survival than keeping them warm (Sinclair & Bracken 1992)



Birth – a thermoregulatory crisis

- Immediately after birth body temperature of a neonate falls rapidly
- The rate of fall is greatest in the first few minutes
- The body temp of a neonate approaches that of an adult within 24 hours



- Heat is transferred along a gradient higher to lower
- The neonate is shielded – uterine
- Cold, dry delivery room



Physiological response

- Cold sensitive receptors are stimulated as skin temp falls below 35°C
- Oxygen tensions rise as the neonate is separated from the placenta
- Sufficient BAT, postnatal hypothermia is counteracted by NST via the intact neonatal sympathetic nervous system



- Neonates who have any deficiency in the prerequisites for thermogenesis, such as inadequate oxygen supply or insufficient BAT, have more difficulty reversing hypothermia in the first few hours of life



Adaption to the post birth environment

- MR in the neonate in the 1st days after birth is approximately twice that per Kg body mass of an adult in resting conditions
- Even in warmer climates the neonate is hypermetabolic, because of high levels of tissue growth and differentiation



Fever in the infant at delivery

- The foetus as well as the newborn has on an average 0.5°C higher temperature than the mother in the normal state due to insufficient heat dissipation
- The placenta serves as the 'main radiator' of the foetus
- 85% of the fetal heat goes to the maternal organism, thus making the foetus thermoregulatory dependent on the mother



- The fetal-maternal gradient has been shown to increase as much as 1°C experimentally with induce maternal hyperthermia and is further increased when the placental circulation is impaired or artificially occluded



Chorioamnionitis

- 226 of 756 (30%) neonates born to mums with chorioamnionitis had an axillary temperature >37.7°C at 30 minutes of age
- Infants with a higher temp were admitted to a neonatal unit



Adverse neonatal outcomes of maternal fever

- Include, increased mortality, birth depression, increase need for bag and mask ventilation, a decrease in apgar scores and hypotonia
- If exposed to maternal fever the neonate is more likely to require admission to the neonatal unit and are at increased risk of seizures and later development of CP



Implications for the care of the neonate

- The limits with which the human neonate can regulate body temperature unassisted are defined largely by its heat generating and conserving and heat losing capabilities and are considered narrower than those of an adult



- The radiant warmer supplies an adequate heat source for premature infants but does increase TEWL
- Neonates left exposed to air movement around the warmer can have increased convective heat loss



- Small full term neonates, incubator nursing desirable but not essential
- Avoiding ambient temperatures that are too low for the premature infant may not be possible in some communities, but the consequences are increased perinatal deaths



- Severe hypothermia in neonates can be fatal
- Moderate hypothermia of a chronic nature in the post-birth period is associated with increased mortality and morbidity, whilst mild hypothermia makes greater metabolic demands on the neonate and leads to decreased growth



- In term infants at high risk of HIE therapeutic hypothermia in NICU may improve Neuro developmental outcome



- Hypothermia is inevitable at birth it may, on the other hand, have some advantages.
- It may enhance the initiation of normal lung function in the newborn
- The higher the brain temperature the more risk of neuronal damage, to be cool would be an advantage especially in hypoxic babies soon after birth



Conclusion

- Close attention to the temperature of the neonate in the delivery room is important in both term and preterm neonates and remains the cornerstone of the initial steps of resuscitation
- Both increases and decreases in temperature may be associated with increased risk of morbidity and mortality



- Simple, clear and concise interventions can make a large difference in the thermal stability of the neonate.



RESEARCH



This is the cornerstone in neonatal and midwifery care



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- Volpe et al (2004). *Journal of Pediatrics*, 146, 790.

- Full reference list available on request

Perinatal Grand Rounds

“Parvovirus”

Presented by:

***Dr John Whitehall
& Jackie Smith NNP
with video link to
Prof Yvonne Cossart
(Dr who discovered Parvovirus)***

***Thursday, 6th March 2008
1230 - 1330 hrs***

Neonatal Auditorium, TTH

All Welcome

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**Nursing in the
perinatal environment
256**

Learning guide

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Nursing in the perinatal environment

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Theme 2

Congenital abnormalities

Theme 3

Infants requiring surgery

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Nursing in the perinatal environment

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Development and production completed by staff of The College of Nursing.

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**Nursing the high risk
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Learning guide

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Resuscitation

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Ongoing concerns for the premature baby

Theme 3

Additional range of diagnoses warranting
admission of the term newborn

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Nursing the high risk newborn

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INTRODUCTION

Nursing the high risk newborn

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Nursing the high risk newborn

Welcome to *Nursing the high risk newborn (257)*.

This learning guide is used in conjunction with the resources, the *Subject information and assessment book* and the *Student guide* and *Student management policy*.

Subject purpose

This subject challenges the student to consider issues specifically related to the special needs of the high risk infant. Babies admitted to level five and level six units often require complex diagnostic investigation and or surgical intervention.

This subject has three themes, supported by a foundational philosophy of family centred, developmentally supportive care.

Learning outcomes

On successful completion of this subject it is anticipated you will be better able to:

- critically reflect on their own values and beliefs in relation to care of the of the sick and unstable neonate
- discuss and analyse the impact of maternal history and maladaptive processes on subsequent adaptation of the high risk infant in the early neonatal period
- analyse the developmental and physiological considerations that lead to high risk neonate's inability to make a successful transition to extrauterine life
- critically analyse the need to promote parent infant interaction balanced with developmentally supportive care
- develop advanced skills in the assessment of neonates, and the provision and coordination of care using evidence from current literature to discuss possible long term outcomes, family support and education
- discuss the value of evidence and research in critically analysing current methods of treatment including the use of pharmacokinetics, muscle relaxants, analgesia, antibiotics and routine emergency drugs.

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Overview

This subject is divided into three themes and in each theme there are directions for reading the specific resources.

Theme 1: Maladaptive processes

The first theme looks at the common maladaptive processes in the newborn found in Neonatal Intensive Care units.

Theme 2: Congenital abnormalities

In this theme, the impact of chromosomal and congenital abnormalities is considered.

Theme 3: Infants requiring surgery

This theme looks at the infant requiring surgery as a result of a congenital defect, and how this impacts your nursing practice as part of the transport team involved in transferring a sick newborn to an appropriate surgical centre.

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Resources and Weblinks

A range of resources and weblinks are supplied in this *Learning guide*. We have selected current resources and references, that is, those published within the last five years, except:

- where references are considered as classics and the area has not been updated or covered better than by the original author
- where few significant changes have occurred and so there are no recent resources
- while there may be more recent information, the explanation is not as succinct or easy to understand.

School of
Nursing, Midwifery & Nutrition



Study Guide

NS5225:03 Care of the 'At Risk' Newborn

Study Period 1, 2011

Faculty of
Medicine, Health & Molecular Sciences



1800-888975 | pgnursing@jcu.edu.au | www.jcu.edu.au/nursing



Faculty of Medicine, Health & Molecular Sciences

School of Nursing, Midwifery & Nutrition



NS5225:03 Care of the 'At Risk' Newborn



Subject Coordinator – Jackie Smith

Contact details:

Email: jacqueline.smith5@jcu.edu.au

Location:

The Townsville Hospital
Douglas Qld 4814

Welcome

Welcome to NS5225:03 *Care of the 'At Risk' Newborn*.

My first experience of a neonatal unit was during my paediatric training, it was in this very brief period I decided what I wanted to do with the rest of my nursing career; this is definitely the place for me and I have never once regretted my decision, I still have the passion and the drive which I know will never waver. Since then I have achieved a diploma in sick children's nursing, diploma in neonatal intensive care, higher diploma in advanced neonatal studies, specialist advanced neonatal nurse practitioner and then went on to study as a neonatal nurse practitioner candidate, studying the Master of Nursing Science (nurse practitioner) in 2006. I'm currently enrolled in the doctorate of nursing science at James Cook University, so my education continues to different heights.

I am part of the neonatal clinical team in The Townsville Hospital neonatal unit, the start of NP duties at the beginning of January 2005 brought closer collaboration with the clinical team, comprising of neonatologists, registrars, nursing director, nurse unit manager, clinical nurse consultant, nurse educator, clinical and registered nurses. I feel an integral part of the neonatal medical and nursing team, carrying out an expanded role which includes prescribing, ordering diagnostic imaging, audiology or laboratory tests, referring patients directly to specialists and admitting patients to the unit. Much of my work is done with the babies in intensive care and special care nursery, but I am also present as required in birth suite or theatre during premature or high-risk births. I also have an important teaching role on the unit. In addition, I am on call for aero-medical retrievals with responsibility for in flight care. I also work on a casual basis for JCU for the nurse practitioner course and now the neonatal course, which in time, I hope to do on a full time basis.

I would appreciate your feedback about this subject. I am particularly interested to know if the contents have met your expectations. I welcome comments on its relevance and usefulness to you; and any other suggestions you may have about the study workload, activities, assignments and possible revisions. I hope you enjoy this subject.

Jackie Smith

Subject Overview

Subject Specifications

Faculty: Medicine, Health & Molecular Sciences
School: School of Nursing, Midwifery & Nutrition
Subject Code: NS5225
Credit Points: 03
Subject Title: Care of the 'At Risk' Newborn
Subject Coordinator: Jackie Smith
Study Period & Year of Offer: Study Period 1, 2011
Campus: Townsville
Mode of Offer: External

Subject Map

Module 1: Fetus to Newborn: The Transition

- Unit 1.1 – Embryological development
- Unit 1.2 – Being born
- Unit 1.3 – Basic newborn resuscitation
- Unit 1.4 – Thermoregulation
- Unit 1.5 – Promoting mother-infant attachment
- Unit 1.6 – Examination of the newborn

Module 2: The Preterm Infant

- Unit 2.1 – Comparison of term and preterm infants
- Unit 2.2 – Lung development, function and respiration
- Unit 2.3 – Fluids and nutrition
- Unit 2.4 – Infection
- Unit 2.5 – Introduction to developmental care

Module 3: Preconceptual and Antenatal Factors Affecting the Newborn

- Unit 3.1 – Physical assessment of SGA & LGA infant
- Unit 3.2 – Birth injury
- Unit 3.3 – Jaundice
- Unit 3.4 – Haematology of the newborn
- Unit 3.5 – Macrosomia
- Unit 3.6 – Neonatal abstinence syndrome

Module 4: Congenital Anomalies

- Unit 4.1 – Spina bifida
- Unit 4.2 – Cleft lip and palate
- Unit 4.3 – Gastro-intestinal tract anomalies
- Unit 4.4 – Diaphragmatic hernia
- Unit 4.5 – Congenital heart disease

Module 5: Neonatal Stabilisation and Transfer

- Unit 5.1 – Risk factors for stabilisation and transfer
- Unit 5.2 – Resuscitation

- Unit 5.3 – Stabilisation
- Unit 5.4 – Maintaining mother-infant dyad
- Unit 5.5 – Preparing for transfer

JCU Handbook Outline

This subject will develop theoretical knowledge of the 'at risk' newborn. This knowledge will be applied with a family centred focus within the clinical practice setting. The knowledge gained will enable the practitioner to interpret signs elicited by the 'at risk' newborn, identify the related anatomical, physiological and pathophysiological processes and evaluate the outcomes of a plan of care.

Learning Outcomes

On successful completion of this subject students will be able to:

- utilise research in the development of a family centred plan of care within a framework of cultural safety;
- critically analyse the outcomes of a plan of care and foster health promotion as a life long outcome;
- gain knowledge of the anatomical, physiological processes related to an 'at risk' newborn;
- develop an understanding of how pre-pregnancy conditions, pregnancy and birth relates to the anatomical and physiological processes in the 'at risk' newborn;
- interpret the pathophysiological processes occurring in the 'at risk' newborn.

Graduate Qualities Emphasised

James Cook University considers that students completing its courses should be recognised as having certain graduate attributes that distinguish them as university graduates, and as graduates of JCU in particular. This subject aims to ensure that graduates possess the following qualities:

- The ability to adapt knowledge to new situations;
- The ability to define and to solve problems in at least one discipline area;
- The ability to think critically, to analyse and evaluate claims, evidence and arguments, and to reason and deploy evidence clearly and logically;
- The ability to deploy critically evaluated information to practical ends;
- The ability to find and access information using appropriate media and technologies;
- The ability to evaluate that information;
- An understanding of the economic, legal, ethical, social and cultural issues involved in the use of information;
- The ability to select and organise information and to communicate it accurately, cogently, coherently, creatively and ethically;
- The acquisition of coherent and disciplined sets of skills, knowledge, values and professional ethics from at least one discipline area;
- The ability to reflect on and evaluate learning, and to learn independently in a self directed manner;
- The ability to manage future career and personal development;
- The ability to read complex and demanding texts accurately, critically and insightfully;
- The ability to speak and write clearly, coherently and creatively;
- The ability to communicate effectively with a range of audiences;
- The ability to lead, manage and contribute effectively to teams;
- The ability to work with people of different gender, age, ethnicity, culture, religion and political persuasion;
- The ability to work individually and independently;



Faculty of Medicine, Health & Molecular Sciences

School of Nursing, Midwifery & Nutrition












NS5226:03 Infant Feeding and Nutrition



Subject Coordinator – Jackie Smith

Contact details:

Email: jacqueline.smith5@jcu.edu.au

Location:

The Townsville Hospital
Douglas Qld 4814

Welcome

Welcome to NS5226:03 *Infant Feeding and Nutrition*.

My first experience of a neonatal unit was during my paediatric training, it was in this very brief period I decided what I wanted to do with the rest of my nursing career; this is definitely the place for me and I have never once regretted my decision, I still have the passion and the drive which I know will never waver. Since then I have achieved a diploma in sick children's nursing, diploma in neonatal intensive care, higher diploma in advanced neonatal studies, specialist advanced neonatal nurse practitioner and then went on to study as a neonatal nurse practitioner candidate, studying the Master of Nursing Science (nurse practitioner) in 2006. I'm currently enrolled in the doctorate of nursing science at James Cook University, so my education continues to different heights.

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Jackie Smith

Subject Overview

Subject Specifications

Faculty: Medicine, Health & Molecular Sciences

School: School of Nursing, Midwifery & Nutrition

Subject Code: NS5226

Credit Points: 03

Subject Title: Infant Feeding and Nutrition

Subject Coordinator: Jackie Smith

Study Period & Year of Offer: Study Period 2, 2012

Campus: Townsville

Mode of Offer: External

Subject Map

Module 1: Infant Feeding and Nutrition: The Beginning

- Unit 1.1 – Growth and development
- Unit 1.2 – Breast milk
- Unit 1.3 – Artificial feeding
- Unit 1.4 – Energy and glucose metabolism: maintaining the balance
- Unit 1.5 – Electrolytes
- Unit 1.6 – Fluids and feeding

Module 2: The Preterm Infant

- Unit 2.1 – Preparation for feeding
- Unit 2.2 – Breastfeeding the preterm infant
- Unit 2.3 – Infant formula and vitamins
- Unit 2.4 – Feed tolerance and intolerance
- Unit 2.5 – Iron and anaemia of prematurity

Module 3: Total Parenteral Nutrition

Module 4: Special Nutritional Management

- Unit 4.1 – Cleft lip and palate
- Unit 4.2 – Chronic lung disease
- Unit 4.3 – Necrotising enterocolitis
- Unit 4.5 – Growth restriction
- Unit 4.6 – Metabolic bone disease of prematurity

JCU Handbook Outline

This subject will develop theoretical knowledge related to infant feeding and nutrition. This knowledge will be applied with a family centred focus using a health promotion framework within the clinical practice setting. Knowledge gained will include an in-depth understanding of the anatomical, physiological and pathophysiological aspects of infant feeding and nutrition. The student will gain knowledge of the physiological processes of breast feeding, specialised feeding and nutrition in the 'at risk' newborn including preterm infant, growth restricted infant, newborn with selected congenital anomalies and the newborn with infection.

Learning Outcomes

On successful completion of this subject students will be able to:

- demonstrate and apply knowledge of WHO Baby Friendly Health Initiative in the 'at risk' newborn;
- demonstrate knowledge of the principles of nutrition in the 'at risk' infant including interpretation of weight changes and calculation of caloric and fluid requirements;
- demonstrate knowledge of pathophysiological processes influencing fluid and feed requirements;
- apply principles related to infant feeding and nutrition to infants with selected congenital abnormalities;
- utilise a culturally safe, family centred approach to infant feeding and nutrition in the 'at risk' infant.

Graduate Qualities Emphasised

James Cook University considers that students completing its courses should be recognised as having certain graduate attributes that distinguish them as university graduates, and as graduates of JCU in particular. This subject aims to ensure that graduates possess the following qualities:

- The ability to adapt knowledge to new situations
- The ability to define and to solve problems in at least one discipline area
- The ability to think critically, to analyse and evaluate claims, evidence and arguments, and to reason and deploy evidence clearly and logically
- The ability to deploy critically evaluated information to practical ends
- The ability to find and access information using appropriate media and technologies
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- The ability to select and organise information and to communicate it accurately, cogently, coherently, creatively and ethically
- The acquisition of coherent and disciplined sets of skills, knowledge, values and professional ethics from at least one discipline area
- The ability to reflect on and evaluate learning, and to learn independently in a self directed manner
- The ability to manage future career and personal development
- The ability to read complex and demanding texts accurately, critically and insightfully
- The ability to speak and write clearly, coherently and creatively
- The ability to communicate effectively with a range of audiences
- The ability to lead, manage and contribute effectively to teams
- The ability to work with people of different gender, age, ethnicity, culture, religion and political persuasion
- The ability to work individually and independently
- The ability to select and use appropriate tools and technologies
- The ability to use online technologies effectively and ethically.

Teaching Modes

This subject will be delivered in distance education mode utilising a combination of electronic, multi-media and online resources. Students are required to have internet access to download study modules, complete learning tasks and access online resources.

The subject resources include:

- subject outline
- study modules