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Thermoregulation in Very Low-Birth-Weight Infants During the Golden Hour

Results and Implications

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ABSTRACT

The survival of very low-birth-weight (VLBW) infants has been shown to be effected by alterations in thermoregulation. Morbidity and mortality in these VLBW infants has remained higher than those in any other group of infants because of their innate vulnerability and because of exposure to risk factors in the environment. This leaves the premature infant vulnerable to cold stress especially in the first hours to weeks of life. At birth, the VLBW infant emerges from a warm, fluid environment and is thrust into a cold, abrasive environment before the protective layers of the epidermis have developed. Within minutes of birth, the core temperature begins to fall, particularly in infants whose birth weights are less than 1500 g. Hypothermia is a major cause of morbidity and mortality in infants; therefore, maintaining normal body temperatures in the delivery room is crucial. We reviewed evidence related to thermoregulation at birth in VLBW infants, including transepidermal water loss and temperature control in the delivery room, during stabilization and upon admission to the neonatal intensive care unit. Delivery room management that focuses on the adaptation of the infant as well as early interventions that improve long-term outcomes may emphasize the "golden hour" of care and improve outcomes in this extremely vulnerable population.

KEY WORDS: golden hour, prematurity, temperature, thermoregulation, very low-birth-weight

The incidence of preterm birth in the United States increased from 10.6% in 1990 to 12.8% in 2006.¹ The percentage of infants born with very low birth weights (VLBW) (<1500-g birth weight) has increased more than 25% during the same time period to 1.5% of all births. The burden of preterm births varies dramatically from state to state, ranging from 9.6% to 18.7% of all births.^{1,2} Advances in neonatal care have allowed for

improved survival of the most premature infants, but the mortality for VLBW infants in the United States is 14%.³ In addition to this, morbidities remain high secondary to late onset sepsis (22%), chronic lung disease (18%), severe intraventricular hemorrhage (11%), and necrotizing enterocolitis (5%).^{1,4} Importantly, each of these morbidities is an independent risk factors for poor long-term neurodevelopmental outcomes.^{1,3}

Premature births and low birth weights are conditions associated with high hospital charges and long length of stays.⁵ In 2006, the Institute of Medicine estimated the annual cost of preterm births in the United States at \$26 billion, or approximately \$51 600 per preterm infant.⁶ Although VLBW infants represent only 12% of premature births in the United States, they account for 30% of total dollars spent on newborn health care.⁷ These higher costs reflect the significantly higher incidence and severity of morbidities that impact VLBW infants during the NICU stay.

For VLBW infants, the events that occur immediately after birth may be comparable to the "golden hour," which is discussed throughout the trauma literature.⁸

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The term *golden hour* in the trauma literature refers to the time of first encounter to admission to the emergency department. There may be a “golden hour” of care for VLBW infants that begins with the first encounter at delivery until admission to the NICU. During this time period, attention to thermal stress is critical. Innate protective mechanisms that can be employed by children and adults to adjust heat transfer are limited and ineffective in the extremely preterm infant.

Conventional practice for the prevention of heat loss in the delivery room has been in place since almost 1966 and includes placing the newborn under a radiant warmer and drying them quickly.^{9,10} Several methods to reduce heat loss in the delivery room, such as coating the infants skin with paraffin,^{11,12} heat shields or plastic hoods,¹³⁻¹⁵ and plastic wraps or blankets,¹⁶⁻²⁰ have been investigated. The “golden hour” initiative goes beyond looking to change 1 clinical outcome and instead looks at a process for providing care to implement multiple evidence-based practice initiatives, called “bundles,” which could improve short- and long-term outcomes to VLBW infants.

The “golden hour” bundle is a systematic evaluation of the scientific knowledge for each aspect of care for VLBW infants during resuscitation and stabilization. The “golden hour” guideline incorporates processes of neonatal resuscitation on the basis of the neonatal resuscitation program (NRP) guidelines and expands on these guidelines to ensure that the unique needs of the VLBW infant are addressed.²¹ The “golden hour” addresses unique strategies and evidence including thermoregulation during the first minutes to hours after birth.

THEMREGULATION AND PREMATURETY

Temperature control is essential to survival, and studies since 1950s have shown that infants with hypothermia have poor outcomes.²² Despite all that is known about heat loss in infants, hypothermia continues to be a significant problem especially in VLBW infants. Fetal temperature is approximately half a degree (centigrade) higher than maternal temperature in utero. This temperature relationship (fetus > mother) results from a combination of endogenous heat production by the fetus and the surrounding core temperature of the mother. To dispose of excess endogenous heat, the fetus’ temperature must be greater than maternal core temperature, creating the necessary temperature gradient to support heat transfer.

At birth, heat is lost rapidly secondary to the cold external environment and significant evaporative heat losses. Studies from the 1970s demonstrate that core body temperatures can drop 2°C to 3°C in the first 30 minutes of life.¹⁰ The body temperature of premature infants drops precipitously after birth

because of their disproportionate body mass-to-surface ratio, exposed body posture, decreased amounts of subcutaneous fat, poor vasomotor control, and thin skin with increased permeability.²³⁻²⁵ Indeed, despite attempts to reduce heat loss in the delivery room, data collected by the Vermont Oxford Network demonstrate that 27.8% of VLBW infants have admission temperatures less than 36°C.²⁶ Despite the rapid loss of heat immediately after birth, thermal homeostasis is essential for survival. Such uncontrolled losses as described earlier place the infant at risk for significant morbidities and mortality.

Adults respond to cold stress with peripheral vascular constriction, inhibition of sweating, postural changes, voluntary muscle movements, and shivering and nonshivering thermogenesis.²⁷ Neonates lack many of these responses including a diminished capacity to shiver or alter their body position. While shivering thermogenesis does occur in neonates, it is usually a response to extreme thermal stress and is insufficient to protect the infant due to the relative immaturity of the skeletal muscles resulting in diminished heat production. Nonshivering thermogenesis is the primary mode of heat production requiring an increase in norepinephrine and thyroid-stimulating hormone. Thyroid-stimulating hormone leads to an increase in thyroxine (T4) and conversion to triiodothyronine (T3), causing increased fat oxidation and heat production. This represents a large caloric demand. A newborn infant will lose 150 kcal/min in an attempt to keep warm.²⁷ Infants born <32 weeks do not have adequate brown fat stores to fully initiate nonshivering thermogenesis and are not able to effectively convert T4 for heat production.²⁸

Hypothermia causes a variety of physiologic stresses, may delay transition from fetal to neonatal circulation at birth, and is an independent risk factor for mortality in preterm infants. The entire thermogenic process requires oxygen and glucose. Thus, hypothermia (with increased need for thermogenesis) occurring during the adaptation to extrauterine life presents increased demands for oxygen during a period of time when oxygen delivery may be compromised. In addition, in VLBW infants, increased glucose needs may be coupled with inadequate stores and a lack of dextrose delivery due to delays in intravenous access. Therefore, cold stress can be associated with increased oxygen demands, respiratory compromise, and hypoglycemia.

With hypoxia, the infant utilizes anaerobic metabolism resulting in metabolic acidosis and pulmonary vasoconstriction. This effects pulmonary vasomotor tone and can lead to a vicious cycle leading to decreased cardiac output, acid-base abnormalities, shock, coagulation defects, altered cerebral blood flow leading to severe intraventricular hemorrhages, necrotizing enterocolitis, acute renal failure, and sometimes death.²⁹⁻³¹

TYPES OF HEAT LOSS

Humans, including the tiniest of preterm infants, are obligate heat producers capable of altering heat production to maintain body temperature (homeotherm). We must continuously modify heat transfer to maintain our core temperature in a relatively narrow range. Often this involves physiological and behavioral changes to allow for loss of excess heat. However, in infants, heat losses are more often excessive and steps must be taken to reduce losses rather than encourage losses. Heat transfers between the infant and the environment by conduction, radiation, evaporation, and convection and heat loss by these means far exceed heat production at birth. Heat transfer by conduction occurs when objects of differing temperatures come in contact with each other. Heat is always transferred from the hotter object to the cooler object. While conduction can result in transfer of heat to the newborn infant, this is very rare and usually limited to the use of heating pads and chemical warming pads. The usual situation clinicians face in the delivery area is transfer of heat from the infant's skin surface (36°C-37°C) to other surfaces (27°C, if the surface is in equilibrium with ambient air temperature). Such conductive heat transfer is minimized by the use of prewarmed equipment, towels, and blankets.

The temperature gradient between the infant and the air (approximately 37°C and 27°C, respectively) creates the potential for heat loss to the air (convection) and poses considerable threat to temperature homeostasis. Control of airflow is critical in the delivery and stabilization room. Airflow maintains the gradient between the infant and the surrounding air by moving warmed air away from and moving cooler air toward the infant. Forced convection results from air currents from vents, movement of personnel, or the opening and closing of doors. Free convection results from the tendency of warm air to rise off the newborn's body. Attention to sources of air movement and interventions that reduce airflow across the infant's skin (wraps, air diverters that divert air from vents or shields similar to double-walled incubators, etc) are essential for health care providers caring for newborn VLBW infants.

Radiant heat loss occurs when heat is lost to cooler objects that are not in direct contact with the infant, such as walls and windows. Radiant heat transfer is dependent on temperature gradients and exposed surface areas of the heat donor and recipient. Radiant warmers are used to transfer heat to the infant from an intense heat source, thereby replacing heat losses. As in convective heat loss, it is essential that providers are aware of sources of radiant heat losses and take steps to minimize such losses. Maintenance of appropriate air temperatures will heat wall surfaces and in turn reduce the gradient driving radiant heat transfer.

Evaporative heat loss is the major source of heat loss in the first 2 weeks of life.^{32,33} Heat is lost by evaporation when water is lost through the skin, undergoing conversion from a liquid to a gas. While other forms of heat transfer can occur either from infant to environment or from environment to infant, evaporation is unidirectional, always resulting in transfer of heat from the infant to the environment. The maturity of the epidermal layer and the maturation and development of the skin barrier function in premature infants has been studied.³⁴ The epidermis is the outer layer of the skin and provides a barrier to microorganisms and is key to retaining water. The stratum corneum makes up the outermost layer of the epidermis. The premature infant has very few layers to the stratum corneum, with an epidermis that is only 2 to 3 cell-layers thick compared with 10 to 20 layers in a term infant.³⁵

The thinness of the skin due to the lack of keratin leads to a high amount of transepidermal water loss (TEWL) that diminishes heat regulation. Measurement of insensible water loss in newborns has been shown to reflect the effectiveness of the skin barrier. It is important to understand and control TEWL in premature infants because it is a source of heat loss and can alter overall water balance.^{36,37} A mature stratum corneum is relatively water-impermeable compared to the high insensible water losses from the immature stratum corneum of premature infants.³⁸ Water loss can be as great as 200 mL/kg/d and evidence has shown that for each gram of water lost by evaporation from the body surface, the body loses approximately 580 calories (0.58 kcal) of heat.³⁹ This water loss is from both the respiratory track and the transepidermal, and the rate of this evaporation depends on the relative humidity (RH) of the air when it is less than 100%. Transepidermal water loss depends on the permeability of the skin. At birth, term infants lose about 7 g/kg of water through their skin compared to infants of less than 30-week gestation who lose 129 g/kg of water.⁴⁰ "Appropriate for gestational age" infants have a higher water loss than "small for gestational age" infants related to the thickness and water content of the corneal layers of the epidermis.

The stratum corneum becomes functionally mature between 32 and 34 weeks' estimated gestational age.⁴¹ Research has shown that TEWL is associated with gestational age in the first 4 weeks of life and that the skin serves as the most important route of water depletion early after birth.⁴⁰ Maturation of the stratum corneum can take as long as 4 weeks in infants 23- to 25-week gestation and 2 to 4 weeks in infants between 30- and 32-week gestation.⁴¹⁻⁴³ It is important to note that even at 4 to 5 weeks of age, infants who are less than 27-week gestation at birth continue to have more than twice as high TEWL than full-term infants despite the steady drop over time.^{32,42}

The ability to maintain equilibrium between heat loss and heat gain is restricted in the first 12 hours of life despite environmental temperatures. The magnitude of TEWL at birth depends not only on the environmental temperature but also on the humidity of the environment.⁴⁴ The enormous water loss in these infants can lead to dehydration, electrolyte imbalance, weight loss, and thermal instability.⁴⁵ Evaporation of free water results in contraction of the extracellular space and may be complicated by the development of a hyperosmolar, hypernatremic state.⁴⁵⁻⁴⁸ Treatment of infants with high-volume fluid replacement presents a risk of acute fluid overload resulting in patent ductus arteriosus, congestive heart failure, and pulmonary edema.^{40,45,48,49} Prevention of large TEWL during the early development of epidermal barrier properties may reduce the requirement for massive fluid replacement volumes and prevent the morbidity associated with fluid overload.⁴⁸

Environment

Cold stress is more common than is thought. In 2005, a large survey demonstrated that more than 5069 VLBW inborn infants had abnormally low temperatures upon admission to the NICU with 46.6% having less than 36°C temperature.⁵⁰ It is essential that VLBW infants be cared for in environments that prevent heat loss utilizing measures that improve thermoregulation.

The environment affects the vital function of the VLBW infants influencing heart rate, respiratory rate, oxygen consumption, and TEWL.⁵¹ Sources of cold stress resulting in hypothermia exist at birth in the delivery room, during procedures and in transport to the NICU. The American Academy of Pediatrics, along with the World Health Organization, suggests that infants' temperatures be kept between 36.5°C and 37.5°C.⁵² They further outlined the following:

- Potential cold stress (36°C-36.5°C): Cause for concern
- Moderate hypothermia/32°C-36.0°C): Dangerous, requires immediate warming of the infant
- Severe hypothermia (<32.0°C): Outlook grave, skilled care is urgently needed.

Infants can maintain normal rectal temperatures in the face of severe cold stress until their normal physiologic response to this stress is overwhelmed.⁵³ Infants compensate by increasing their oxygen and caloric demands to generate heat. It has been shown that body temperatures more than 36°C reduce mortality.⁵³ Risk of mortality increases when neonates are nursed at environmental temperatures outside the neutral thermal range.⁵⁴ The mortality rates of low-birth-weight neonates can be reduced if health care providers take the necessary steps required to reduce body heat loss and maintain temperatures.

It was shown in the late 1950s that maintenance of a normal body temperature through the control of the thermal environment significantly reduces mortality in low-birth-weight infants.⁵⁵ The relative range of ambient temperature, within which the VLBW infant can maintain a normal body temperature, with the lowest expenditure of energy and consumption of oxygen is called the neutral thermal environment.²⁰ The neutral thermal environment with a stable body temperature requires a steady state where heat production equals heat loss. A critical temperature is one that falls above or below the neutral thermal environment and is narrow in infants. The relative range of ambient temperature to maintain thermal stability in VLBW infants is between 22°C and 27°C (72°F-80°F).^{56,57} Air temperature fluctuation of (2°C (approximately 3°F) is sufficient to induce thermal stress in premature infants.⁵⁸⁻⁶⁰ This presents a thermal challenge to health care providers in the delivery room as well as in the NICU. The World Health Organization recommends that delivery room temperatures be kept at 27°C (80°F).⁶¹

In all humans, including the VLBW infant, the normal basal metabolic function of the body results in obligate heat production. The inability to disperse heat may result in hyperthermia and complications of hyperthermia. Temperatures more than 37.5°C may lead to vasodilation, tachycardia, lethargy, and apnea.⁶² Therefore, prevention of hyperthermia is as important as prevention of hypothermia. Infants have a decreased ability to dissipate heat due to a decreased response by sweat glands that develop around 30 to 32 weeks. Overly vigorous interventions to replace heat losses or to prevent heat loss can result in progressive overheating and the complications listed earlier. It is essential that health care providers ensure that measures to prevent hypothermia do not cause hyperthermia.

PREVENTION OF HEAT LOSS

One basic mechanism to prevent heat loss is manipulation of the environmental temperature. Environmental temperature refers to the aggregate influence of the environment on body temperature. For example, heat index and wind chill are examples of environmental temperature. Delivery rooms are sometimes kept at a temperature comfortable for the mother and staff with little consideration of the newborn. This results in greater temperature gradients between the infant and the air (increased convective losses) and cool walls (increased radiant losses). Interventions that increase air temperature in delivery area reduce convective and radiant heat loss. Prewarming of surfaces and items coming in contact with the infant will result in reductions in conductive heat losses. Table 1 provides recommended delivery room temperatures and humidity on the basis of gestational age and birth weight.⁵⁷

TABLE 1. Recommended Stabilization Room Temperatures (Based on Postmenstrual Age and Birth Weight)

Estimated Postmenstrual Age, wk	Estimated Birth Weight, g	Delivery/Stabilization Room Temperature	Humidity
≤26	≤750	78–80°F	50%
27–28	751–1000		
29–32	1001–1500	≥72°F (Goals 75°F)	

In addition to the air temperature, it is important to control humidity. The evaporative heat loss is very high with dry, draughty air and can lower the infant's core temperature below that of the surrounding air. It is easier to prevent hypothermia by reducing TEWL than by increasing heat production.³⁹ The epidermal barrier matures rapidly over the first 2 weeks of life. Nothing is known to accelerate this maturation process. However, we can alter TEWL by altering RH. At 100% RH, TEWL is zero because there is no water vapor pressure gradient driving water loss. An RH of 90% will result in a fall of the total body water loss of 45% for VLBW infants.^{63,64} At 80% to 90% RH, the decrease of evaporative skin cooling impedes the fall of body temperature with increase in weight, and decreased fatality in VLBW infants.^{54,65} When RH is raised TEWL will be low regardless of the effectiveness of the infant's epidermal barrier. Relative humidity of at least 50% premature infants has been shown to greatly improve temperature control, body temperature, and fluid balance.^{44,66,67} Table 1 provides recommended delivery room temperatures and humidity based on gestational age and birth weight.

Polyethylene Wrap in the Delivery Room

Studies have shown that using a plastic wrap made of polyethylene in babies immediately before or after drying can further minimize evaporative and convective heat losses.^{18–20} Radiant heaters are often used as the sole source of thermal care in the delivery room although they cannot achieve a positive energy balance to warm the premature infant immediately after birth.⁶⁸ Occlusive wrap has been clearly established through 4 randomized controlled trials, involving 300 infants, and a Cochrane review, as effective in preventing hypothermia (<36.5°C) in premature infants younger than 29-week gestation in the delivery room and significantly improving admission temperatures.^{18–20,69} A 2005 systematic review found that occlusive wrap significantly improved admission temperature and significantly reduced hypothermia.⁷⁰ Occlusive wrap permits heat gain by the infant through radiation and reduces the amount of evaporative heat loss. Studies show decreased mortality in infants who were cared for using plastic wrap and hat.⁶⁹

Polyethylene wrap has also been shown to reduce insensible water loss by 70% and improve temperature control.^{11,71} Despite the use of polyethylene wraps, VLBW infants continue to have problems with hypothermia in the first few days of life and polyethylene wraps must be used in combination with other thermoregulatory measures. Polyethylene wrap placed on VLBW infants before drying in the delivery room may produce a micro-humidified environment and improve TEWL and temperature control. The poorly developed epidermal barrier in VLBW infants leads to high TEWL, percutaneous absorption, and trauma.³⁹ High TEWL leads to poor temperature control and difficulty in fluid balance. It can and should be reduced by manipulation of the ambient humidity and by covering the skin. The wrap serves as a shield for the infant and forms a barrier keeping higher ambient air humidity under the wrap.⁷²

Once an infant is wrapped in the delivery room, it is essential to maintain that wrap. Reports have shown that infants in NICUs may be manipulated by health care providers up to 30% of the total day.^{73,74} The thermal microenvironment may be significantly altered by frequent wrap removal. For example, Lyon et al⁷⁵ reported that a reduction in skin temperature of more than 1°C can result in thermal stress, which may lead to hypovolemia. Heat loss has been shown to be minimized by the humidified microenvironment for reasons discussed earlier.⁵¹ Relative humidity that builds up in the microenvironment underneath the wrap will drop quickly when the infant is unwrapped, TEWL will increase at the same time, and the infant's body temperature will fall. It may take awhile once closed for humidity to increase again. The clear plastic wrap allows the provider to observe and assess the infant. It is essential for health care providers to learn techniques to effectively wrap the infant so that unwrapping is unnecessary even for procedures such as umbilical catheters.

Despite advances in technology, 31% to 78% of VLBW infants exhibit cold body temperatures after delivery room stabilization, and improvement in care remains a significant challenge to the health care team.⁵⁷ In 2005, the American Academy of Pediatrics and the American Heart Association recommended that polyethylene bags in the delivery room be

considered for prevention of heat loss in VLBW infants. Prior to this recommendation, a survey of NICUs in the United States found that only 20% of responding units used occlusive wrap in the stabilization and resuscitation of infants.⁷⁶ Optimizing delivery room temperatures combined with the use of occlusive skin wrap may be the best method for decreasing hypothermia in VLBW infants.

TRANSWARMER MATTRESSES

There has only been 1 small study evaluating the use of the transwarmer mattress in VLBW infants in the delivery room. Although this trial demonstrated improved admission temperatures in the mattress treated group, the study is too small to make recommendations.⁷⁷ Further studies are needed looking at the addition of transwarmer mattresses with wrap to ensure iatrogenic hyperthermia and burning are avoided. There may be a use for this type of warmer during transport in a cohort of infants who, despite maximal thermoregulatory control, still arrive cold in the NICU.

Hats

Heat exchange between the uncovered head and the environment is very high.⁷⁸ Use of stockinet caps has not been shown to improve core body temperatures in VLBW infants and currently there are 2 studies evaluating woolen hats and showing an improvement in temperature in the first 30 minutes of life.^{69,79-81} A Cochrane review looking at measures to reduce hypothermia concluded that hats had only a minimal effect in reducing heat loss from the head.⁶⁹ There have been no studies looking at the effect of hats in VLBW infants. One issue is that currently available hats prevent heat from escaping but do not prevent evaporative heat loss. In infants wrapped in plastic bags, the large surface area of the infant's head remains available for evaporative heat loss. About 50% of the total heat loss is through the head.⁸² One small study evaluated the use of a polyurethane-lined hat and was able to show a reduction in cranial heat loss between 63% and 72%.⁸³ It is clear that the use of stockinet or cotton hats does not provide adequate thermoregulatory support for VLBW infants. The addition of the plastic wrap under the hat may make a significant difference in heat loss and improve thermoregulation in VLBW infants. Development of strategic wrapping techniques by delivery room staff to place the wrap under the hat may decrease thermal losses.

Further Reduction in Heat Loss

It is important to further reduce heat loss by controlling all 4 methods of heat exchange. To reduce conductive heat loss, it is recommended that any surface in direct contact with the infant be prewarmed. This

includes radiant warmers in the delivery room and NICU, in-bed scales, blankets, wraps, clothing, thermal mattresses, and x-ray plates. Reduction in convective heat loss requires a warm environmental temperature without drafts and the need for warm gases for respiratory support. Evaporative heat loss can be controlled by drying the infant using a prewarmed wrap and hat, providing a humidified environment, and using humidified oxygen. When placing umbilical catheters utilizes a clear plastic sterile drape during the procedure to allow for radiant heat transfer is essential. Although radiant heat loss cannot be totally eliminated, radiant warmers along with measures to prevent other types of heat loss may improve outcomes in VLBW infants.

Drying

The epidermis of the VLBW infant is a major clinical problem. Large areas of skin may be easily denuded and the most premature infants often have problems with weeping.^{38,39} The epidermis of the VLBW infant easily separates from the underlying dermis and has limited resistance to physical trauma.³⁸ The moist dermis is exposed, which makes the VLBW infant prone to bacterial and yeast infections.⁸⁴⁻⁸⁶ Skin breakdown can increase the rate of TEWL and provide a portal of entry for microorganisms that can lead to bacteremia.⁸⁷ Removal of the epidermis in the delivery room with towels may be further exposing these infants to trauma and increasing their risk of nosocomial infections. One study evaluating the use of polyurethane bags without drying the infant's body showed an improvement in admission temperatures.¹⁸ Currently drying the infant thoroughly at birth and removing the wet towel is recommended in the NRP guidelines.²¹ This can be accomplished using an absorbent towel and patting technique avoiding rubbing the infant, which can damage the fragile skin.

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Transport to NICU

The VLBW infant should be transported in a prewarmed transport incubator set to maximum air temperature to the NICU. The infant should be maintained in the wrap during transport and the temperature of the transport incubator should be adjusted to meet the infant's thermoregulatory needs. Upon arrival to the NICU, VLBW infants should be placed in humidified, double-walled incubators. Double-walled incubators, which direct warm air between the inner and outer incubator walls, have been shown to reduce radiant heat loss through the reduction of temperature gradients between the infant and its environment. If a VLBW infant is admitted on a radiant warmer, it is essential to provide a humidified environment utilizing a heat shield, wrap or, in some cases, using a radiant

warmer that converts down to incubator as soon as possible.

GOLDEN HOUR GUIDELINES FOR THERMOREGULATION

It is essential that 1 team member have a lead role in thermal care of the VLBW infant at birth and that it be incorporated into ongoing neonatal resuscitation. In developing the “golden hour” guidelines, we evaluated all the available evidence utilizing research, current NRP guidelines, and potentially better practice. The recommendation of NRP is that the delivery room temperature should be increased and a preheated radiant warmer should be utilized as well as a cap. We evaluated each of these recommendations as well as other evidence, guidelines, and potentially better practice to develop the “golden hour” standards.

In implementation of the “golden hour”, standardized air temperatures guidelines in both the delivery room and stabilization areas were developed on the basis of recommendations of experts and outlined in Table 1.^{22,88,89} This table was posted for the stabilization team and agreed upon by the obstetric team. Involving all disciplines in the educational process is key to implementation of the “golden hour” bundle and holding onto gains. When discussing the environmental temperature changes with obstetrical staff, it is essential to point out that normothermia in mothers during cesarean sections have been shown to reduce wound infection, hospitalization, and blood loss and has led to earlier extubations offering significant benefit to both the mother and the infant.⁹⁰

The conventional care of drying infants in prewarmed towels and providing care under a radiant warmer has been shown to be ineffective in a large number of VLBW infants.^{30,68} It is important to recognize that these measures should not be abandoned but rather supplemented with additional interventions to reduce heat transfer. The “golden hour” guidelines recommend additional measures to insure that thermoregulation is achieved in these infants. The decision was made to utilize a sterile wrap in all infants younger than 29 weeks on the basis of the highest level of evidence. We provide absorbent sterile towels for the OB staff for placement of the VLBW infant immediately at birth and transfer to the NICU team. The babies were encased in the towels to prevent evaporative and convective heat loss during transfer. They are then placed on the preheated radiant warmer and dried using a patting technique to prevent skin damage. The wet towel is immediately removed and the infant is placed on the sterile wrap. The nurse member of the team was assigned oversight of thermoregulation and trained in a wrapping technique to improve temperature control. The wrap is placed at an angle with 1 portion placed under the preheated cap. The wrap is cut at the 2 angles toward

the center so the infant is wrapped leaving the umbilical cord exposed for line placement. The limb leads, temperature probe, and the saturation probe are all placed before wrapping, and wrapping is usually completed in the first minute of life. The wrap is done in coordination with neonatal resuscitation. Visualization and the initial examination are done with the wrap intact and then further examination as needed is completed after the wrap is removed. Maintenance of the wrap until infant is stable in the NICU humidified environment for 1 hour is critical. Thermal equilibrium, which is the state of constant temperature, is not achieved until about 30 to 60 minutes of being placed in a new environment or change of air temperature.⁶² The infant is cared for in a humidified incubator with the wrap intact until stable at 60 minutes, and then the wrap is removed.

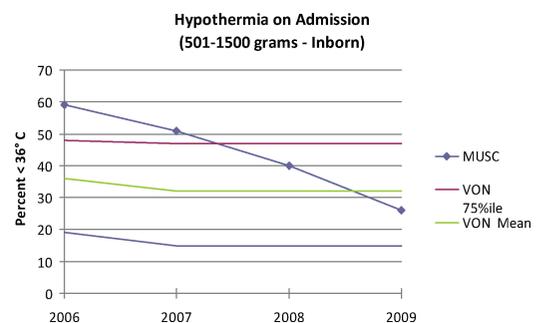
We had already incorporated the scale for weight within the preheated environment and utilize a controlled heated environment for transfer to the NICU, but these are an essential part of “golden hour” care.

The implementation of the “golden hour” guidelines at the Medical University of South Carolina and follow-up data demonstrates that the use of wrap and recommended environmental temperature for VLBW infants significantly improves the incidence of hypothermia on admission to NICU (Figure 1). With implementation of the changes to prevent hypothermia, we decreased our admission hypothermia rate from 60% to 24%.

CONCLUSION

Despite improvements in neonatal care during the past 10 years, preterm births are the second leading cause of neonatal mortality in the United States and these infants continue to have the highest morbidities.⁹¹ For premature infants (<37 weeks' completed gestation), health care decisions made in the first

FIGURE 1.



Incidence of hypothermia on admission to the neonatal intensive care unit.

hours of life (“golden hour”) determine subsequent decades of survivor-experienced morbidity. There have been few well-powered randomized controlled trials in premature infants and, as a result, anecdotal experience and consensus statements rather than high-quality evidence drive practice change. Recent comparative effectiveness research has shown that using these standards is fatally flawed and suggests that we can improve care by decreasing practice variability and reducing the use of harmful therapies. Neonatal health care providers must begin to implement evidence-based practices and best practices to address the needs of vulnerable infants beginning in the first minutes of life. Very low-birth-weight infants are vulnerable in the delivery room because of their gestational age, birth weights, and immaturity, which puts them at risk to the effects of the environment.¹⁹ It is essential that thermoregulatory management of premature infants in the delivery room be a priority.

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