Optimal care of sick newborn and premature infants requires meticulous attention to detail. The consequences of overlooking some details may not be readily apparent, whereas other details may affect the very survival of the neonate. Such was the case late in the nineteenth century when French authorities sought to decrease infant mortality as one way to increase the population and provide the needed manpower to support industrialization and the armies of the expanding French empire. Dr. Stephane Tarnier, Chairman of Obstetrics of the University of Paris, was distressed with the plight of the “weaklings” and applied earlier concepts of incubators to the regular care of premature and sick infants, believing that maintaining thermal stability was a key factor for their survival.

The first incubator for neonates was introduced in 1835 by Von Ruehl in St. Petersburg, Russia, and in 1857, the incubator was described by Denunce as a double-walled box that circulated warmed water within the interspace. The care of newborns was delegated to Madame Henry, Midwife-in-Chief, who oversaw the building of a pavilion specifically for the care of these weakling newborns. This pavilion housed 12 incubators in which fragile newborns were warmed over a hot-water reservoir attached to an external source of heat. These were impressive first steps in attempting to control the fragile heat balance of weak preterm infants and contributed to the reported decreased mortality rate from 66% to 38% in babies with birth weights between 1200 and 2000 g. Dr. Tarnier’s successor, Dr. Budin, continued this important early practice of neonatology, focusing on the home care of these high-risk babies. Alexandre Lion improved the design of incubators and charged spectators a fee to see them in action, which led to a very popular show at the Berlin Exposition of 1896. An associate of Lion, Martin Couney, brought the incubator shows to the United States, where Dr. Joseph DeLee adopted the technology and opened an “incubator station” in 1900 at the Chicago Lying-in Hospital. Nearly all of the large expositions in America hosted “Incubator Baby Side Shows.” These began in 1898 with the Trans-Mississippi Exposition and continued on to the New York World’s Fair in 1939.

Dr. Couney’s display of incubators at Luna Park on Coney Island and at a second park named Dreamland hosted premature babies from New York hospitals that lacked the facilities to care for them. These infants were lined up under heaters in incubators, and they breathed filtered air. At least 8000 babies passed through these incubators, and at least 6000 were saved. Servocontrolled radiant heat in incubators was initially reported by Agate and Silverman in 1963. Today’s radiant warmer is an evolution from the original idea of Agate and Silverman. Radiant energy as the sole source of heat from an overhead panel was described in 1969 by Due and Oliver. Widespread use of the warmer in the delivery room was readily accepted and soon led to its use in the neonatal intensive care unit. The factors that effect heat loss and heat production were elucidated. As intensive care became more readily available, easy accessibility to the infants became increasingly necessary and the open warmer became more readily used.

Changes in the radiant warmer have included introduction of incubators that are interchangeable with and convert to radiant warmers. The use of humidification in the incubators has also been improved to allow for varying humidification based on the infant’s gestational age and weight. These new beds allow the caregiver to rotate the mattress 360 degrees for easy patient access and provide an in-bed scale. Recent studies have encouraged the introduction of polyethylene plastic bags and wraps for use with babies born at approximately 30 weeks’...
gestation or less. This type of warming is ideal for a preterm infant (at birth and the immediate hours following) awaiting transportation to a tertiary care facility or indeed a baby born in a tertiary care facility. The baby is placed on a warm towel (but not dried) and placed under a radiant warming heating device. The baby (excluding his or her head) is placed fully in the polyethylene bag or is wrapped in the polyethylene sheet. The baby should remain under the radiant warmer as the heat, acting through the covering on the baby’s moist skin, creates a warm thermal environment. Cutting an appropriate-size hole through the covering over the area of insertion can facilitate the introduction of any catheter or cannula. Polyethylene bags for warmth have been adopted by the Neonatal Resuscitation Program (NRP) (see Chapter 4).

NRP guidelines emphasize how hypothermia may reduce the extent of brain injury after hypoxia and that hyperthermia may worsen the extent of brain injury during reperfusion after hypoxic events. The recommended goal is to maintain normothermia for the infant and avoid iatrogenic hyperthermia in resuscitated newborns (see Chapter 26).

Building on these early findings and occasional misguided efforts over the next several decades, researchers have gained insight into the physiology of thermoregulation and developed the technology to maintain thermal neutrality in the tiniest and sickest neonates. Although the staffs of modern neonatal intensive care units (NICUs) have the expertise and equipment to avoid the consequences of inadequate thermoregulation, determining the most appropriate ways of attaining the best temperature balance is the subject of ongoing investigation. This chapter discusses the current knowledge of the physiology and pathophysiology of neonatal thermoregulation and techniques used not only to prevent heat loss but also to manage heat balance.

**PHYSIOLOGY**

Animals that maintain their body temperature within a narrow range through a wide range of environmental temperatures are known as *homeotherms*. Humans, as homeotherms, maintain a “normal” body temperature by balancing the amount of heat lost from the body with the amount of heat generated from within the body. Our ability to cope with changing thermal environments improves physically and physiologically with age. Eventually we are physically able to move to a different place with a more suitable environment or dress more appropriately when the temperature is uncomfortable.

Babies, especially preterm or small-for-gestational-age (SGA) babies, of course cannot physically respond as older children would, and even their physiologic responses are different and limited. Adults lose some thermoregulatory control during rapid-eye-movement sleep. Because newborns spend much time in active sleep, loss of their ability to compensate for changes in environmental temperatures may be detrimental to their well-being. Recent evidence suggests that thermoregulation is not impaired during active sleep in the neonate, which indicates the developmental importance of both thermoregulation and active sleep in the maturation of newborn infants.

Physiologic responses to a cold environment include metabolic reactions that consume substrate and oxygen and result in heat production. A neutral thermal temperature is the body temperature at which an individual baby’s oxygen consumption is minimized. Thus a minimal amount of the baby’s energy is expended for heat maintenance, and energy is conserved for other basic functions and for growth. Minimal metabolic activity is possible within a narrow range of temperatures, so temperatures that are too high or too low add stress and increase metabolic rate. Extreme deviations from this range overwhelm the thermoregulatory mechanisms, leading to body temperature changes and potentially death.

**CAUTION:** All studies used to develop Figures 6-1 and 6-2 were conducted under specific, controlled environments that may not exist in the clinical setting. The ideal temperature varies with the particular baby and environmental variables such as relative humidity, type of incubator, and clothing used.

The goal in controlling a neonate’s environment is to minimize energy expended by him or her to maintain a “normal” temperature, thus eliminating thermal stress. This neutral thermal environment is the sum total of factors at which a baby with a normal body temperature has a minimal metabolic rate and therefore minimal oxygen consumption. Both traditional indirect calorimetry and the more accurate and sensitive direct calorimetry are used to study the production
and expenditure of heat in newborns. Factors such as ambient air temperature, airflow velocity, relative humidity, and temperature and composition of objects in direct contact with the infant or to which heat may be radiated compose the infant’s thermal environment.

When exposed to a cold environment, a neonate senses the reduced skin surface temperature (using sensors in the skin, primarily the face) and senses core body temperature (using sensors along the spinal cord and in the hypothalamus). Information from these various sensors is processed (probably in
the posterior hypothalamus), including average temperature, rate of temperature change, and size of the stimulated area. Cold stress results in the initiation of a series of reactions to increase heat production and decrease heat loss. In adults, the most significant involuntary method of heat production is shivering. Neonates rarely shiver and must rely on nonshivering, or chemical, thermogenesis to produce the needed heat. This process is initiated in the hypothalamus and transmitted through the sympathetic nervous system, leading to the release of norepinephrine at the site of brown fat. Brown fat, found mostly in the nape of the neck, axillae, and between the scapulae of newborns, is a specialized type of fat. It is unique in that it contains thermogenin, which is the key enzyme regulating nonshivering thermogenesis. Norepinephrine causes the release of free fatty acids, which with thermogenesis undergo combustion in the mitochondria of brown fat cells, releasing heat. Lipoprotein lipase also provides further triglyceride substrate for heat production.

Oxygen and glucose also are consumed during nonshivering thermogenesis. Thus an infant who already has low oxygen or glucose levels may become hypoxemic or hypoglycemic if added thermal stress occurs. Preterm babies do not develop sufficient brown fat stores to mount a significant heat production response to compensate for even minimal cold stress. When servocontrol is used, the thermistor must not be placed over an area of brown fat, which may directly heat the overlying skin, causing a decrease in servocontroller heat output.

Heat generated within the body is transferred by conduction through tissues along a gradient from warmer to cooler areas such as the skin surface. An initial response to a cold environment is to constrict superficial blood vessels to minimize the transfer of heat from the core to the surface of the body. Superficial vasoconstriction, which gives the skin a mottled appearance in response to cold stimulus, results in a lower skin temperature reading to the thermocontroller and consequently causes an increase in the incubator temperature. The smaller the body size, the less effective vasoconstriction is in conserving heat.

Compared with adults, newborns have a very large surface area to body mass ratio and therefore have a relatively large area exposed to the environment from which heat can be lost. More mature infants may try to minimize their surface area by changing positions to decrease exposed surface area when faced with cold stimulus, but immature infants cannot flex the trunk and extremities effectively. They also have little subcutaneous fat tissue (which acts as insulation) to help prevent heat conduction to the body’s surface, where the heat would be lost.

Heat is transferred from the infant’s body to the environment (i.e., everything in proximity to the baby) along a temperature gradient from warmest to coolest. This transfer of heat occurs by four principal mechanisms: radiation, conduction, evaporation, and convection. Figure 6-3 illustrates these four mechanisms and identifies interventions to minimize their effects.

Much less frequently, a newborn must call on physiologic responses to an environment that is too warm, and these responses are somewhat limited. As skin temperature rises, superficial blood vessels dilate, increasing the transfer of core body temperature to the surface. Increasing the temperature gradient between the skin and the environment increases heat loss from the body. When exposed to elevated environmental temperatures, preterm babies generally cannot generate sweat to eliminate heat by evaporation. Maturing babies develop this eccrine gland function first on the forehead, followed by the chest, upper arms, and more caudal areas.

Thermoregulation requires energy (caloric) expenditure:
- Basal metabolic rate: 50 kcal/kg/day
- Thermoregulation: 10 kcal/kg/day
- Thermic effects of feeding: 8 kcal/kg/day (see Chapter 17)

Temperature Management

A neonate’s temperature can be determined by various methods. Deep body (core) temperature may be measured in the rectum or esophagus and on the tympanic membrane. Rectal thermistors are thin, flexible probes that must be inserted at least 5 cm to obtain an accurate reading. Insertion to this depth runs the risk for perforation, because the sigmoid colon makes a right-angle turn approximately 3 cm from the anal opening. Esophageal and tympanic readings are difficult to obtain and usually impractical. Noninvasive infrared thermometry, a rapid and painless method of determining tympanic membrane or axillary temperature in children, is not recommended for use in newborns at this time.
Studies have failed to demonstrate an accurate correlation between infrared thermometer readings and axillary or rectal temperature readings in newborn infants. Continuous monitoring of abdominal skin temperature with the newborn lying supine is a noninvasive method that has been reported to show good correlation with rectal temperatures. It is impractical to keep babies in a supine position constantly, so research to find the best practice to monitor and servocontrol infants' temperatures continues. Correlation with this method and core temperature requires further study, and whether its use with servocontrol is appropriate is yet to be determined, because incubators are programmed to respond to insulated skin temperature, not core temperature.

Because of the risks involved, rectal temperatures should not be taken on a routine basis in...
neonates. Axillary temperatures are easy to obtain and safely measured using glass, electronic, or disposable thermometers. The tip of the thermometer should be held firmly in the midaxillary area for at least 3 minutes in preterm infants and 5 minutes in term infants. When taken properly, axillary temperatures provide readings as accurate as rectal and core temperature methods. In term infants, axillary temperatures should be maintained at 36.5° to 37.5°C (97.7° to 99.5°F). For preterm infants, the normal axillary temperature ranges between 36.3° and 36.9°C (97.3° and 98.4°F).²

In critically ill infants, the skin temperature is usually routinely monitored in addition to regular axillary temperature readings. A skin probe is secured to the right upper quadrant of the abdomen. The temperature probe should not be placed under the axilla or any other position except as recommended by the manufacturer. Because an infant responds to cold stress by vasoconstriction, a drop in skin temperature may be the first sign of hypothermia. The core temperature may not fall until the infant can no longer compensate. The axillary temperature may remain normal (or even be elevated) because of proximity to brown fat stores.

ETIOLOGY

The ambient temperature range in which a healthy full-term infant maintains a stable core temperature is narrower than the temperature range in which an adult maintains a normal temperature. When measures are taken to provide a neutral thermal environment for the neonate, excessive heat losses or gains are avoided and heat balance is maintained. Recognition of infants at risk for heat imbalance is essential in the prevention of thermal stress.

Premature infants have a limited ability to control body temperature and are extremely susceptible to hypothermia. Factors that contribute to temperature instability include very thin skin, large surface area relative to body mass, limited substrate for heat production, decreased subcutaneous tissue, and an immature nervous system. These infants often have multiple health problems that necessitate frequent interventions by health care providers with consequent disruption of the infant’s neutral thermal environment.

A premature infant’s very thin skin and larger surface area to body mass ratio allow for increased evaporative heat loss. Term infants can reduce surface area by flexing their extremities onto their trunk, a skill that increases with gestational age. Unable to maintain flexion, a preterm infant lies primarily with extremities extended. Care providers may reduce the surface area by positioning infants in flexion and supporting them with blankets and rolls. The shortened gestation limits lipid supplies, brown fat, and the accumulation of subcutaneous tissue. The immature response to thermal stress.

The premature infant is likely to experience other complications (e.g., respiratory distress, sepsis, intraventricular hemorrhage, hypoglycemia) that may increase basal metabolic rate and oxygen consumption, thus interfering with the ability to maintain thermal stability. Numerous procedures and interventions (e.g., medication administration, placement of intravascular catheters, obtaining vital signs) may impede efforts to maintain a neutral thermal environment. Care providers should routinely check the infant’s temperature before initiating treatments. If the temperature is low, treatment should be delayed until a more normal temperature is obtained. If interventions are prolonged, temperature should be monitored frequently, an external heat source provided, and the intervention stopped if hypothermia occurs.

Late-preterm infants are predisposed to morbidities because of their developmental immaturity (see Chapter 5). Less adipose tissue for insulation, less brown fat for chemical thermogenesis, more heat loss, and a larger ratio of surface area to weight contribute to problems with heat balance in these infants. Morbidity associated with heat balance in the late-preterm infant is 10% compared with 0% for term infants.³

Low-Birth-Weight Newborns

Low-birth-weight (LBW) (<2500g) infants can be divided into two groups: the very-low-birth-weight (VLBW) infant (<1500g) and the extremely-low-birth-weight (ELBW) infant (<1000g). Preterms in each of these groups have specific needs for thermoregulation. Heated incubators, radiant warmers, and skin-to-skin care are all methods for maintaining the temperature and promoting weight gain of the VLBW infant. Infants weighing more than 1500g may be weaned to an open crib if all criteria are met. (See Figure 6-5 for weaning criteria.)
During the first 12 hours of life, ELBW preterms become hypothermic with procedures such as intubations, chest x-ray examinations, IV line placement and manipulation, suctioning, repositioning, and vital signs. Like the late-preterm and the LBW infant, ELBW infants have even less brown and subcutaneous fat for maintaining body temperature. Their thin skin also contributes to increased insensible water loss.

SGA infants, like preterm infants, have a large surface area relative to body mass and decreased subcutaneous tissue, brown fat, and glycogen stores, all of which contribute to heat imbalance. Decreased placental blood flow frequently contributes to the small size. The relatively large surface area of an SGA infant increases evaporative and radiant heat loss, whereas limited brown fat stores and subcutaneous tissue contribute to a decreased ability to produce and conserve body heat. Some flexion of the extremities may be present because flexion depends on gestational age and not weight. SGA infants have a higher metabolic rate compared with infants at similar weights who are appropriate for gestational age. This is believed to be caused by the larger brain size relative to body weight. Hypoxia in utero may depress the infant’s central nervous system (CNS) and alter the ability to regulate temperature. Increased energy requirements coupled with limited glycogen stores may result in hypoglycemia and limited ability to produce heat. SGA infants may require numerous interventions that disrupt the neutral thermal environment. Care providers should ensure that the infant has a normal and stable temperature before initiation of treatments. If treatments are prolonged, temperature should be monitored frequently, an external heat source provided, and treatments stopped if hypothermia occurs.

Infants with neurologic damage or depression may experience difficulty maintaining a stable temperature. Hypoxia, before, during, or after delivery, neurologic defects, and exposure to drugs such as analgesics and anesthetics may depress the infant’s neurologic response to thermal stress. Hypoxia decreases the effect of norepinephrine on nonshivering thermogenesis, the main route of thermal regulation in the newborn infant. Hypoxia also may reduce the oxidative capacity of the mitochondria in brown fat and skeletal muscles, which are involved in thermogenesis. Infants who have experienced hypoxia in utero may have increased norepinephrine concentrations, which result in peripheral vasoconstriction. This may cause a delayed metabolic response to cold stress and delayed vasodilatation in response to heat stress.

Neurologic defects that affect the hypothalamus also may interfere with heat balance. The hypothalamus coordinates temperature input from various sensors. Drugs such as analgesics and anesthetics cause CNS depression and reduce the infant’s ability to respond to thermal stress. Neuromuscular blocking agents inhibit the infant’s ability to maintain a flexed position, increasing exposed body surface and heat loss. Care providers must be alert to the effect of drugs on the CNS and the infant’s ability to regulate temperature.

Infants with sepsis may have hypothermia or hyperthermia. In a newborn, an elevated temperature may begin as a response to cold stress, with peripheral vasoconstriction and thermogenesis. Heat production continues as the infant attempts to achieve a higher core body temperature. Exogenous and endogenous pyrogens may enhance thermogenesis.

Initially, an infant with sepsis may feel cool to the touch and may have a low body temperature. As fever progresses, temperature may rise and the infant feels warm to the touch. Infants nursed in servocontrolled incubators may not have an elevated temperature. The lower heater output in response to increasing skin temperature (by manual or servocontrol adjustment) may mask a fever by keeping the baby’s temperature within normal limits. The care provider should be alert to a sudden decreased need for incubator heat support in a previously stable infant.

Hyperthermia may be iatrogenic, caused by inappropriate control of the neonate’s environmental temperature. The most common cause is the inappropriate use of external heat sources. Dehydration also may contribute to hyperthermia. Infants nursed with the use of external heat sources should have their temperatures monitored frequently. Phototherapy, sunlight, and the use of excessive clothing and blankets contribute to overheating. Dehydration may be avoided by early recognition of infants at risk for increased fluid loss. Increased insensible water loss occurs in preterm infants because of increased skin permeability and the use of phototherapy and radiant warmers. Vomiting, diarrhea, gastric suction, and ostomy drainage also increase fluid loss. These infants should receive additional fluids to replace the increased losses (see Chapter 14).
Heat balance is determined by the amount of heat lost to the baby’s environment offset by the amount of heat generated by the body plus the amount of heat supplied from outside sources. Because a smaller, more immature, and sicker baby is less able to regulate body temperature, it is crucial that care providers understand the physical and physiologic principles of heat balance and be able to maintain a neutral thermal environment. Two broad categories of interventions foster thermal neutrality: blocking avenues of heat loss; and providing external heat and environmental support to maintain temperature within the normal range of 36.5° to 37.5° C (97.7° to 99.5° F). The theoretical neutral thermal environment necessary for neonates of 1 and 2 kg at a given age is graphed in Figure 6-2. Newborns of less than 800 g are not adequately addressed in currently available tables but should have a starting environmental temperature setting of 36.5° C (97.7° F).

Attention to the details of these interventions begins in the delivery room, in which the first step is to adjust the ambient delivery room temperature higher than ordinary operating rooms or patient rooms. The air temperature in newborn care areas should be kept at 23.8° to 26.1° C (75° to 79° F), and humidity should be kept at 30% to 60%.

Warming the room and placing the resuscitation table away from doors or drafts minimize convective heat loss. The newborn’s skin temperature may drop by as much as 0.3° C/min, with core temperature dropping more slowly after delivery. At birth, most heat loss results from evaporation of amniotic fluid from the baby’s skin surface. Drying the infant with prewarmed towels and immediately replacing used ones with dry, warm towels minimize evaporative heat loss. Dry towels conduct heat poorly when contacting the neonate’s skin. However, cold examiner hands, stethoscopes, scales, and bare mattresses are good heat conductors and can add significant cold stress if not warmed before coming in contact with the newborn.

Another means of preventing heat loss in very preterm infants in the delivery room is to wrap them in a polyethylene bag or sheet immediately after delivery. Resuscitation then proceeds as usual, and the baby is unwrapped after placement in a warmed incubator. Admission temperatures were higher in the wrapped group and did not drop after unwrapping when the infants were compared with babies who were dried but not wrapped. Treating hypothermia in the newborn prevents serious and life-threatening complications. In an attempt to maintain heat balance, the neonate increases cellular metabolism and oxygen consumption, which increases the risk for hypoxia, cardiorespiratory problems, and acidosis. Hypoglycemia is also a risk factor, since the infant must consume more glucose for heat production. Other complications include clotting disorders, neurologic problems, hyperbilirubinemia, and even death if the untreated hypothermia progresses.

Resuscitation should take place on a preheated radiant warmer so that the adverse consequences of hypothermia are avoided. Because a significant amount of heat is lost through the surface area of the head, with its abundant blood supply and the brain’s high heat production, covering the infant’s head with some insulating material conserves heat during transfer to the nursery or NICU and afterward. Stockinet material is relatively ineffective for this purpose and provides poor insulation. The best material is thick, maintains its shape with use, and has a high percentage of air volume trapped in the fibers. Knitted wool caps or Thinsulate material may provide the best results.

There are a variety of ways to maintain thermal neutrality. Accessibility, insensible water loss, servocontrol versus manual control of temperature, and safety are major considerations when determining the method to use for an individual neonate.

Incubators

Incubators provide a controlled, enclosed environment that is heated convectively with warm air. The temperature in an incubator may be servocontrolled to maintain a desired skin temperature or air temperature. As the temperature varies from the desired “set point,” proportional control units gradually increase or decrease heat output to maintain a constant temperature (without the wider temperature fluctuations seen with simple on-off controllers). In setting the servocontrolled incubator to the desired skin temperature, the sensor should be attached to the right upper quadrant of the abdomen with insulated temperature patches. The sensor should not be placed over areas of brown fat deposits,
because the higher-than-expected temperature information to the controlling unit will result in a lower-than-desired heat output.

Inadvertent cooling may take place if the sensor is covered with clothes or a blanket or if the baby lies on it. If the sensor becomes disconnected from the skin, unwanted heating may occur because an erroneously low temperature reading causes an unwanted increase in heat output. One also must consider that when an insulated patch is used to cover the thermistor, skin temperature is sensed as being higher than if tape covers the thermistor, resulting in decreased heat output by the warming device. The desired skin temperature used for skin servocontrol is generally 36.0° to 36.5° C (96.8° to 97.7° F). Modern incubators also can be servocontrolled to a desired air temperature. This mode has been shown to provide a more stable thermal environment and less temperature variation when compared with skin servocontrol.

Air servocontrol maintains a constant ambient air temperature when other factors such as phototherapy, external radiant heat, unstable room temperature, or direct sunlight are not confounding variables. Recently it has been shown that infants who had been managed with skin servocontrol had more variable but higher air temperatures and spent more time in a neutral thermal environment. Babies managed with air servocontrol had less variability in air temperatures but more variability in infant body temperature. A review of published trials concluded that VLBW babies whose skin servocontrol is set at 36° C had a lower mortality rate than those managed with air servocontrol at 31.8° C. The question of air versus skin servocontrol or manual control is still debatable for any given situation, and probably neither is the perfect solution for all babies. Figure 6-4 is a research-based algorithm for weaning from servocontrol to air control in an incubator.

Radiant heat loss to cooler incubator walls, especially in single-walled incubators, is a significant source of heat loss. The use of double-walled incubators (with the inner wall warmed to the ambient air temperature inside the incubator) results in less radiant heat loss from the baby. With a skin-set servocontrol temperature, the decreased radiant heat loss (because of warmer incubator walls) is offset by increased convective heat loss (because the ambient air temperature necessary for the desired skin temperature is lower). Consequently, there is no net change in the mean environmental temperature. Double-walled incubators provide less temperature fluctuation when doors are open, thus providing a more stable caregiving environment. Evaporative heat loss is not appreciably different with single- and double-walled incubators. One may increase the humidity in incubators to decrease the infant's metabolic rate only if a neutral thermal environment cannot be achieved by increasing the ambient temperature.

The tiniest neonate has a large evaporative heat loss, and maximum air temperature is limited by the incubator controls, thus making it difficult to reach an air temperature high enough for thermal support.
In such cases, hypothermia can be avoided by increasing the ambient humidity within the incubator by using the water reservoir or supplying warmed humidified air into the incubator with respiratory humidifiers. Humidification has been shown to decrease fluid requirements and decrease the incidence of electrolyte imbalances in babies weighing less than 1000 g. Careful attention should be given to preventing bacterial growth in the humidification system (see Chapter 23). Incubator temperatures may also be controlled manually by estimating the appropriate temperature for the baby’s age and weight from Table 6-1 and setting the incubator to that temperature.

Regardless of whether one is using skin or air servocontrol or manual temperature adjustments, the baby’s temperature and the air temperature must be monitored and recorded regularly. The incubator should be kept away from air conditioning ducts, direct sunlight, and cool windows that may cool or warm the incubator. Room temperature should be kept at 23.8° to 26.1° C (75° to 79° F) and humidity should be kept at 30% to 60%. Alarms for both high and low temperature levels always should be turned on.

The principal disadvantage of maintaining sick newborns in incubators is the limited access to them when extensive procedures are necessary. Incubators also may be perceived by mothers as a barrier between them and their infants and prolong feelings of fear and insecurity, compared with heating methods that provide easier access to the baby. Holding their baby for short periods outside the incubator may help promote bonding and relieve some of their fears. Stable preterm infants dressed in a diaper, shirt, and cap and wrapped in two blankets can maintain a normal temperature when held close to their parent’s body. Keeping the skin probe attached to the infant and plugged into the incubator allows frequent monitoring of the infant’s temperature. We also have an increasing awareness of and concern about the high noise levels within incubators. Such noise poses a potential deleterious effect on the hearing development of preterm infants (see Chapter 13). Improved alarm technology minimizes the risk for inappropriate heating, but malfunctions still occur occasionally. When experienced nurses provide care, infants can be appropriately managed in incubators using any of the three modes of temperature control. Box 6-1 outlines dos and don’ts when using an incubator to provide heat and humidity.

Weaning an infant from an incubator to an open crib is an important step in preparing for discharge but may result in an increase in the resting metabolic rate for LBW infants. Indicators that an infant may be successfully weaned include weight of at least 1500 g, 5 days of consistent weight gain, an absence of medical complications, and tolerance of enteral feeds. Weaning may occur over several days and involves dressing the infant in a shirt, hat, and diaper and swaddling with a blanket. The incubator temperature is manually lowered while monitoring the infant’s temperature. Abdominal skin temperature should be 36° to 37° C (96.8° to 98.6° F). Figures 6-5 and 6-6 are research-based algorithms for weaning infants to open cribs. After weaning has been successful, the crib should be placed in a draft-free environment. If an infant cannot maintain his or her temperature in an open crib, he or she is returned to the incubator. An attempt at weaning should be considered again by 48 hours after the initial weaning if all criteria for weaning have been met. The temperature in the neonatal unit should be evaluated, as well as the location of the crib in relation to air conditioner vents or drafts. There may also be other medical reasons (e.g., infection) that the infant cannot maintain his or her temperature in the open crib if all other conditions have been ruled out.

**Humidification and Topical Ointments**

Many studies and clinical trials have demonstrated the clinical application of the uses of both humidification and topical ointment therapy (see Chapter 19) in preterm infants. The optimal humidity level for the neonate is 50% relative humidity (RH). This is achieved by a variety of methods such as closed humidified incubators and humidity “tents.” In the first 2 weeks of life, extremely premature infants may require up to 85% RH. Box 6-2 describes the advantages and disadvantages of using heated, humidified air for ELBW infants while in an incubator.

**Radiant Warmers**

Radiant warmers provide infrared energy to heat the baby’s skin while he or she lies naked on an open bed. The radiant warmer must generate enough energy to offset the tremendous amount of radiant
**TABLE 6–1**

**NEUTRAL THERMAL ENVIRONMENTAL TEMPERATURES**

<table>
<thead>
<tr>
<th>AGE AND WEIGHT</th>
<th>STARTING TEMPERATURE (°C)</th>
<th>RANGE OF TEMPERATURE (°C)</th>
<th>AGE AND WEIGHT</th>
<th>STARTING TEMPERATURE (°C)</th>
<th>RANGE OF TEMPERATURE (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6 hr</td>
<td>Under 1200 g</td>
<td>35.0</td>
<td>34.0-35.4</td>
<td>Under 1200 g</td>
<td>34.0</td>
</tr>
<tr>
<td></td>
<td>1200-1500 g</td>
<td>34.1</td>
<td>33.9-34.4</td>
<td>1200-1500 g</td>
<td>33.5</td>
</tr>
<tr>
<td></td>
<td>1501-2500 g</td>
<td>33.4</td>
<td>32.8-33.8</td>
<td>1501-2500 g</td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>33.9</td>
<td>32.0-33.8</td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>31.3</td>
</tr>
<tr>
<td>&gt;6-12 hr</td>
<td>Under 1200 g</td>
<td>35.0</td>
<td>34.0-35.4</td>
<td>4-5 days</td>
<td>31.0</td>
</tr>
<tr>
<td></td>
<td>1200-1500 g</td>
<td>34.0</td>
<td>33.5-34.4</td>
<td>5-6 days</td>
<td>30.9</td>
</tr>
<tr>
<td></td>
<td>1501-2500 g</td>
<td>33.1</td>
<td>32.2-33.8</td>
<td>6-8 days</td>
<td>30.6</td>
</tr>
<tr>
<td></td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>32.8</td>
<td>31.4-33.8</td>
<td>8-10 days</td>
<td>30.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10-12 days</td>
<td>30.1</td>
</tr>
<tr>
<td>&gt;12-24 hr</td>
<td>Under 1200 g</td>
<td>34.0</td>
<td>34.0-35.4</td>
<td>&gt;12-14 days</td>
<td>38.5</td>
</tr>
<tr>
<td></td>
<td>1200-1500 g</td>
<td>33.8</td>
<td>33.3-34.3</td>
<td>36.5-37.6</td>
<td>32.1</td>
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<td></td>
<td>1501-2500 g</td>
<td>32.8</td>
<td>31.8-33.8</td>
<td></td>
<td>31.0</td>
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<tr>
<td></td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>32.4</td>
<td>31.0-33.7</td>
<td></td>
<td>30.6</td>
</tr>
<tr>
<td>&gt;24-48 hr</td>
<td>Under 1200 g</td>
<td>34.0</td>
<td>34.0-35.0</td>
<td>&gt;2-3 wk</td>
<td>32.6</td>
</tr>
<tr>
<td></td>
<td>1200-1500 g</td>
<td>33.5</td>
<td>33.1-34.2</td>
<td>36.1-37.2</td>
<td>32.1</td>
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<tr>
<td></td>
<td>1501-2500 g</td>
<td>32.6</td>
<td>31.6-33.6</td>
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<td>31.7</td>
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<tr>
<td></td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>32.1</td>
<td>30.7-33.5</td>
<td></td>
<td>30.5</td>
</tr>
<tr>
<td>&gt;36-48 hr</td>
<td>Under 1200 g</td>
<td>34.0</td>
<td>34.0-35.0</td>
<td>&gt;3-4 wk</td>
<td>32.6</td>
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<tr>
<td></td>
<td>1200-1500 g</td>
<td>33.5</td>
<td>33.0-34.1</td>
<td>36.1-37.6</td>
<td>32.1</td>
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<tr>
<td></td>
<td>1501-2500 g</td>
<td>32.5</td>
<td>31.4-33.5</td>
<td></td>
<td>32.0</td>
</tr>
<tr>
<td></td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>31.9</td>
<td>30.5-33.3</td>
<td></td>
<td>30.9</td>
</tr>
<tr>
<td>&gt;48-72 hr</td>
<td>Under 1200 g</td>
<td>34.0</td>
<td>34.0-35.0</td>
<td>&gt;4-5 wk</td>
<td>32.0</td>
</tr>
<tr>
<td></td>
<td>1200-1500 g</td>
<td>33.5</td>
<td>33.0-34.0</td>
<td>36.1-37.6</td>
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<td></td>
<td>1501-2500 g</td>
<td>32.3</td>
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<td>31.9</td>
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<tr>
<td></td>
<td>Over 2500 g (and &gt;36 wk)</td>
<td>31.7</td>
<td>30.3-33.2</td>
<td></td>
<td>30.8</td>
</tr>
</tbody>
</table>


**Note:** For their table, Scopes and Ahmed had the walls of the incubator 1° to 2° C warmer than the ambient air temperatures. Generally, the smaller infants in each weight group require a temperature in the higher portion of the temperature range. Within each time range, the younger the infant, the higher the temperature required.
heat lost to the room by a naked baby lying in an open environment. Heat output can be servocontrolled or manually controlled. Because with manual control no feedback from the infant is used, this poses a greater risk for overheating or overcooling. Therefore manual control should not be used routinely except for short periods (e.g., while initiating resuscitation). The servocontrol sensor measuring skin temperature must be protected from the infrared heat source, or the probe will sense a temperature higher than the skin temperature and decrease radiant heat output, leading to cold stress. Conversely, insulating the sensor with an aluminum reflective patch protects the underlying skin from the radiant heat and keeps the protected skin cooler than the surrounding skin. When the skin under the patch is warmed to the desired temperature, the rest of the skin may be overheated. Vasodilation then may increase convective heat loss, resulting in an effective, although precarious, heat balance. Caregivers must use caution to ensure that the sensor does not become detached from the skin; otherwise the baby could be exposed to excess heat and become hyperthermic.

Insensitive water loss (IWL) for babies cared for under radiant warmers is increased by 40% to 50% compared with losses in incubators. Directly related to the amount of heat necessary from the warmer, this loss also is influenced by other factors (e.g., low relative humidity and convective air currents) on an open bed. Even though transepidermal water loss is increased under radiant warmers, there is evidence that the hydration of the stratum corneum is not affected; therefore the barrier function of the skin remains the same.15 With very premature infants, severe dehydration may occur if water intake is not increased to replace the inordinate IWL (see Chapter 14). Plexiglas heat shields and polyethylene blankets (plastic wrap) have been used in an attempt to prevent large IWLs. Studies have shown these to be somewhat effective for this purpose; however, the microenvironment created by these blankets undergoes drastic

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**BW, Birth weight; GA, gestational age.**
change every time the blanket is removed for procedures or routine nursing care. Even without such blankets, the baby may experience wide swings in heat balance when the infrared heat is blocked from reaching him or her by hands, heads, or drapes during a procedure. These blankets should not be used while the infant is in an incubator, since the purpose is to have the humidity and heat reach the infant.

Both incubators and radiant warmers are effective in maintaining an appropriate thermal balance in sick and preterm infants. Evidence is insufficient to show a clear advantage of one method over the other with the caveat that IWL is significantly higher under radiant warmers. The method chosen should be individualized to the infant and to the situation. Experience, skill, and nurse preference often influence the choice of heating methods. These factors also influence the extent to which incubators are perceived to interfere with the performance of care providers’ tasks. Basic principles of care (e.g., keeping bed linens dry to prevent evaporative heat loss) apply to use of both heating methods. Box 6–3 lists advantages and disadvantages of open radiant
B O X 6-2
RESEARCH-BASED ADVANTAGES AND DISADVANTAGES OF HEATED HUMIDITY IN THE INCUBATOR OF ELBW INFANTS

**Advantages**
1. Decreased transepidermal water loss (TEWL) (e.g., insensible water loss [IWL], evaporative water loss, and epidermal heat loss) from the skin of infants less than 31 weeks’ gestation. IWL is inversely proportional to the gestational age of the infant.
2. Increased ability to maintain infant’s temperature.
3. Improved maintenance of fluid and electrolyte balance.
4. Improved energy balance—fewer calories expended in temperature maintenance.
5. Improved skin integrity.
6. Possible reduction in the incidence of (1) PDA, (2) IVH (grades III/IV), and (3) BPD because of improved fluid and electrolyte balance.

**Disadvantages**
1. Increased risk for infection associated with contamination of the humidifier reservoir with bacteria.
2. Moist environment impairs adhesion of equipment (e.g., electrodes, ETT, dressings).
3. Unstable temperatures when procedures are performed and the incubator door is open.

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BPD, Bronchopulmonary dysplasia; ELBW, extremely low birth weight; ETT, endotracheal tube; IVH, intraventricular hemorrhage; PDA, patent ductus arteriosus.

B O X 6-3
ADVANTAGES AND DISADVANTAGES OF OPEN RADIANT WARMER VERSUS INCUBATOR USE FOR PREMATURE INFANTS

**Advantages: Open Radiant Warmer**
1. Easy access to the infant and larger surface on which to work
2. Useful for initial admission procedures (e.g., intubation, line placement, x-ray examination)
3. Decreased risk for infection without the use of humidity
4. Decreased risk for unplanned extubation and lines being pulled out
5. Better access by parents and staff

**Disadvantages: Open Radiant Warmer**
1. Increased insensible water loss (without humidification or plastic blanket)
2. Increased stimulation from external noise and light
3. Decreased growth and weight gain patterns
4. Decreased ability to wean the infant slowly from the heat source
5. Better access by parents and staff

**Advantages: Incubator**
1. Less insensible water loss with use of humidity
2. Acts as a barrier with more difficult access that decreases tactile contact. Easier to use minimal stimulation
3. Increased weight gain
4. Heat provided by two methods: convection and conduction
5. Ability to wean temperature control from servocontrol to air control, and from air control to an open crib
6. Ability to cover the incubator to decrease exposure to light

**Disadvantages: Incubator**
1. Decreased access for treatments, line placements, intubations, and laboratory draws
2. Increased chance of infection with humidity
3. Increased risk for extubation or accidental clamping of lines

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Radiant warmers provide easy access for performing procedures—a definite advantage over incubators, in which procedures must be done through portholes. Advances in equipment technology now make it possible to convert a single unit from radiant mode to convection mode without moving the baby from one platform to another. This seems to be an efficient way to provide the improved access needed when a baby’s condition changes while maintaining appropriate warming without the potential risks of moving the baby. Fluid management is easier for infants in incubators because humidity is easily added to the enclosed environment and there are fewer losses from radiation and convection. The large flux of heat exchange between radiant heat source, the baby, and the environment makes wide fluctuations in heat balance more likely when compared with the more easily controlled temperature within an incubator. Many variables influence oxygen consumption using these two heating methods. The metabolic rate and oxygen consumption of infants under radiant warmers are slightly higher than in incubators; however, the clinical significance of this finding is uncertain. Infection rates are comparable between the two methods. Regardless of the type of heat supplied, care must be taken to minimize thermal instability during nursing interventions. Radiant warmers may be able to rewarm a baby faster than an incubator with convective heating after a procedure. Organizing interventions so their frequency and duration limit as much as possible the exposure to a thermally unstable environment can minimize this instability. Box 6–4 outlines dos and don’ts when using a radiant warmer for providing heat.

**Other Methods**

In the tiniest preterm infants, a conductive heat source (e.g., a heating pad) may also be needed to raise and maintain body temperature. Heated water mattresses provide a neutral thermal environment for less critically ill babies lying in open cribs (making access easier than in closed incubators). This may also provide a feasible and effective means of rewarming hypothermic infants. Heated, water-filled mattresses are most useful in the newborn units of developing countries.

**Electric warming mattresses** filled with water provide additional moist heat when caring for the infant in surgery, to use for rewarming techniques, or when caring for the LBW or ELBW infant. Manufacturer’s recommendations should be followed, and the temperature is usually set at

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**BOX 6–4 USE OF OPEN RADIANT WARMER (RW): DOS AND DON’Ts**

<table>
<thead>
<tr>
<th>Dos</th>
<th>Don’ts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Use the automatic mode (skin probe/servocontrol) for continuous thermal support.</td>
<td>1. Don’t forget to switch from manual to servocontrol after weighing the infant. When removing the infant from the RW, keep the bed on servocontrol and silence the alarm until the infant is returned to the RW.</td>
</tr>
<tr>
<td>2. Use the manual mode for short-term warming only; check the infant’s condition and temperature at least every 15 minutes.</td>
<td>2. Never use a rectal temperature probe for warmer control. Before normal core temperature is reached, the infant’s skin may be burned.</td>
</tr>
<tr>
<td>3. Place the sensor on the skin surface exposed to the warmer and never beneath the infant. (Follow manufacturer’s recommendations.)</td>
<td>3. Don’t place anything flammable on top of or under the radiant warmer.</td>
</tr>
<tr>
<td>4. Check sensor attachments frequently. Poor skin contact causes poor temperature control.</td>
<td>4. Never just reset alarms; instead, determine the cause of any alarms.</td>
</tr>
<tr>
<td>5. Change temperature probe sites according to unit policy and manufacturer’s recommendations.</td>
<td>5. Never use your hand to estimate the amount of heat reaching the infant. Set temperature control point at 36.5°C.</td>
</tr>
<tr>
<td>6. Adjust fluid replacement to compensate for increased insensible water loss (IWL).</td>
<td>6. Avoid use of thermal blankets (e.g., bubble wrap); may cause incorrect skin temperature sensing and overheating.</td>
</tr>
</tbody>
</table>
100°F. Heat is provided by conduction; therefore a linen layer should be placed between the mattress and the infant to avoid skin burns. The temperature of these mattresses should be weaned prior to weaning any temperature of the open warmer or incubator.

Some portable, disposable, warming mattresses containing a gel that is chemically activated by squeezing may be used for initial stabilization of the infant and for transport. Because heat is provided by conduction, a linen layer is placed between the infant and the mattress surface. The usual temperature for these mattresses is 100°F.

Heel warmers, which are pads that are chemically activated by squeezing, are used to warm the heels of infants before obtaining blood and are especially necessary when obtaining capillary blood gases. The temperature should never exceed 104°F.

Swaddling materials include various types of infant wrappings (e.g., blanket, clothing, foil, or bubble wrap). The use of swaddling materials makes observation of the infant more difficult and blocks heat from overhead radiant warmers. Before one wraps the infant in insulating materials, the infant must be warm, because these merely retain body warmth and do not generate heat.

Oxygen and air delivered to the neonate should be warmed and humidified to minimize convective and evaporative heat loss (see Chapter 23).

Skin-to-skin (kangaroo) care provides a safe and effective alternative method of caring for premature infants. Both appropriate-for-gestational-age (AGA) and SGA infants experience a beneficial warming effect and a stable skin and core temperature when held skin to skin. Mothers exhibit thermal synchrony with the infants so that their body temperature increases or decreases to maintain the infant’s thermal neutrality. Regardless of the care provider (e.g., father, adoptive parent, grandparent) during skin-to-skin care, heat loss does not occur and temperature rises and can be maintained in acceptable parameters (see Chapter 5). In one study, each mother’s skin temperature met the neutral thermal environmental zone of her particular infant. Mothers also preferred this method for holding their infant, compared with the traditional method of wrapping the infant in a blanket and the infant being cradled in the parent’s arms. Heat loss may occur during the transfer process from bed to parent. Having a protocol in place that uses one or more staff to help with the transfer and covering the infant with a blanket will reduce the transfer time and subsequent heat loss (see Chapter 13).

Skin-to-skin contact between mother and infant reduces conductive and radiant heat loss and is an excellent way to maintain a neutral thermal condition for the healthy newborn. If the infant remains with the parents for an extended time, temperature should be monitored. In the case of a preterm infant in stable condition, the use of an additional heat source (e.g., a radiant warmer) enables parents to spend more time with their infant before transfer to the NICU. Skin-to-skin contact should be delayed at least until week 2 of life in extremely premature infants, because they have been shown to lose heat during skin-to-skin contact during the first week of life.

Bathing is important for removing blood and body fluids from the newborn’s skin, to prevent the transmission of infections, and to promote bonding. Sponge bathing is traditionally done in the NICU and newborn nursery and can result in significant heat loss. Immersing the stable infant in a tub of water reduces evaporative heat loss and helps maintain a normal temperature.

Transport

The same principles of heat balance that apply to infants in a NICU apply to infants during transport. Infants should have a normal and stable temperature before transport. The infant should be transferred from nursery to transport incubator rapidly to prevent prolonged exposure to an uncontrolled thermal environment. Transport incubators that can provide thermal stability inside the transport vehicle must be used. Oxygen provided during transport also should be warmed and humidified. The infant’s temperature should be monitored continuously or at least every 30 minutes. Thin plastic wrap may be useful in decreasing IWL and convective and radiant heat loss. Chemically heated mattresses can also be used to provide a short-term heat source.

After Cesarean Delivery

Most cesarean section (C-section) deliveries are performed using an epidural or spinal anesthesia so the mother is awake and able to hear her infant as soon as he or she is born. Once the baby is assessed after birth, he or she is then placed skin-to-skin on the
mother's chest and both are wrapped with a warm blanket. When the infant recovers in the same room as the mother, skin-to-skin contact and bonding are facilitated. If the mother is unable, the father may provide skin-to-skin care and keep the baby warm after C-section (see Chapter 5).

Providing Thermoregulation for the Surgical Patient

The chilled environment of the surgical suite poses extra challenges to the newborn for thermoregulation. Heat losses occur by (1) evaporation during surgery, (2) conduction when placed on cold surfaces, (3) convection with cold drafts around the infant, and (4) radiation of heat from opened body cavities. Coordination between neonatal and surgical staff will be necessary to prevent heat imbalance, as follows:

- Prewarm transport incubator.
- Use portable, disposable mattresses in the incubators and on the operating table.
- Use radiant heat in the operating suite.
- Wrap the infant’s extremities in warmed soft cotton material.
- Prewarm all surfaces, as well as all fluids for cleansing and irrigation of body cavities.
- IV fluids should be at room temperature and prewarmed if stored in refrigeration.
- Temperatures should be monitored/documented before, during, and after surgery.

DATA COLLECTION

Anticipation and early recognition of the infant at risk for temperature instability are important in the management and prevention of complications associated with both hypothermia and hyperthermia. The perinatal history and ongoing neonatal evaluation identify events and early risk factors of temperature instability.

History

Events during pregnancy and the early neonatal period may increase an infant’s risk for thermal instability. Review of the maternal history should include estimated date of confinement because preterm infants at delivery are at increased risk for hypothermia. Exposure to viral agents (e.g., herpes), as well as vaginal and cervical colonization, increases the risk for acquiring an infection before or during delivery (see Chapter 22). Intrapartal use of analgesics and anesthetics may depress the infant’s CNS and mute the thermoregulatory ability.

Fetal stress manifested as fetal decelerations, meconium-stained fluid, or low Apgar scores may suggest an impaired thermoregulatory response. Neonatal interventions that may depress the CNS and thermal response include resuscitation and administration of analgesics, anesthetics, or neuromuscular blocking agents. Invasive procedures (e.g., endotracheal intubations, umbilical catheterization) increase the infant’s risk for infection and need for prolonged use of antibiotics. Poor handwashing by care providers also may contribute to infectious nursery outbreaks, such as outbreaks of necrotizing enterocolitis (see Chapters 22 and 28).

Physical Examination: Signs and Symptoms

Physical assessment of the infant should include not only gestational age but also appropriateness of size. Evaluation of the infant’s neurologic status (e.g., tone, activity, alertness) may give the caregiver an indication of the extent of neurologic impairment. Hypotonia results in decreased flexion, with an increased exposed surface area and resultant heat loss.

TEMPERATURE DETERMINATIONS

Temperature determinations may need to be made as often as every 30 minutes until thermostability is achieved. After that, temperatures should be recorded every 1 to 3 hours in LBW and preterm infants and every 4 hours in the healthy term infant. Critically ill infants should have continuous monitoring of skin temperature, with axillary determinations every 1 to 2 hours. Documentation should include environmental temperature (e.g., air temperature in the incubator or radiant warmer settings). Measuring the skin and core temperatures simultaneously may help differentiate fever as a result of disease versus environmental overheating. Noting that the baby’s servocontrolled skin temperature is relatively stable but that the environmental temperature has dropped also may be indicative of fever as the incubator responds to the high probe reading by cooling the infant’s environment.
HYPOTHERMIA
As the infant attempts to conserve heat by vasoconstriction, he or she may be pale, appear mottled, and feel cool to touch, particularly on the extremities. Acrocyanosis and respiratory distress may occur as the infant increases oxygen consumption in an attempt to increase heat production. If hypothermia continues, apnea, bradycardia, and central cyanosis may occur. The hypothermic infant initially may be irritable but may become lethargic as cold stress continues. Other changes that may occur include hypotonia, weak cry, weak suck, increased gastric residuals, abdominal distention, and emesis. Infants generally do not shiver in response to cold stress, but shivering may occur in more mature babies in the presence of severe hypothermia. Chronic hypothermia may result in poor weight gain. (See the Critical Findings box below.)

HYPERTHERMIA
The hyperthermic infant may feel warm to touch, and skin color may be ruddy as the infant attempts to increase heat loss by vasodilation. Sweating may occur in a term infant but generally is not present in infants of less than 36 weeks' gestation. Sweating may first appear on the forehead, followed by the chest, upper arms, and lower body. Hyperthermia is manifested by irritability, lethargy, hypotonia, apnea, a weak or absent cry, or poor feedings. Tachypnea or tachycardia may be seen as the infant attempts to increase heat loss.

Infants with thermal instability should be closely watched for changes in behavior, feeding patterns, and respiratory status. Temperatures should be monitored frequently in any infant exhibiting these symptoms or who feels cool or warm to touch. Early recognition of thermal instability may prevent further consequences and possibly permanent injury or death. (See the Critical Findings box below.)

Laboratory Data
The following may be used to evaluate metabolic derangements associated with thermal instability:
- Arterial blood gases (to assess for hypoxemia and metabolic acidosis)
- Complete blood count (to assess for sepsis)
- Blood glucose level (to assess for hypoglycemia)
- Electrolytes, blood urea nitrogen (BUN), serum and urine osmolality (to assess hydration, acid-base balance, and renal function)

TREATMENT AND INTERVENTION
Hypothermia
To avoid the complications of hypothermia, rewarming of cold infants should begin immediately by providing external heat. However, rewarming too rapidly may further compromise the already cold-stressed infant and result in apnea. Oxygen consumption is minimal when

Critical Findings

HYPOTHERMIA
Critical assessment findings for hypothermia are as follows:
- Pale, mottled skin that is cool to touch
- Acrocyanosis
- Respiratory distress
- Apnea, bradycardia, central cyanosis
- Irritability initially
- Lethargy developing as hypothermia worsens
- Hypotonia
- Weak cry and suck
- Gastric residuals, abdominal distention, emesis
- Shivering in more mature babies
- Metabolic acidosis
- Hypoglycemia

HYPERTHERMIA
Critical assessment findings for hyperthermia are as follows:
- Reddened skin that is warm to touch
- Tachypnea
- Tachycardia
- Irritability, lethargy, hypotonia, weak cry
- Poor feeding
- Apnea
- Sweating in more mature babies
- Dehydration
the difference between the skin and the ambient air temperature is less than 1.5°C (2.7°F). Avenues of heat loss should be blocked, temperatures should be monitored, and iatrogenic or pathologic causes should be investigated.

If hypothermia is mild, slow rewarming is preferred. External heat sources should be slightly warmer than the skin temperature and gradually increased until the neutral thermal environmental temperature range is attained. Efforts to block heat loss by convection, radiation, evaporation, and conduction should be initiated. Skin, axillary, and environmental temperatures should be measured and recorded every 30 minutes during the rewarming period. For more extreme hypothermia (i.e., core temperatures less than 35°C [95°F]), more rapid rewarming with radiant heaters (servocontrol 37°C [98.6°F]) or heated water mattresses prevents prolonged metabolic acidosis or hypoglycemia and decreases mortality.

Hyperthermia

The usual approach to treating the hyperthermic infant is to cool by removing external heat sources and by removing anything that blocks heat loss. The most common causes of hyperthermia in intensive care nurseries are iatrogenic. Check the heating controls for proper function and thermistors for proper position. Consider other sources of heat (e.g., direct sunlight, heaters, lights) as possible causes of hyperthermia. Excessive bundling with blankets and a hat and elevated environmental temperature can cause a newborn’s body temperature to rise into the febrile range. When evaluating the treatment options in the hyperthermic infant, one should consider removing extra blankets or swaddling materials. Non-environmental causes of hyperthermia (e.g., infection, dehydration, CNS disorders) should be considered. During the cooling process, skin, axillary, and environmental temperatures should be monitored and recorded every 30 minutes.

COMPLICATIONS

Hypothermia

Acute cold stress results in the release of norepinephrine, which causes vasoconstriction to reduce heat loss and initiate thermogenesis. As glycogen stores are depleted and oxygen consumption increases, the infant uses anaerobic metabolism to increase heat production, resulting in lactic acid production (metabolic acidosis). Pulmonary vasoconstriction, accentuated by metabolic acidosis, is associated with hypoxia, decreased surfactant production, and further acidosis (see Chapter 23). Blood flow to vital organs is diminished, and pulmonary hemorrhage and death may occur if hypothermia continues.

Hyperbilirubinemia and kernicterus may occur as non-esterified free fatty acids from brown fat metabolism compete with bilirubin for albumin-binding sites. Acidosis not only decreases the affinity of albumin for bilirubin but also increases the permeability of the blood-brain barrier, allowing bilirubin to enter brain tissue. If hypothermia continues, carbohydrate, protein, and fat supplies will be used for heat production instead of growth.

Close monitoring of the hypothermic infant is essential for early identification and prevention of complications. Evaluation of vital signs, arterial blood gases, and oxygen saturation may give early indication of hypoxia and metabolic acidosis. The infant’s skin may be dusky or bright red because failure of dissociation of oxyhemoglobin occurs at low body temperatures. Respirations may be rapid, shallow, and grunting and accompanied by bradycardia. Oxygen and ventilation should be initiated as needed to reduce hypoxia. Sodium bicarbonate may be given to correct metabolic acidosis. Seizures may occur as a result of hypoxia, requiring the administration of anticonvulsants.

Intravenous glucose may be necessary to prevent or correct hypoglycemia. Blood glucose levels should be monitored hourly until stable (see Chapter 15). Blood pressure and urine output should be measured to evaluate hydration and kidney function. An elevated BUN and hyperkalemia may be indicators of decreased renal perfusion and impaired renal function. As fluid is retained, edema of the extremities and face may occur.

Bilirubin should be monitored on a regular basis, and phototherapy may be initiated at a lower-than-usual level to prevent kernicterus. Adequate nutrition to promote growth should be given either intravenously or enterally. While the infant is hypothermic, nipple feedings should be avoided to conserve calories and energy for heat production and growth and to avoid aspiration.

During the rewarming process, the hypothermic infant should be observed for hypotension
as vasodilation occurs. Volume expanders may be needed to maintain an adequate blood pressure. Apnea and seizures may occur as a result of hypoxia or decreased cerebral blood flow after vasodilation. Hypothermia as a strategy to minimize adverse outcomes from hypoxic-ischemic-encephalopathy continues to be the focus of considerable research to determine safety and efficacy (see Chapter 26).

**Hyperthermia**

Vasodilation to increase heat loss may cause hypotension and dehydration as a result of increased IWL. Seizures and apnea may also occur as a result of high core temperature. Fluid status should be monitored by assessing intake, output, electrolytes, serum and urine osmolality, skin turgor, and mucous membranes. Fluids should be adjusted to account for IWL. Blood pressure should be assessed to detect hypotension, and volume expanders should be administered as needed.

Cardiorespiratory monitoring to detect apnea should be used. Ventilation may be needed if apnea persists or is unresponsive to stimulation. Subtle signs of seizures may include facial grimacing, nystagmus, tremors, apnea, opisthotonus posturing, tongue thrusting, or staring (see Chapter 26).

**PARENT TEACHING**

While the neonate is in the NICU, parents should be taught the importance of maintaining the newborn’s normal body temperature. Temperature should be taken before parents touch the infant through the portholes of the incubator or hold their infant. While the infant is outside the incubator, monitor the skin temperature continuously with a telethermometer. Unwrapping the infant to check the temperature exposes him or her to cold stress. Additional heat sources (e.g., radiant warmer, hat, extra blankets) may be needed while parents hold the infant. Teach parents to monitor their infant’s temperature and notify the nurse if it rises or falls. (See the Parent Teaching box above.)

Before discharge, teach parents to take an accurate axillary temperature and to notify their physician if it drops below 36°C (96.8°F) or rises above 37.8°C (100°F). A parent should not routinely take a rectal temperature. The temperature should be taken whenever the infant feels cool or warm to the touch. The nurse should observe the parents taking the infant’s axillary temperature before discharge.

The home environment should be kept at a temperature that prevents heat and cold stress. A room temperature that is comfortable for the parent usually is suitable for the infant. The infant should be in clothing appropriate for the room temperature. For example, if the parent requires a sweater to be comfortable, then the infant probably also requires a sweater. Parents often overdress the infant or overheat the home, and this may cause hyperthermia. Parents should be given written instructions before discharge on how and when to take an axillary temperature, when to call the physician, and how to maintain a comfortable environment for their infant.

**REFERENCES**

5. Reference deleted in proofs.