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NEONATAL HYPOTHERMIA

Developed by Mekala Neelakantan and Dr. Paulomi Chaudhry for PedsCases.com.
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Introduction

Hello! My name is Mekala Neelakantan, and I am a fourth-year medical student at the Western Michigan University Homer Stryker M.D. School of Medicine in Kalamazoo, Michigan, USA. This podcast will discuss neonatal hypothermia, including a case presentation and general overview of risks, symptoms, consequences, and management. It has been created under the guidance of neonatologist Dr. Paulomi Chaudhry, Assistant Professor of Clinical Pediatrics within the Section of Neonatal-Perinatal Medicine at the Indiana University School of Medicine.

Learning Objectives

The objectives of this podcast are to:

- *Define neonatal hypothermia.*
- *Review the pathophysiology associated with neonatal hypothermia.*
- *Discuss the risk factors and consequences associated with neonatal hypothermia and inadequate thermoregulation in the newborn.*
- *Underscore treatment and prevention strategies to prevent neonatal hypothermia.*

Case Presentation

Let's begin with a clinical case scenario. You are on a night shift during your Pediatrics clerkship, when you are called for the impending admission of a male newborn of low birth weight, noted to be at 29 weeks of gestational age. The baby is being brought in by EMS following his unexpected home delivery and is accompanied by his mother of G1P0 status. The mother relates that she did not receive prenatal care and did not realize that she was in premature labor. Her partner called 911 as soon as they realized she was not going to make it to the hospital to deliver the baby. You notice the baby's skin is quite mottled, and tinges of blue appear near his fingers and toes. You begin the physical exam and note that the baby is bradycardic with a heart rate of 80 beats/minute and in mild respiratory distress with increased work of breathing. You check his axillary temperature, which is noted to be 35 C.

As we delve into the topic of hypothermia below, keep in mind the possible causes and risk factors for the development of this condition in the newborn discussed above.

Literature Review

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Neonatal hypothermia is a concern of enormous scale, significantly affecting the morbidity and mortality of the newborn population[1, 2]. According to the World Health Organization, the condition is prevalent in every continent. The most significant ramifications are often seen in developing and low-resource areas around the world, where awareness of the issue is only beginning to be brought forth; improved techniques for prevention and treatment in more developed regions have curbed occurrences, although the problem still persists [3, 4]. Reports from England note infant hypothermia is the most common reason for morbidity prior to admission, and studies from Nepal show that the winter months portend neonatal hypothermia developments in more than 80% of delivered newborns[2]. As such, it is vital to understand the intricacies of neonatal hypothermia and continue efforts to bring awareness of the issue, especially in the context of premature infants[5].

We will begin this review with a discussion of the definition and pathophysiology of neonatal hypothermia, before moving onto the risk factors, consequences, treatment, and prevention strategies.

Definition of hypothermia in neonates:

According to the World Health Organization, hypothermia occurs at core body temperatures below 36. 5 C[5]. This is additionally broken down into three categories of **cold stress***, between 36 C and 36.4 C,* **moderate hypothermia***, between 32 C and 35. 9 C, and* **severe hypothermia***, or less than 32 C[1, 2, 6, 7]. While these are relatively concrete numbers and categories, it is also important to recognize that the ramifications of hypothermia may occur at even higher temperatures based upon the ensuing metabolic stress experienced by the body[5]. In the context of the neonatal population, who have a limited ability to thermoregulate at baseline, this may pose stressors that have end effects on overall growth and organ function[2].*

Pathophysiology of neonatal hypothermia:

Why does this happen in the first place? Well, the shiny, new environment that a newborn is brought into is fraught with thermal instability, quite the opposite from the stable setting in which the fetus grows - closely coupled with the maternal temperature in what has been described as a "heat clamp"[7].

While there are various causes for the initial dysfunction in thermoregulation, the neonatal population is affected primarily by four mechanisms of hypothermia: **radiation** *(an infant being placed in a setting containing cooler materials without direct contact, therefore creating a gradient for temperature loss),* **evaporation** *(the most important cause, often from amniotic fluid evaporation),* **conduction** *(an inadequately wrapped infant being directly placed in contact with a cooler object) , and* **convection** *(surrounding cold air causing removal of heat from the infant)[5, 8]. The stress due to heat loss leads to a significant change in metabolic function of the neonate, as energy is shifted toward increasing heat rather than toward growth and development[5, 8].*

Newborns utilize various different mechanisms to battle the cold stress being experienced by their bodies - including increased energy and heat production by organs such as the heart, liver, and brain; muscle flexion to generate heat from voluntary movements as well as minimize surface area; peripheral constriction of blood vessels to decrease heat dissipation, and…

This is where non-shivering thermogenesis comes in[8].

In a mechanism by the sympathetic nervous system triggered by cold stress, neonates utilize the norepinephrine - directed lipolysis of brown adipose (most commonly around the neck,

scapular area, and kidney regions) to create local heat reactions that are carried throughout the rest of the bloodstream to warm the body[5]. The downsides to this, however, are that these neonates subsequently experience a rapid increase in overall metabolic rate that can then lead to hypoxia and hypoglycemia as the stores of brown fat are used up with consumption of oxygen and glucose in the process; it is then easy to see that when applied to a premature infant with underdeveloped vital organs, such an elevated energy requirement can lead to unfortunate consequences such as organ damage, metabolic acidosis, and hypoxia[1, 5, 8]. Additionally, the premature infant may not even have the limited capacity to generate heat under cold stress conditions, as their bodies contain less brown adipose and overall fat stores[1].

Risk factors and causes for neonatal hypothermia:

We will talk about consequences more in-depth in a couple of minutes, but first, let us transition to a discussion of what most commonly places neonates at risk for hypothermia.

It is easiest to present risk factors and causes for neonatal hypothermia by housing them in various different categories[1, 6]:

Number 1*, quite importantly, encompasses the premature neonate, who, as we discussed previously, have a higher risk of developing hypothermia. In a study through the National Institute of Child health and Human Development Neonatal Research Network, it was indicated that 39 percent of newborns between 29 to 33 weeks of gestational age and 41 percent of newborns at less than 29 weeks of gestational age showed NICU admission temperatures of less than 36.5 C[9]. This vulnerable population has an increased body surface area to mass index, larger amount of total body water, underdeveloped integumentary barriers, as well as an inadequate thermoregulation system due to their shortened time in utero; such infants, as well as those with decreased growth capacity, should be closely observed[1, 3, 6]. Other risk factors affecting the premature newborn would include birth by C-section and the necessity of respiratory measures which often delivers cooler air[10]. The first twelve hours after birth for any neonate, really even the first twenty minutes, is a crucial time at which hypothermia may rear its head[1, 6, 8]. This is why, as you will see in the next sections, it is so important to undertake swift preventative and treatment measures.*

Number 2*, of course, is exposure to cold environments, causes could include: inadequate drying after birth, inadequate clothing/blanket protection or inadequate local heating[6]*

Number 3*, birth and care in resource-poor environments. Specific risks within this category would include areas where there is a higher rate of preterm and low-birth-weight infants, inadequate delivery room environments, decreased thermoregulation during transport, and overall decreased awareness of preventative measures to avoid hypothermia[7].*

Number 4, *Infection or sepsis is always a risk for premature infants and often presents as temperature instability or hypothermia. Infants with a history of premature rupture of membranes present an additional risk factor for sepsis.[6]*

Number 5, *is the large category of metabolic and endocrine dysfunction, including possibilities such as hypothyroidism, inborn errors of metabolism, hypoglycemia, and Addison's disease [6,11].*

Number 6, *consists of organ system issues, most significantly within the integumentary and neurologic systems. This would include conditions that compromise the skin barrier, including gastroschisis or neural tube defects, as well as CNS dysfunction from causes including intracranial hemorrhage and hypoxemic ischemic encephalopathy (HIE) especially within the temperature-regulatory zones of the hypothalamus[1, 6].*

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Case Presentation: Potential Causes

Back to our case! The most important risk factor that placed our newborn male at a higher risk for hypothermia, was his premature status and unexpected home birth. It is important to note that families preparing for an expected home delivery can take measures to ensure a warm environment (heating the room, keeping the mother and baby close, quickly initiating breastfeeding), but it absolutely requires awareness of the issue of neonatal hypothermia as a whole - something that is continuing to be brought to the forefront.

Consequences of neonatal hypothermia and inadequate thermoregulation:

Neonates demonstrate clinical findings that alert the practitioner toward hypothermia including: palpable cold temperature, acrocyanosis, irritability, hypotonia, decreased feeding, and hypoglycemia as the cold stress heightens[1, 8]. In premature infants particularly, the consequences of neonatal hypothermia are quite dire with demonstrations of increased mortality, and dangerous sequelae including intraventricular hemorrhage and worsened metabolic derangements[12].

As the state of hypothermia continues to affect the neonate's body, one can start to see cardiovascular complications such as bradycardia, apnea, hypoxia, metabolic acidosis, hypoglycemia, hematologic and coagulation dysfunction, as well as gastrointestinal and renal changes that may lead to fatal consequences[1]. Sclerema neonatorum is a rare panniculitis that causes a diffuse waxy appearance to the skin, has been discussed in the context of severe hypothermia with significant comorbid conditions such as sepsis and cardiac and gastrointestinal diseases[7].

Treatment:

While the sequelae of hypothermia should be specifically managed based on etiology, we will focus on the treatment of neonatal hypothermia as a whole. The name of the game, of course, is diligent rewarming and the utilization of an environment that would reduce the diversion of the neonate's metabolic and oxygen requirements toward heat generation[1, 5]. The first and most critical intervention is drying the baby post-delivery and placing the premature infant on a radiant warmer. In the NICU setting, incubators/isolettes or overhead warmers are utilized for this, creating a well-controlled atmosphere with minimal effects on heat loss by the four mechanisms discussed prior[1]. Other important methods of temperature control include hats for the newborns to prevent heat loss from the scalp, and maintenance of thermoregulation even during any necessary transfers or procedures[1]. It is important to remember that while the rewarming process is crucial, a close eye must be kept on the patient's temperature, re-checking this every hour to avoid any possibilities of over-heating[2].

Prevention Strategies:

Equally important are methods of preventing neonatal hypothermia in the first place. As a worldwide issue, it is crucial that prevention strategies are in place from the very start. This means anticipatory actions such as a warm delivery atmosphere, at an ideal temperature between 23 and 25 C according to the WHO, and specifically around 25 to 28 C for less-than-32-week-old newborns, according to the Canadian Pediatric Society[13]. Ensuing management may warrant a variety of measures depending on the status of the newborn; this includes immediate swaddling and drying of the infant, along with skin-to-skin contact as determined by the situation[2, 4]. Updated practice points from the Canadian Pediatric Society with guidelines from the International Liaison Committee on Resuscitation Neonatal Task Force, indicate the

utility of a polyethylene wrap for preterm infants, preserving humidity by not drying them off prior to wrapping [5, 13]. Following this, the baby's temperature should continuously be monitored and regulated between 36.5 to 37.5 C with use of a servo-controlled warmer or incubator. All of these measures are in direct association with the big four mechanisms of hypothermia discussed earlier, most pertinently, conduction, convection, and evaporation[5].

More specifically, the WHO presents what is known as the "warm chain", a ten-step method of preventing and decreasing the risk of neonatal hypothermia by maintaining optimal thermal conditions[2, 3, 8]. The process includes several points that we discussed previously, including maintaining a warm delivery atmosphere, drying the newborn as indicated, initiating skin-to-skin contact, commencing breastfeeding as tolerated, delaying bathing and weighing measurements while taking judicious care to maintain temperature regulation when they are done, clothing the newborn appropriately, keeping the mother and baby in close proximity at all times, continuously maintaining a warm temperature even during transportation, monitoring for any additional indications for warming the patient, and promoting a deep understanding and awareness of neonatal thermal regulation and protection [2, 8].

Case Presentation: Completion

Upon discovery of the newborn's moderate hypothermia status, you discuss with your attending that the very next steps are to immediately rewarm the patient. Luckily the hospital at which you are at has a NICU. The baby is rewarmed to normal temperature status with an overhead warmer. Your attending particularly mentions to you the importance of monitoring the baby's temperature every hour throughout this time, as well as noting any signs of infection especially given his premature status and still-developing immunity and organ systems. You both also discuss the importance of continuing feeds during this time to maintain his nutritional status and avoid any episodes of hypoglycemia, initiating with nasogastric breast milk supplementation with plans to wean to oral feeds as tolerated. If the baby is unstable and/or unable to tolerate gastric feeds, then intravenous supplementation with dextrose and electrolytes is initially instigated. Blood glucose levels are closely monitored in premature or sick infants.

As you continue to keep an eye on the patient now peacefully in the incubator, you begin to wonder what other methods there are for rewarming newborns suffering from hypothermia, especially in areas with less resources. Your research into efforts by the World Health Organization lead you to the information that there are various methods of rewarming processes depending on the severity of the hypothermia. These include the use of a water-filled heated mattress, increased room temperature, the use of a warm bed without any harmful objects nearby (I.e. a hot stone or hot bottle), and mother-baby skin-to-skin contact.

Several hours later, the temperature of your newborn patient seems to be normalizing! You speak with your attending about this, who is quite pleased, and tells you never to forget the utility of the "warm chain".

Brief description of therapeutic hypothermia in the context of HIE.

As a last aside, I did want to mention the implication of therapeutic hypothermia in the context of neonatal hypoxic-ischemic encephalopathy. For a more in-depth review, be sure to check out our podcast on the topic! However, I want to state that significant evidence has shown the efficacy of therapeutic whole-body hypothermia in neonates with hypoxic-ischemic encephalopathy in creating better neurodevelopmental outcomes and improvements in CNS injury[14]. This is a unique setting where hypothermia is actually medically indicated and has been demonstrated to be of therapeutic value!

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Learning Points

Let's review some main points of this podcast!

- *Neonatal hypothermia is an issue of global concern, significantly affecting the morbidity and mortality of newborns, especially following premature delivery.*
- *Newborns have a limited ability to thermoregulate and experience heat loss rapidly after birth in four main ways: radiation, evaporation, convection, and conduction.*
- *There are various risk factors leading to the development of neonatal hypothermia, including but not limited to: preterm status, birth in resource-poor environments, infection, metabolic derangements, and inadequate organ system function. Consequences of neonatal hypothermia include dangerous possibilities such as intraventricular hemorrhage, hypoxia, acidosis, and rarely sclerema neonaturm.*
- *Prevention is key, with understanding around the causes, complications, and treatment measures. With strategies such as the "warm chain" developed by the WHO to maintain thermoregulation as much as possible, the hope is that preventative measures can be applied, with modifications as necessary, across the globe with the goal of positively impacting neonatal morbidity and mortality*

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