Infants of Diabetic Mothers: The Effects of Hyperglycemia on the Fetus and Neonate

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Abstract

News that a woman with diabetes is about to deliver brings up images of a macrosomic infant. This infant may experience birth injuries, asphyxia, respiratory distress, hypoglycemia, hypocalcemia, hyperbilirubinemia, polycythemia/hyperviscosity syndrome, asymmetric septal hypertrophy, and other congenital malformations. Uncontrolled diabetes has profound effects on embryogenesis, organogenesis, and fetal and neonatal growth, and evidence increasingly indicates that some of these effects are lifelong and may contribute to adult obesity. Preconception control of diabetes and monitoring throughout pregnancy are important in reducing the impact of diabetes on the fetus and newborn.

Diabetes during pregnancy, whether Type I (insulin dependent) or Type II (non–insulin dependent), has many effects on the neonate. When a mother has poorly controlled diabetes, the fetus is subjected to high levels of glucose and responds with increased insulin levels to break down excess fuels (carbohydrates). This can result in macrosomia, which when combined with birth injury occurs ten times as frequently in infants of diabetic mothers (IDMs) as in the general population.[1] Furthermore, the risk of serious birth injury is doubled for IDMs, the cesarean section rate is tripled, the incidence of admission to the NICU is quadrupled, and the rate of stillbirths is five times the rate in the general population.[1–3]

This article examines the effects of maternal diabetes (preconceptional and/or gestational) on the infant. It discusses the effects of hyperglycemia on the fetus during embryogenesis and organogenesis and looks at intrapartal and postnatal effects on the neonate. Also included are a summary of the literature and suggested management strategies for care of this infant population.

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Incidence

Abnormal glycemic control complicates approximately 4 percent of pregnancies in the U.S., with preexisting diabetes occurring in 4–8 percent of all pregnancies and gestational diabetes occurring in 0.08 percent of all pregnancies. Approximately 106,000 American women were diabetic during pregnancy in 1999, and approximately 50,000–150,000 infants are born to diabetic mothers each year.[2,4] According to Catalano, over the past 20-plus years, there has been a significant increase (33 percent) in the incidence of Type II diabetes, associated with an increase in obesity within the general population.[5] Among those at highest risk for gestational diabetes are African-American, Hispanic/Latina, American Indian, Asian, and Native Hawaiian women and also obese women (Table 1). At lowest risk are Caucasian women younger than 25 years of age with a normal weight before and during pregnancy and with no history of abnormal glucose metabolism.[6,7]

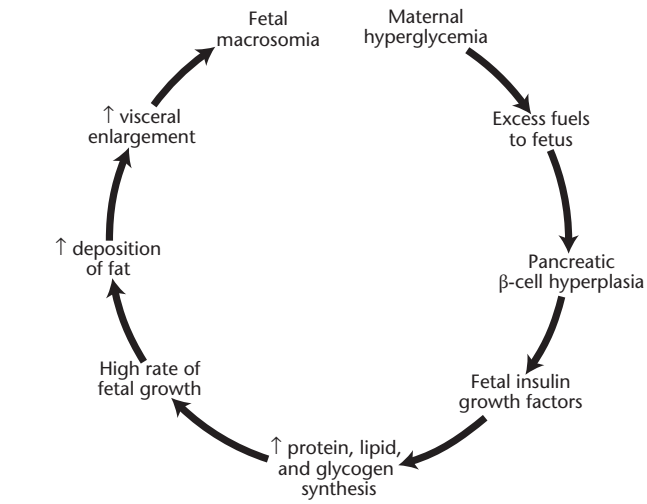
Since insulin was discovered in 1922, improved fetal surveillance and strict maternal metabolic control for all forms

TABLE 1 ■ Groups Associated with a Higher Risk of Gestational Diabetes

Population*
African-Americans
Hispanic/Latinas
Native Americans
Asians
Native Hawaiians
Obese women (>20% over ideal body weight)
Women with previous history of gestational diabetes
Women with previous baby ≥9 lb
Women with glycosuria
Women with strong family history of diabetes

*Listed in order of prevalence

FIGURE 1 ■ Effects of maternal hyperglycemia on the fetus.



of diabetes have reduced perinatal losses from 30 percent to 2–4 percent in recent years.[1,8] Nutritional and metabolic intervention to tightly control glucose levels prior to and during pregnancy have positively affected outcomes for IDMs, with perinatal losses closely approaching the average of perinatal losses for infants born to nondiabetic mothers.[1,8,9] Of all perinatal deaths that do occur as a result of diabetes, 30–40 percent are caused by malformations, 20–30 percent by prematurity, and 20–30 percent as a result of intrauterine asphyxia.[9] Table 2 lists the major causes of neonatal morbidity.

PATHOPHYSIOLOGY

The diabetic pregnancy is complicated by the diverse systems involved with maternal glucose control. Maternal glucose control has been identified as the single most important factor in determining the outcome of the IDM.[1,8] Normal maternal adaptations to pregnancy include alterations in carbohydrate metabolism, most evident in late pregnancy; acquired insulin resistance in response to increased human placental lactogen, progesterone, and cortisol; and a normal "diabetogenic" effect, which results in an increase in available glucose and amino acid transfer to the fetus and increased free fatty acids for maternal energy.[10] The pattern for pregnant diabetic mothers is very different, however.

TABLE 2 ■ Major Causes of Neonatal Morbidity in Diabetes-Affected Pregnancies

Large or small infant for gestational age
Hypoglycemia
Prematurity
Respiratory distress syndrome
Intrapartum asphyxia
Macrosomic infants
Shoulder dystocia causing brachial plexus injuries

During pregnancy, diabetic women develop a pronounced peripheral insulin resistance; decreased numbers of insulin receptors; and decreased binding of insulin to target cells because of insulin resistance. This maladaptation results in a progressive alteration in glucose tolerance and an increase in insulin levels to two to three times prepregnancy values.[10] The diabetic mother experiences frequent episodes of hyperglycemia and high levels of amino acids, and transfer of these nutrients to the fetus is increased.

Effects on the Developing Fetus

The hormonal and metabolic changes that cause maternal problems in diabetic pregnancy also adversely affect the developing fetus. During organogenesis, at 3–8 weeks gestation, the abnormal metabolic environment is teratogenic,

FIGURE 2 ■ Fetal hyperinsulinemic state.

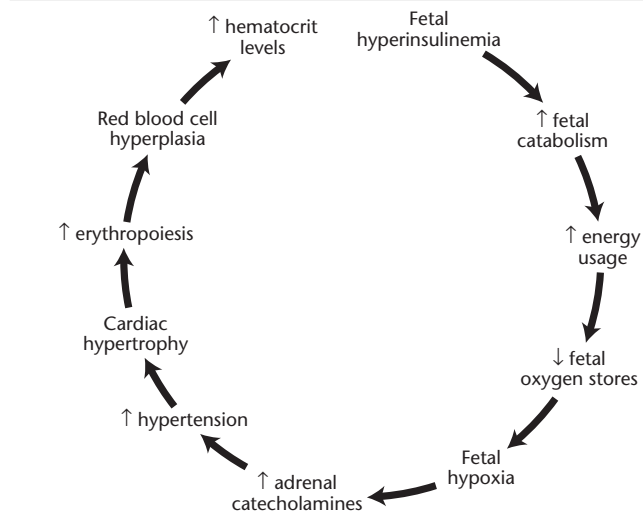
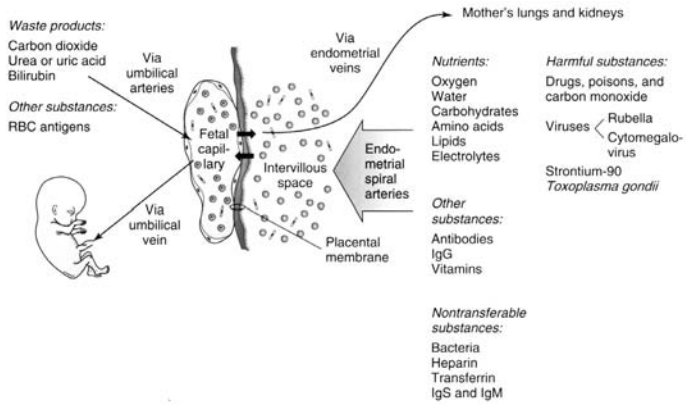


FIGURE 3 ■ Normal placental function.

Summary of substances across the placenta between the mother and fetus.



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resulting in a higher incidence of congenital malformation, such as cardiac, musculoskeletal, and central nervous system (CNS) anomalies.[11] In addition, maternal insulin does not cross the placenta, and fetal hyperinsulinemia occurs as a natural response to the overabundance of carbohydrates that enter the fetal circulation from the mother.

The mechanism by which hyperglycemia disturbs embryonic development is multifactorial and remains controversial. Some suspect that altered arachidonic acid and myoinositol levels or fetal hyperglycemia promote excessive formation of oxygen radicals in cells, which damages the mitochondria, inhibits prostacyclin, and leads to increased oxidative stress in diabetic pregnancies.[1,12,13] This results in an overabundance of thromboxanes (thromboxane A2 is a potent vasoconstrictor) and other prostaglandins, which disrupts vascularization of developing tissues.[1,10,11] Hyperglycemia alters the expression of regulating genes, resulting in altered cellular mitosis and normal apoptosis (programmed cell death). Exaggerated apoptosis results in fetal anomalies.[1,10,14]

The maternal hyperglycemic state (Figure 1) results in the delivery of excess fuels (carbohydrates) to the fetus, stimulating fetal pancreatic β-cell hyperplasia and increasing fetal insulin and insulin-like growth factors.[8–10] Fetal insulin-like growth factors stimulate protein, lipid, and glycogen synthesis, causing a high rate of fetal growth, increased deposition of fat, and visceral enlargement (specifically of the heart and liver), resulting in fetal macrosomia.[10,11,13] The hyperinsulinemic state of the fetus (Figure 2) further drives catabolism from the oversupply of fuel, leading to energy use and depletion of fetal oxygen stores. Depleted fetal oxygen stores lead to fetal hypoxia and the release of a flood of adrenal catecholamines, which in turn cause hypertension, cardiac hypertrophy, stimulation of erythropoietin, red blood cell hyperplasia, and increased hematocrit levels.[1]

Hyperglycemic states also affect the placenta. (Figure 3 illustrates normal placental function.) As the placenta develops, the basement membrane of the chorionic villi thickens and the shape of the placenta changes, increasing the distance for oxygen diffusion between the mother and fetus and resulting in a decrease of uterine blood flow at the placental bed by as much as 35–45 percent.[10,15,16] These changes result when the increased maternal glucose load at the time of placental implantation leads to an abnormal metabolic environment and a resultant fetal hyperinsulinemia. According to Blackburn, placental blood flow could also increase as a compensatory mechanism to increase delivery of oxygen to the fetus due to increases in metabolic rate and oxygen consumption.[10]

One of the focal points when counseling a diabetic woman prior to pregnancy is glucose control. Maternal hyperglycemia, as indicated by elevated glycosylated hemoglobin A_{1c} levels at the time of conception or up to the 16th week of pregnancy, correlates directly with an increased frequency of congenital malformations in IDMs.[9,13,17] With preconception counseling, the teratogenic environment caused by hyperglycemia is under better control when a woman becomes pregnant, and the fetus has a greater chance of developing appropriately.[10,18]

Congenital Malformations

A correlation between maternal diabetes and fetal malformations was noted by the end of the 19th century. In 1978, Priscilla White introduced a diabetes classification system that allowed evaluation of the effects of diabetes on the mother during pregnancy and on the fetus/neonate. This classification was based on length of maternal disease, use of insulin, and vascular effects.[19] It was designed to estimate the prognosis for pregnancy outcome for women with diabetes who became pregnant and was based on observations that women with diabetes had poorer pregnancy outcomes. Gestational diabetes was later added to the original classification when unexplained morbidity and mortality were seen to be caused by undiagnosed diabetes in pregnancy.[20]

The occurrence of congenital anomalies in IDMs (Table 3) is approximately two to five times that in the general population, with malformations accounting for a large portion of perinatal losses. These congenital anomalies affect primarily the central nervous, cardiovascular, respiratory, skeletal, and urogenital systems.[13] See Table 3 for the most frequent malformations.

Birth of an IDM

For health care team members attending deliveries, the presentation of an IDM invokes images of a puffy, ruddy, limp infant. Macrosomia, a well-known characteristic of these infants, occurs with up to 45 percent of diabetic pregnancies.[1,20] It is defined as a weight greater than the 90th percentile for gestational age or >4,000 gm.[21] In addition, incidence of birth injuries is increased for IDMs over the general population. The most frequent of these

injuries involve the facial nerve and cephalohematoma, but injuries also include shoulder dystocia, brachial plexus injuries, and Erb's palsy.[22] Boulet and colleagues found in a review of studies between 1997 and 2002 that cesarean sections would be necessary to prevent all persistent birth injuries.[23] However, the benefit of reducing the rate of shoulder dystocia in IDMs, for example, must be weighed carefully against maternal morbidity from cesarean section.[24] Another study, done by Nassar and coworkers, found more nursery admissions and longer nursery stays for macrosomic neonates born by cesarean section, possibly due to earlier delivery dates.[25] Although macrosomia is is more common, pregnant women with severe Type I diabetes (with chronic hypertension) may have infants who are growth restricted.[26]

After birth, the neonatal pancreas continues to produce insulin at its previous (fetal) rate, and glucose stores are rapidly used, resulting in an increased risk of neonatal hypoglycemia. Maternal glucose homeostasis during pregnancy, as well as maternal glycemia levels during delivery, influence the degree of neonatal hypoglycemia immediately after birth.[11,27,28] Approximately 45 percent of IDMs experience asymptomatic hypoglycemia, putting them at risk for neural impairment.[9,18] Symptomatic hypoglycemic infants are generally quiet and lethargic and may exhibit apnea, respiratory distress, hypotonic shock, cyanosis, and seizures.[21] Ketogenesis and lipolysis are suppressed by hyperinsulinemia, leaving the brain without a supply of alternative fuels for metabolism. The IDM's ability to mobilize glycogen stores is decreased, which can result in an exaggerated and persistent hypoglycemia that can negatively affect the brain. Without adequate glucose, the neonate metabolizes other energy sources, including lactic acid, free fatty acids, amino acids, and ketones, which eventually leads to cerebral anaerobic glycolysis and hypoxic ischemia.[9,18,29]

Although definitions are controversial, most authors agree that neonatal hypoglycemia is a plasma glucose concentration of <45 mg/dl (2.5 mmol/liter) within the first 24 hours of life or <50 mg/dl (2.8 mmol/liter) thereafter; levels lower than this place the neonate at risk for hypoglycemic-induced neurologic dysfunction.[27,30]

Sperling and Menon classified neonatal hypoglycemia as transient (days)—due to hyperinsulinemia; transient (weeks)—due to hyperinsulinemia; or persistent—generally caused by other metabolic disorders.[31] The IDM generally falls into one of the categories of transient hypoglycemia, lasting for days or for weeks.

In 1998, Cordero and colleagues found in a large retrospective study of 530 infants that one-third of the infants born to diabetic mothers (Type I and Type II) experienced hypoglycemia. The majority responded to treatment, but 10 percent had hypoglycemia that persisted for up to a week despite treatment.[32]

The metabolic adjustments that the IDM needs for successful transition can be overwhelming. Hypocalcemia, defined as a serum calcium level of <7 mg/dl (1.75 mmol/liter), can occur in up to 50 percent of IDMs during the first three days of life.[1,8] According to Nold and Georgieff, abnormalities in calcium metabolism most likely represent a delayed transition from fetal to neonatal parathyroid control.[18] Normally, fetal parathyroid glands are relatively inactive *in utero,* and activity increases after delivery.[21] During normal neonatal transition, calcium production decreases as a result of low fetal parathyroid hormone levels at the end of gestation. Hypocalcemia in term IDMs is usually asymptomatic and resolves without treatment.[33] But when hypocalcemia is combined with hypomagnesemia, the latter can complicate the former and make treating it more difficult.

TABLE 3 ■ Congenital Anomalies Associated with Maternal Diabetes

Caudal regression syndrome
Hydronephrosis
Renal agenesis
Micropenis
Cystic kidneys
Intestinal atresias

Hypomagnesemia, which occurs in up to 40 percent of IDMs, is defined as a serum magnesium concentration of <1.5 mg/dl (0.62 mmol/liter).[18] According to Kicklighter, the cause of hypomagnesemia is likely related to the parathyroid glands issues that underlie hypocalcemia but may also be complicated by mothers with Type I diabetes because of renal insufficiency.[2] An excessive maternal urinary magnesium loss potentially decreases available magnesium for placental transport to the fetus.[33] Signs and symptoms of neonatal hypocalcemia and hypomagnesemia are similar to those of hypoglycemia—including jitteriness, sweating, tachypnea, irritability, and seizures—but present later than for hypoglycemia, at 24 to 72 hours of life.[2]

Neurologic Manifestations

Central nervous system malformations are 16 times more likely in IDMs than in nondiabetic pregnancies. Malformations include anencephaly, with a rate 13 times that in the general population; spina bifida, at 20 times the risk; and caudal dysplasia, at 600 times the occurrence.[2] CNS damage can also occur as the result of perinatal asphyxia, glucose and electrolyte abnormalities, polycythemic vascular sludging, and birth trauma. Symptoms of these disorders include seizures, jitteriness, lethargy, and changes in tone. Timing of symptoms can help in differentiating the cause: Perinatal depression and hypoglycemia generally occur in the first 24 hours, with other etiologies presenting later.[18]

The spinal cord is also vulnerable to birth trauma for IDMs, with most symptoms related to brachial plexus injuries, including Erb's palsy (roots C5–7), Klumpke palsy

(roots C7–8), diaphragmatic nerve paralysis (roots C3–5), and recurrent laryngeal nerve damage (roots T1–2). These injuries are more common in the macrosomic IDM and are related either to the positioning of the macrosomic fetus *in utero* or to stretching of the neck or shoulder during delivery.[22,34]

Respiratory System

Respiratory distress syndrome (RDS) requiring admission to the NICU occurs almost six times as frequently in IDMs as in infants of nondiabetic mothers.[35] Delayed maturation of surfactant synthesis has been observed in IDMs, but it is unclear whether the cause is hyperglycemia, hyperinsulinemia, or both, and research continues to provide conflicting results.[18] It has been noted that glycogen is normally depleted from the lungs as part of the lung maturation process and that this depletion coincides with increased surfactant synthesis. Insulin inhibits glycogen breakdown, decreasing the substrate available for synthesis of phosphatidylglycerol (PG), an important component of surfactant.[10] The presence of PG (>3 percent) in the amniotic fluid eliminates the risk of false positive lecithin/sphingomyelin ratios (which should exceed 2:1) in diabetic pregnancies and has been associated with decreased incidence of persistent pulmonary hypertension, which can complicate the course of RDS in the IDM.[10,21]

Cardiovascular System

Congenital heart defects are seen in up to 30 percent of IDMs and include asymmetric septal hypertrophy, transposition of the great vessels, transient hypertrophic subaortic stenosis from ventricular septal defects, and/or a thickened myocardium.[21] The pathogenesis of cardiac defects is unclear, but chronic fetal hyperglycemia and hyperinsulinemia prior to or during formation of the heart tube in the third week of gestation can result in glycogen loading of the intraventricular septum.[18,36] Infants may present with heart failure and poor cardiac output, which worsens with increasing septal thickness and cardiomegaly.[2,21] Most symptoms resolve spontaneously with supportive care within two weeks, and septal hypertrophy generally resolves by four months.[21,26]

Hematology

Hyperglycemia decreases fetal oxygen tension, which in turn stimulates fetal erythropoietin production, resulting in an increase in red blood cells.[1,2] Fetal hyperglycemia and hyperinsulinemia increase total body oxygen consumption by as much as 30 percent, leading to chronically accelerated erythropoiesis, polycythemia (hematocrit >65 percent), and hyperviscosity (hematocrit >70 percent).[2,21,37] This increase in *in utero* red cell mass leads to greater iron demands and depletion of iron stores in the liver, brain, and heart. This can result in myopathies and altered neurodevelopment.[18] As a result of the increased erythropoiesis within the bone marrow, thrombocytopenia may occur. Hypoglycemia is also a significant factor for polycythemic IDMs because it leads to excessive red blood cell glycolysis.[31]

Polycythemia may lead to hyperviscosity syndrome, increasing the risk of ischemia and infarction of the kidneys and/or CNS and contributing to the increased incidence of stroke, seizures, necrotizing enterocolitis, and renal vein thrombosis seen in the newborn IDM.[37] Sludging of hyperviscous blood in the cerebral microcirculation can be responsible for symptoms of irritability, jitteriness, and a high-pitched cry, symptoms usually ascribed to hypoglycemia or hypocalcemia. As a result of sludging, renal vein thrombosis is also seen more commonly in IDMs. It presents with hematuria, flank masses, thrombocytopenia, and hypertension. Intestinal sludging may present with feeding intolerance or full-blown necrotizing enterocolitis. Pulmonary vascular bed sludging may manifest as persistent pulmonary hypertension and can significantly compromise the IDM with RDS.[2,18] In addition, IDMs are at increased risk for hyperbilirubinemia because of the expanded red cell mass, a decreased red blood cell life, and immature hepatic bilirubin conjugation and excretion.[2,9]

NURSING STRATEGIES IN THE MANAGEMENT OF AN IDM

Management of an IDM is individually based and involves a systematic evaluation and review of systems. The objective is to observe each infant for signs and symptoms of maladaptation to extrauterine life. Neurologically, for example, if the infant appears jittery, the health care provider must consider whether the condition is a result of hypoglycemia or hypocalcemia or a complication of hyperviscosity. Is the infant exhibiting signs of respiratory distress? If so, is the cause transient tachypnea of the newborn or a cardiac malformation? Evaluating and assessing each system leads to the initial crucial steps essential in the care of an IDM.

Infants of diabetic mothers are naturally in a hyperinsulinemic state, and signs and symptoms indicative of hypoglycemia in these neonates may be subtle if at all present.[26,30,38] Controversy exists regarding what glucose level is considered low and when treatment should be initiated. Hypoglycemia in itself cannot be defined by a single value; rather, it is dependent upon each infant with his respective history and delivery events. In 2000, a cross-sectional study conducted in Denmark by Hoseth and colleagues of 223 healthy breastfed infants found blood glucose concentrations within the first 24 hours to range from 25–88 mg/dl (1.4 to 4.9 mmol/liter) and thereafter from 38–95 mg/dl (2.1 to 5.3 mmol/liter). None of these infants had clinical signs of hypoglycemia, and breastfeeding was initiated within the first hour of delivery.[39] In a 2003 literature review conducted by Nicholl, the normal range of blood glucose levels for a term healthy newborn was approximately 27–108 mg/dl (1.5 to 6 mmol/liter) in the first days of life, with the lowest concentrations on day

1 of life.[40] The Word Health Organization recommendations for prevention and management of hypoglycemia of the newborn and the Canadian Paediatric Society position statement on screening guidelines for infants at risk for hypoglycemia recommend using a blood glucose level of 47 mg/dl (2.6 mmol/liter) as the low level for intervention based on evidence of adverse effects seen when glucose levels are between 32 and 45 mg/dl (1.8 and 2.5 mmol/liter) in asymptomatic infants.[41,42]

Nursing management includes early breast or bottle feedings (within the first 30 minutes of life) and early blood sugar screening, taken before feedings for at least the first 24 hours. In all infants, the first glucose nadir is 30–60 minutes after delivery, so the first glucose level should be obtained within the first hour after birth, followed by frequent prefeeding levels.[26,30] Screening includes point-of-care testing as well as monitoring of central glucose levels done to confirm a blood glucose level requiring intervention.[42] A common definition and a clear understanding of unit policy on hypoglycemia are of utmost importance when working with these infants because approximately 45 percent of all IDMs develop hypoglycemia. With these infants, it seems prudent to err on the conservative side of the definition of hypoglycemia and treat early based on the possible severe lifelong consequences of hypoglycemic-induced neurologic injury.

Treatment for symptomatic hypoglycemic infants with glucose levels of <47 mg/dl (2.6 mmol/liter) consists of immediate intravenous (IV) therapy of 2 ml/kg 10 percent dextrose followed by a maintenance glucose infusion rate of 6–8 mg/kg/minute to prevent rebound hypoglycemia.[43] If follow-up glucose levels remain <47 mg/dl (2.6 mmol/liter), dextrose infusion should be increased by 2 mg/kg/minute until euglycemia is achieved. Glucose infusion requirements can reach up to 15 mg/kg/minute.[26,30,43] Once the infant's blood glucose levels have stabilized for 12 hours, the glucose infusion rate may be gradually tapered 1–2 mg/kg/minute with each prefeeding glucose level of >50 mg/dl (2.8 mmol/liter) as long as the infant maintains adequate oral intake.[2,27,30]

Neonatal polycythemia and/or hyperviscosity need to be managed based on clinical symptoms rather than on absolute hematocrit values. An initial hematocrit might be obtained shortly after birth, with follow-up on a daily basis. An increase in the hematocrit is commonly seen within the first three days of life, with a leveling off to approximate cord blood values by the end of the first week of life.[10] This increase is secondary to the free water diuresis and low fluid intake that occur during the first three days in all newborns. Hematocrit and blood viscosity do not necessarily correlate in individual patients. Consequently, infants with a hematocrit of <65 percent may be symptomatic, whereas infants with hematocrits >65 percent may remain asymptomatic. Asymptomatic infants with venous hematocrits of 65–70 percent can be hydrated with IV fluids at a rate of at least 100 ml/kg/day.[37] Although partial volume exchange transfusion is controversial, it needs to be considered if the infant becomes symptomatic or if the venous hematocrit rises despite therapy. A falling platelet count in a polycythemic IDM indicates significant microvascular sludging and thrombosis in any number of vascular beds secondary to polycythemia.[18]

Infants of diabetic mothers are also prone to hyperbilirubinemia as a result of polycythemia and excessive red blood cell hemolysis. Treatment of hyperbilirubinemia includes phototherapy, and exchange transfusions may be necessary if bilirubin levels are markedly elevated.[1]

IDMs with symptomatic hypocalcemia are typically treated with slow and cautious administration of 10 percent calcium gluconate, preferably through a central venous catheter. Treatment of hypocalcemia is rarely successful unless accompanying hypomagnesemia is also rectified. Symptomatic hypomagnesemia can be corrected by the slow IV administration of 0.5–2.5 ml/kg of a 5 percent solution of magnesium sulfate over one hour.[2,18]

Respiratory management is adapted to the individual infant based on signs and symptoms. If management or therapy is needed for infants with signs of congestive heart failure or asymmetric septal hypertrophy, propranolol appears to be the drug of choice; digoxin may be contraindicated because of a resultant increase in myocardial contractility, which may cause a potential decreased left ventricular output.[2,9]

POTENTIAL LONG-TERM EFFECTS

Research indicates that accelerated growth during fetal life, stimulated by excessive glucose delivery, may extend into late childhood.[1,10] A permanent derangement in glucose-insulin kinetics, resulting in increased incidence of impaired glucose tolerance in later childhood, results in obesity by seven and a half years of age. Fifty percent of macrosomic infants of diabetic mothers weigh more than the heaviest nondiabetic children at five to eight years of age.[1,44]

IDMs are at increased risk for delayed motor and cognitive development that may manifest later in life. Long-term delays can be a function of acute perinatal events (e.g., asphyxia) or may be related to alterations in brain development from the adverse intrauterine environment characterized by hypoxemia, hypo- or hyperglycemia, and acidosis. The risk of adverse neurologic outcome is a function of abnormal neonatal glucose, calcium, and magnesium metabolisms; degree of fetal hypoxia, polycythemia, and iron deficiency; and presence of birth trauma and asphyxia.[45]

Plagemann and colleagues investigated the influence of early neonatal breast milk feedings (during the first week of life) on neurodevelopment in IDMs. Infants who received those feedings experienced less delay in psychomotor development and closely approached the general population of breastfeeding infants in psychomotor parameters such as lifting the head while prone or walking without help. Researchers did not discover any benefits of early breastfeeding on cognitive

processes such as speaking first words, however. In fact, these processes were actually delayed in the study group.[46]

CONCLUSION

Major abnormalities affecting infants of pregnant women with diabetes include metabolic derangements, maternal obesity, and excessive weight gain in pregnancy, which directly increase the rate of neonatal macrosomia. Optimal care for optimal outcomes of both mother and infant must begin prior to conception. Careful preconception control of diabetes demonstrably reduces the incidence of major fetal anomalies.

Those providing care to IDMs must understand the gravity of the risks. The chance of serious birth injury is doubled in this population, the cesarean section rate is tripled, the incidence of NICU admission is quadrupled, the rate of stillbirths is five times that in the general population, and congenital malformations are observed two to five times as often in infants of diabetic mothers as in other infants, with anomalies occurring in any organ system. A vigilant review and assessment of systems will guide nurses in the care and management of this group of infants.

REFERENCES

1. Moore, T. R. (2003). Diabetes in pregnancy. In R. K. Creasy & R. Resnik (Eds.), *Maternal-fetal medicine* (5th ed., pp. 1023–1062). Philadelphia: WB Saunders.
2. Kicklighter, S. D. (2001). Infant of diabetic mother. Retrieved September 9, 2005, from http://www.emedicine.com/ped/topic845.htm
3. Lauenborg, J., Mathiesen, E., Ovesen, P., Westergaard, J. G., Ekbom, P., Molsted-Pedersen, L., et al. (2003). Audit on stillbirths in women with pregestational type 1 diabetes. *Diabetes Care, 26,* 1385–1389.
4. Sheffield, J. S., Butler-Koster, E., Casey, B. M., McIntire, D. D., & Leveno, K. J. (2002). Maternal diabetes mellitus and infant malformations. *Obstetrics and Gynecology, 100,* 925–930.
5. Catalano, P. M. (2003). Gestational diabetes and insulin resistance: Role in short- and long-term implications for mother and fetus. *The Journal of Nutrition, 133,* 1674–1683.
6. Joslin Diabetes Center and Joslin Clinic. (2005). Guideline for detection and management of diabetes in pregnancy. Retrieved May 28, 2006, from http://joslin.org/Files/Gest_guide.pdf
7. Kale, S. D., Kulkarni, S. R., Lubree, H. G., Meenakumari, K., Deshpande, V. U., Rege, S. S., et al. (2005). Characteristics of gestational diabetic mothers and their babies in an Indian diabetes clinic. *The Journal of the Association of Physicians of India, 53,* 857–863.
8. Cunningham, F. G., Gant, N. F., Leveno, K. J., Gilstrap, L. C., Hauth, J. C., & Wenstrom, K. D. (2001). *Williams obstetrics* (21st ed.). New York: McGraw-Hill.
9. Schwartz, R., & Teramo, K. A. (2000). Effects of diabetic pregnancy on the fetus and newborn. *Seminars in Perinatology, 24,* 120–135.
10. Blackburn, S. (2003). Maternal, fetal, and neonatal physiology: A clinical perspective (2nd ed.). St. Louis: WB Saunders.
11. Armentrout, D. (2004). Glucose management. In M. T. Verklan & M. Walden (Eds.), *Core curriculum for neonatal intensive care nursing* (3rd ed., pp. 192–204). St. Louis: Elsevier Saunders.
12. Rajdl, D., Racek, J., Steinerova, A., Novotny, Z., Stozicky, F., Trefil, L., et al. (2005). Markers of oxidative stress in diabetic mothers and their infants during delivery. *Physiological Research, 54,* 429–436.
13. Wender-Ozgowska, E., Wroblewska, K., Zawiejska, A., Pietryga, M., Szczapa, J., & Biczysko, R. (2005). Threshold values of maternal blood glucose in early diabetic pregnancy—Prediction of fetal malformations. *Acta Obstetricia et Gynecologica Scandinavica, 84,* 17–25.
14. Gamblian, V. W., Weiland, J., & Park, N. C. (2003). Assessment and management of the endocrine system. In C. Kenner & J. W. Lott (Eds.), *Comprehensive neonatal nursing* (3rd ed., pp. 531–549). Philadelphia: WB Saunders.
15. Ashfaq, M., Janjua, M. Z., & Channa, M. A. (2005). Effect of gestational diabetes and maternal hypertension on gross morphology of placenta. *Journal of Ayub Medical College, Abbottabad, 17,* 1, 44–47.
16. Belkacemi, L., Lash, G. E., Macdonald-Goodfellow, S. K., Caldwell, J. D., & Graham, C. H. (2005). Inhibition of human trophoblast invasiveness by high glucose concentrations. *The Journal of Clinical Endocrinology and Metabolism, 90,* 4846–4851.
17. Galerneau, F., & Inzucchi, S. E. (2004). Diabetes mellitus in pregnancy. *Obstetrics and Gynecology Clinics of North America, 31,* 907–933.
18. Nold, J. L., & Georgieff, M. K. (2004). Infants of diabetic mothers. *Pediatric Clinics of North America, 51,* 619–637.
19. White, P. (1978). Classification of obstetric diabetes. *American Journal of Obstetrics and Gynecology, 130,* 228–230.
20. Lucas, M. J. (2001). Medical complications of pregnancy: Diabetes complicating pregnancy. *Obstetrics and Gynecology Clinics, 28,* 513–536.
21. Lee-Parritz, A. and Cloherty, J. P. (2004). Maternal conditions that affect the fetus: Diabetes mellitus. In Cloherty, Eichenwald, & Stark (Eds.), *Manual of neonatal care,* (5th ed., pp 9–19). Philadelphia: Lippincott, Williams & Wilkins.
22. Mathew, M., Machado, L., Al-Ghabshi, R., & Al-Haddabi, R. (2005). Fetal macrosomia. Risk factor and outcome. *Saudi Medical Journal, 26,* 96–100.
23. Boulet, S. L., Salihu, H. M., & Alexander, G. R. (2004). Mode of delivery and birth outcomes of macrosomic infants. *Journal of Obstetrics and Gynecology, 24,* 622–629.
24. Conway, D. L. (2002). Choosing route of delivery for the macrosomic infant of a diabetic mother: Cesarean section versus vaginal delivery. *The Journal of Maternal-Fetal & Neonatal Medicine, 12,* 442–448.
25. Nassar, A. H., Usta, I. M., Khalil, A. M., Melhem, Z. I., Nakad, T. I., & Abu Musa, A. (2003). Fetal macrosomia (> or + 4500 g): Perinatal outcome of 231 cases according to the mode of delivery. *Journal of Perinatology, 23,* 136–141.
26. Sehring, S. (2004). Infants of diabetic mothers. In J. A. Kitterman (Ed.), *The William H. Tooley intensive care nursery house staff manual* (pp. 151–152). University of California San Francisco.
27. Cowett, R. M., & Loughead, J. L. (2002). Neonatal glucose metabolism: Differential diagnosis, evaluation, and treatment of hypoglycemia. *Neonatal Network, 21*(4), 9–19.
28. Jensen, D. M., Damm, P., Moelsted-Pederson, L., Ovesen, P., Westrgaard, J. G., Moeller, M., et al. (2004). Outcomes in Type 1 diabetic pregnancies. *Diabetes Care, 27,* 2819–2823.
29. Vannucci, R., & Vannucci, S. J. (2000). Glucose metabolism in the developing brain. *Seminars in Perinatology, 24,* 107–115.
30. Newborn Nursery QI Committee. The Barbara Bush Children's Hospital at Maine Medical Center. (2004). *Neonatal hypoglycemia: Initial and follow up management*. Retrieved May 28, 2006, from National Guideline Clearinghouse at www.guideline.gov
31. Sperling, M. A., & Menon, R. K. (2004). Differential diagnosis and management of neonatal hypoglycemia. *Pediatric Clinics of North America, 51,* 703–723.
32. Cordero, L., Treuer, S., Landon, M., & Gabbe, S. (1998). Management of infants of diabetic mothers. *Archives in Pediatric and Adolescent Medicine, 152,* 249–254.

33. Donati-Genet, P. C., Ramelli, G. P., & Bianchetti, M. G. (2004). A newborn infant of a diabetic mother with refractory hypocalcaemic convulsions. *European Journal of Pediatrics, 163,* 759–760.
34. Gurewitsch, E. D., Johnson, E., Hamzehzadeh, S., & Allen, R. H. (2006). Risk factors for brachial plexus injury with and without shoulder dystocia. *American Journal of Obstetrics and Gynecology, 194,* 486–492.
35. Gillean, J. R., Coonrod, D. V., Russ, R., & Bay, R. C. (2005). Big infants in the neonatal intensive care unit. *American Journal of Obstetrics and Gynecology, 192,* 1948–1955.
36. Wren, C., Birrell, G., & Hawthorne, G. (2003). Cardiovascular malformation in infants of diabetic mothers. *Heart, 89,* 1217–1220.
37. Pappas, A., & Delaney-Black, V. (2004). Differential diagnosis and management of polycythemia. *Pediatric Clinics of North America, 51,* 1063–1086.
38. Sisto, P. A. (2004). Endocrine disorders in the neonate. *Pediatric Clinics of North America, 51,* 1141–1168.
39. Hoseth, E., Joergensen, A., Ebbesen, F., & Moeller, M. (2000). Blood glucose levels in a population of healthy breast fed, term infants of appropriate size for gestational age. *Archives of Disease in Childhood. Fetal and Neonatal Edition, 83,* F117–F119.
40. Nicholl, R. (2003). What is the normal range of blood glucose concentration in healthy term newborns? *Archives of Disease in Childhood, 88,* 238–239.
41. World Health Organization. (1997). Hypoglycaemia of the newborn: Review of the literature. Geneva. Retrieved July, 15, 2006, from http://www.who.int/reproductive-health/docs/hypoglycaemia_newborn.htm
42. Canadian Paediatric Society. (2004). Screening guidelines for newborns at risk for low blood glucose (position statement). *Paediatric Child Health, 9,* 723–729.
43. Newborn Emergency Transport Service: NETS Handbook. (2005). Infant of diabetic mother (IDM). Retrieved May 28, 2006, from www.netsvic.org.au/nets/handbook/index.cfm?doc_id=889
44. Touger, L., Looker, H. C., Krakoff, J., Lindsay, R. S., Cook, V., & Knnowler, W. C. (2005). Early growth in offspring of diabetic mothers. *Diabetes Care, 28,* 585–589.
45. DeBoer, T., Wewerka, S., Bauer, P. J., Georgieff, M. K., & Nelson, C. A. (2005). Explicit memory performance in infants of diabetic mothers at 1 year of age. *Developmental Medicine and Child Neurology, 47,* 525–531.
46. Plagemann, A., Harder, T., Kohlhoff, R., Fahrenkrog, S., Rodekamp, E., Franke, K., et al. (2005). Impact of early neonatal breast-feeding on psychomotor and neuropsychological development in children of diabetic mothers. *Diabetes Care, 28,* 573–578.

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