PART III

NUTRITION SUPPORT OF SPECIFIC STATES

20

Pregnancy and Lactation

Kris M. Mogensen, MS, RD-AP, LDN, CNSC, and Miriam Erick, MS, RD, LDN, CDE

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References

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Objectives

Describe nutrition requirements for pregnancy and lactation.

Identify special considerations for assessing nutrition status in pregnancy.

Determine indications for enteral nutrition (EN) and parenteral nutrition (PN) in pregnancy and lactation, and understand the decision process for selecting enteral and venous access devices.

Identify nutrition monitoring parameters that are altered by pregnancy.

Test Your Knowledge Questions

1. Which of the following statements is true regarding the nutrition status of the pregnant woman and its impact on the fetus?

A. Obese pregnant women should lose weight during pregnancy to improve fetal outcomes.
B. The fetus is a “perfect parasite,” and the nutrition status of the mother is of no consequence.
C. Appropriate weight gain for women of all body mass index (BMI) ranges is essential to fetal health.
D. Poor maternal health and nutrition status has only short-term impact on the fetus.

2. Which of the following statements about energy needs during pregnancy is true?

A. Energy requirements are the same for pregnant and nonpregnant women.
B. Energy needs are increased only during the second and third trimesters of pregnancy.
C. Compared with nonobese women, energy requirements are lower for obese women to promote weight loss during pregnancy.
D. Energy goals should only focus on nonprotein energy intake.

3. Which of the following parameters is appropriate for monitoring glycemic control of pregnant women receiving nutrition support?

A. Urine glucose
B. Urine lactic acid
C. Serum glucose
D. Serum insulin

Test Your Knowledge Answers

1. The correct answer is C. Appropriate weight gain for women of all BMI ranges is essential to fetal health. Inadequate or excessive maternal weight gain can lead to poor fetal outcomes. Weight gain below recommended targets set by the Institute of Medicine (IOM; now the Health and Medicine Division of the National Academies of Science, Engineering, and Medicine) in 2009 has been associated with low birth weight (LBW) infants.1 Obese women who lost weight during pregnancy had twofold greater odds of LBW infants and 1.8 greater odds of small-for-gestational age (SGA) infants. Excessive weight gain increases the odds of gestational hypertension or preeclampsia, macrosomia, and a decrease in the infant's 5-minute appearance, pulse, grimace, activity, and respiration (APGAR) scores.2
2. The appropriate answer is B. Energy requirements in pregnancy increase in the second and third trimesters.3 Most women do not need to increase energy intake in the first trimester, although underweight women may be encouraged to do so.
3. The correct answer is C. Serum glucose levels must be strictly monitored during pregnancy to avoid the possible detrimental effects of neonatal hyperglycemia and hyperinsulinemia. The presence of glucose in a pregnant woman's urine is not abnormal and therefore does not necessarily indicate the presence of maternal diabetes.4 The presence of lactic acid in the urine is typically observed during strenuous exercise and has no value in terms of monitoring glycemic control.

Background

Good maternal nutrition is essential for positive fetal outcomes. Inadequate maternal weight gain affects fetal growth and increases the risk of delivering a LBW infant. In addition, maternal micronutrient deficiencies may also impact fetal outcomes. After delivery, good maternal nutrition must continue to ensure adequate infant growth and development during breastfeeding as well as maintenance of good nutrition status of the mother.

Achieving adequate nutrition intake can be challenging when a pregnant woman cannot take adequate oral nutrition, as in cases of severe hyperemesis gravidarum. Pregnant women with medical conditions that affect digestion and absorption, such as cystic fibrosis or inflammatory bowel disease (IBD), may require EN or PN to ensure adequate nutrition to support fetal growth. In addition, women with pre-existing metabolic diseases such as phenylketonuria or maple syrup urine disease require specialized nutrition planning before conception and close monitoring and adjustment of the nutrition plan throughout the pregnancy.5 Discussion of pregnancy in women with genetic and metabolic conditions is beyond the scope of this chapter. Patients with these conditions may require the attention of the nutrition support clinician along with the genetic-metabolic team.

This chapter reviews physiological changes during a healthy pregnancy and proposes an approach to nutrition assessment that focuses on malnutrition in pregnancy and the determination of the woman's

nutrition needs during pregnancy and lactation. It also addresses indications for EN and PN, special considerations for nutrition support during pregnancy, and some disease-specific considerations.

Maternal Weight Gain in Pregnancy

Appropriate maternal weight gain is an important component of a positive fetal outcome. Weight gain is spread among multiple compartments of the body, in varying amounts. Table 20-1 outlines components of weight gain for singleton and multiple pregnancies.6 In its 2009 guidelines, IOM recommended weight gain goals by pregravid BMI.7 Table 20-2 outlines these recommendations for singleton pregnancies.7 Weight gain guidelines with anticipated fetal weight for women pregnant with multiples are outlined in Table 20-3.8 Clinicians should be aware that recommendations for triplets and quadruplets are based on much smaller numbers of pregnancies than singleton and twin pregnancies and, thus, should be used more cautiously.8 Siega-Riz and colleagues1 conducted a systematic review evaluating outcomes of maternal weight gain according to the IOM recommendations and found strong evidence associating weight gain below the recommendations and LBW infants.

TABLE 20-1 Components of Pregnancy Weight Gain

	Weight Gain, lb (% Total Weight Gain)			
Compartment	Singleton	Twins	Triplets	Quadruplets
Gestational				
Fetus	8 (22%–32%)	10–16 (26%–27%)	12–18 (20%–24%)	12–20 (17%–25%)
Amniotic fluid	2–3 (8%–12%)	4–6 (10%–11%)	6–8 (8%–10%)	10–12 (14%–15%)
Placenta	2–3 (8%–12%)	4–6 (10%–11%)	6–8 (8%–10%)	10–12 (14%–15%)
Maternal				
Breast tissue	2–3 (8%–12%)	3–5 (8%–8.5%)	3–5 (5%–7%)	3–5 (4%–6%)
Uterus	2–5 (8%–14%)	3–8 (8%–13%)	3–8 (5%–10%)	3–8 (4%–10%)
Blood volume	4 (11%–16%)	8 (13%–21%)	8–10 (13%–14%)	8–10 (11%–12%)
Adipose	5–9 (20%–26%)	6–10 (16%–17%)	10–12 (16%–17%)	10–12 (14%–15%)
Muscle mass	Not described	Not described	Not described	Not described
Total, lb	**25–35**	**38–59**	**58–75**	**70–80**

Source: Adapted with permission from reference 6: Luke B. Nutrition for multiples. Clin Obstet Gynecol. 2015;58:585–610. doi:10.1097/GRF.0000000000000117.

TABLE 20-2 Recommended Weight Gain Based on Prepregnancy Body Mass Index

Prepregnancy BMI	Recommended Weight Gain Range, lb	Rate of Weight Gain for 2nd and 3rd Trimesters, mean (range), lb/wk
<18.5	28–40	1 (1–1.3)
18.5–24.9	25–35	1 (0.8–1)
25.0–29.9	15–25	0.6 (0.5–0.7)
>30	11–20	0.5 (0.4–0.6)

BMI, body mass index.

Source: Adapted with permission from reference 7: Institute of Medicine and National Research Council. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington, DC: National Academies Press; 2009.

TABLE 20-3 Summary of Data on Multiple Gestations and Maternal Weight Gain

	Singleton[a]	Twins[b]	Triplets[c]	Quadruplets[d]
Gestation, weeks	38–41	36–38	34–35	31–33
Birth weight				
Average, g	3700–4000	2500–3800	1900–2200	1500–1800
LBW, %	6	50	90	98
VLBW, %	1	10	32	75
Maternal weight gain				
At 24 weeks, lb	12	24	36	50
Total, lb	25–35	40–45	50–60	60–80

LBW, low birth weight (<2500 g); VLBW, very low birth weight (<1500 g).

[a]Sample size = 3,851,109 infants.

[b]Sample size = 97,064 infants.

[c]Sample size = 4233 infants.

[d]Sample size = 360 infants.

Source: Data are from reference 8.

Obesity

For women with preexisting obesity, it may be tempting to limit weight gain to amounts below the IOM recommendations. However, this choice may have detrimental consequences for the fetus. Although maternal obesity alone is a risk factor for infant mortality, very low weight gain is also a risk factor for infant mortality.9 Cox Bauer and associates2 found that obese women who lost weight during pregnancy had twofold greater odds of having a LBW infant and 1.8 greater odds of having an SGA infant. Conversely, excessive weight gain beyond the IOM recommendations was also problematic, increasing the odds of gestational hypertension or pre-eclampsia, macrosomia, and a decrease in 5-minute APGAR scores.2 Planning for appropriate weight gain and avoiding weight loss or excessive weight gain are important aspects of managing the obese pregnant patient.

Multiple Births

The most recent data from the National Vital Statistics Reports state that the twin birth rate in the United States reached a record high in 2014, resulting in 1 of every 30 babies born being a twin. For 2014, there were 135,336 twin births, 4233 triplet births, 246 quadruplet births, and 47 quintuplets and

higher order births.10 Women with multiple pregnancies are at high risk for premature delivery and SGA infants. The weight gain guidelines in Table 20-3 should be followed for women pregnant with multiple births to promote appropriate fetal growth; however, as stated previously, these recommendations are based on small numbers of triplet and quadruplet pregnancies and should be interpreted and implemented with caution.8

Nutrition Assessment

As with all other clinical conditions, a comprehensive nutrition assessment is the first step in nutrition care for a pregnant patient. The assessment should include evaluation of the patient's pregravid nutrition status as well as her current status. The outcome of conception is influenced by preconception and gestation nutrition, absence or presence of complications from the fetal compartment (eg, discordant growth in twin or triple gestations), and the absence or presence of acute maternal disease (eg, viral infections such as Ebola, mumps, measles, and Zika; bacterial infections). In addition, other nutrition challenges may occur during pregnancy, such as pre-existing maternal metabolic conditions (eg, diabetes, obesity), chronic illnesses that affect digestion and absorption (eg, IBD), and acute events (eg, motor vehicle crash or cerebral vascular accident). All of these factors may affect a patient's nutrition status and nutrition requirements. Many of these situations are not common, and, because there is a paucity of published case reports, clinicians in these situations have little published data for guidance.

Assessment of Pregravid Nutrition Status

When assessing a pregnant woman, clinicians should aim to identify any nutrition deficiencies that existed prior to pregnancy. This part of the nutrition assessment includes careful evaluation of the pregravid weight status, which can be challenging when an accurate pregravid weight is not be available and the clinician must rely upon a patient's recall of her most recent weight prior to pregnancy.

When pregnancies are unplanned, determining the timing of the last menstrual cycle and the true, non-fluid-overloaded, pregravid weight may be more challenging. Also, women whose pregnancies are unplanned may not have optimized their own nutrition status to adequately bear the additional metabolic burden of pregnancy. In the United States, approximately 45% of pregnancies were unintended in 2011, as compared with 51% in 2008.11 The rates of unintended pregnancies declined by 18% between 2008 and 2011, from 54 to 45 per 1000 US women and girls ages 15 to 44 years. The rates of unintended pregnancies were 2 to 3 times the national average for women and girls whose incomes were below or within 199% of the federal poverty level. Rates of unintended pregnancy were also substantially above average for those who were unmarried, those who did not have a high school education, and Hispanics.11

Women with significant comorbidities may have more frequent pregravid medical monitoring and an accurate weight may be available from their medical records. Clinicians can also use pregravid percentage of ideal body weight, BMI, and weight change prior to pregnancy to help evaluate pregravid nutrition status, identify malnutrition, and set weight gain goals for the pregnancy. Review of pregravid

laboratory values such as hemoglobin, hematocrit, and mean corpuscular volume helps evaluate patients for anemia.

Assessment of Current Nutrition Status

The nutrition support clinician may see a pregnant patient at any stage during her pregnancy, and the appropriate nutrition assessment process will depend on stage of pregnancy. Pregnant patients may have signs of malnutrition, but those signs may not be easily categorized by the malnutrition characteristics identified by the Academy of Nutrition and Dietetics (AND) and the American Society for Parenteral and Enteral Nutrition (ASPEN).12 As described in detail in Chapter 9, ASPEN and AND categorize malnutrition by its etiological context: acute illness or injury, chronic illness, or social or environmental circumstances. Any of these contexts can be relevant in pregnancy (eg, trauma, IBD, or severe financial limitations leading to limited access to food). ASPEN and AND also identify several individual characteristics that may support a diagnosis of malnutrition: insufficient energy intake, weight loss, loss of muscle mass, loss of subcutaneous fat, localized or generalized fluid accumulation, and diminished functional status.12 These characteristics can be evaluated in the pregnant patient, but interpretation may present challenges and there is no current, validated tool specifically for evaluating malnutrition in pregnant women. Therefore, this section reviews evaluation of each characteristic in the context of pregnancy.

Insufficient Energy Intake

A detailed diet history is an important part of evaluating the adequacy of energy and protein intake. In addition to the basic diet history, the clinician should also ask questions about vitamin supplements (especially prenatal vitamins), mineral supplementation (eg, iron supplementation), and use of other supplements (eg, herbal supplements). Information about the patient's support system for food shopping and meal preparation is helpful. For the acutely ill pregnant patient, the clinician should evaluate how long the patient was nil per os status or restricted to clear liquids.

Weight Loss

Evaluation of weight change in the pregnant woman can be very challenging. Some pregnant women (eg, those with severe hyperemesis gravidarum or patients with active IBD with extremely limited oral intake) lose weight below their pregravid weight. The nutrition support clinician should compare current weight to the pregravid weight and compare the current weight to the expected weight gain for the patient's stage of pregnancy. The Centers for Disease Control and Prevention offer weight tracking tools that can assist with this process.13 This practice is not noted in the current published malnutrition characteristics, but it can give the clinician a sense of how "behind" a patient is in her expected weight gain. As stated previously, inadequate maternal weight gain is associated with LBW and SGA infants.

Evaluation of Muscle Mass, Subcutaneous Fat, and Edema

Muscle mass, subcutaneous fat, and edema can be evaluated during the nutrition-focused physical examination. Like other malnourished patients, malnourished pregnant patients may exhibit no wasting, profound wasting, or varying degrees of fat and muscle wasting.

Edema, particularly in the lower extremities, is a common problem starting in the second trimester of pregnancy.14 The clinician must interpret this complication with great care to determine whether the edema is related to malnutrition, a "normal" part of pregnancy, or the beginning of fluid accumulation associated with the onset of early pre-eclampsia.

Functional Status

There are no validation studies of changes in functional status in pregnant women. Therefore, it may be difficult to evaluate this change using a validated tool. Measures of handgrip strength could be attempted for appropriate patients, but it is not known whether the interpretation of such measures should change during pregnancy.

Micronutrient Status

In addition to evaluating the 6 characteristics for determining presence or absence of malnutrition, clinicians should assess pregnant women for specific micronutrient concerns that can affect the woman's health and pregnancy outcomes. Iron deficiency is common in pregnancy and should be evaluated and corrected if present. In addition, deficiency of other micronutrients (particularly folate, vitamin B12, calcium, and zinc) may have a negative impact on fetal growth. These deficiencies may also contribute to long-range health consequences for the child, including impaired neurologic development and diseases such as hypertension and diabetes in adulthood.15 Micronutrient requirements and the consequences of deficiencies and excess are discussed in greater detail later in this chapter.

Specific disease states or clinical conditions increase the risk of preexisting micronutrient deficiencies. For example, women who have had bariatric surgery may see an increase in fertility after weight loss16 and may become pregnant unexpectedly. Micronutrient deficiencies are more prevalent in Roux-en-Y gastric bypass (RYGB) patients compared with sleeve gastrectomy patients. Monitoring recommendations have been published and should be followed to ensure that all micronutrient deficiencies are corrected.17 If an RYGB patient becomes pregnant unexpectedly, vitamin B12, folate, vitamin D, and an iron panel should be checked as soon as feasible and deficiencies should be promptly corrected. Pregnant women with a history of malabsorptive disorders, such as cystic fibrosis, IBD, or short bowel syndrome, are also at risk for micronutrient deficiencies and require close examination and monitoring. Physical signs and symptoms of micronutrient deficiencies as well as deficiencies in the initial surveillance levels may prompt additional assessment of micronutrient status.

Determining Nutrition Requirements

General guidelines for determining energy, carbohydrate, fat, protein, fluid, and micronutrient requirements are covered in Chapters 2, 3, 5, 6, 7, and 8, respectively. This section discusses specific considerations for pregnancy.

Energy

Multiple methods are available to determine energy requirements in pregnancy (see Table 20-4).3,18 All methods take into consideration that additional energy is required to support normal body composition changes in pregnancy (eg, increased development of fetal, uterine, and mammary tissue and increased maternal fat deposition) and the increased metabolism associated with these tissues. The equations vary in complexity. Some equations estimate energy needs based on height, weight, and activity level, and add additional calories for weight gain.3 Others are simple calorie-per-kilogram methods.18 Energy requirements are generally calculated using pregravid weight or ideal body weight. The overall energy "cost" of pregnancy has been reported to be approximately 78,000 kcal.19 However, it is important to note that additional energy is generally not required in the first trimester, and increased energy goals for weight gain should be applied in the second and third trimesters. Unfortunately, no research is available to guide recommendations for severely underweight pregnant women, who may require additional energy for weight gain throughout the pregnancy, including the first trimester.

TABLE 20-4 Equations to Determine Energy Requirements in Pregnancy

Age Group	Type of Pregnancy	Recommendation
IOM recommendations		
14–18 y	Singleton	EER + Pregnancy Energy Deposition Where: • EER = 135.3 − (30.8 × A) + PA × [(10.0 × Wt) + (934 × Ht)] + 25 • PA = 1.00 for sedentary PAL; 1.16 for low active PAL; 1.31 for active PAL; 1.56 for very active PAL • Pregnancy energy deposition = 0 kcal for 1st trimester; 340 kcal for 2nd trimester; 452 kcal for 3rd trimester
≥19 y	Singleton	EER + Pregnancy Energy Deposition Where: • EER = 354 – (6.91 × A) + PA × [(9.36 × Wt) + (726 × Ht)] • PA = 1.00 for sedentary PAL; 1.12 for low active PAL; 1.27 for active PAL; 1.45 for very active PAL • Pregnancy energy deposition = 0 kcal for 1st trimester; 340 kcal for 2nd trimester; 452 kcal for 3rd trimester
AND recommendations		
All ages	Singleton	Use IOM guidelines
All ages	Multiples	• BMI <18.5: 42–50 kcal per kg pregravid weight • BMI 18.5–24.9: 40–45 kcal per kg pregravid weight • BMI >25: 30–35 kcal per kg pregravid weight

A, age (years); AND, Academy of Nutrition and Dietetics; BMI, body mass index; EER, Estimated Energy Requirement (kcal/d); Ht, height (meters); IOM, Institute of Medicine; PA, physical activity coefficient; PAL, physical activity level (sedentary: ≥1.0 to <1.4; low active: ≥1.4 to <1.6; active: ≥1.6 to <1.9; very active: ≥1.9 to <2.5); Wt, weight (kg).

Source: Data are from references 3 and 18.

There are little data to guide calculations for energy delivery in pregnant women undergoing metabolic stress. In pregnant women with trauma, burn, severe sepsis, or other illness that may contribute to hypermetabolism, predictive equations may underestimate energy requirements. Serial indirect

calorimetry measurements (see Chapter 2) are beneficial to guide the energy prescription during times of severe illness during pregnancy. In the absence of indirect calorimetry, the clinician could consider use of standard equations for the acute illness and then add additional energy for the appropriate trimester. Close monitoring of weight gain and the health of the fetus are essential during this time. Serial fetal ultrasound may be beneficial, but discovery of intrauterine growth restriction, depending on the severity, may demonstrate that fetal harm has already been done.20

Protein

Changes in protein metabolism can be seen within weeks of conception,21 and whole body protein turnover increases in the second and third trimesters of pregnancy.3 The IOM report on protein requirements states that in a singleton pregnancy with a 12.5-kg weight gain and a 3.3-kg fetus, there is accretion of 148 g nitrogen (approximately 925 g protein); this protein accretion is divided among the fetus (440 g), uterus (166 g), expanded maternal blood volume (81 g), placenta (100 g), extracellular fluid (135 g), and amniotic fluid (3 g).3 One can assume that these accretions are greater with multiples. Ziegler et al22 conducted a landmark study of fetal body composition and found that as gestation advanced, the percentage of fetal body water decreased while protein, fat, carbohydrate, and minerals were accrued. Table 20-5 summarizes recommendations for protein intake in healthy pregnant women.3,18

TABLE 20-5 Protein Requirements in Pregnancy for Healthy Women

Institution/Society	Recommendation
Institute of Medicine	• Singleton: – RDA (1.1 g/kg/d) *or* – Maintenance protein requirements + 25 g/d • Multiples: Maintenance protein requirements + 50 g/d (starting in the 2nd trimester)
Academy of Nutrition and Dietetics	• Singleton: No specific protein recommendation • Multiples: – 20% of total kcal *or* – Maintenance protein requirements + 50 g/d

RDA, Recommended Dietary Allowance.

Source: Data are from references 3 and 18.

Recent work by Elango and Ball21 suggest that protein requirements in pregnancy may be higher than the amounts recommended by the IOM. Using the minimally invasive indicator amino acid oxidation method, they found that protein requirements are 1.2 g/kg/d in early pregnancy and 1.52 g/kg/d in late pregnancy. Adequacy of protein delivery seems to have a “sweet spot,” with excessively low or high protein intake posing potential for harm.23 Inadequate protein intake may lead to poor growth and development, but excessive protein delivery may also be harmful. In early work by Rush and colleagues,24 the addition of high-protein supplements to prenatal diets (470 kcal and 40 g protein vs 322 kcal and 6 g protein vs no supplementation) in addition to the usual oral diet was associated with higher rates of early premature births and neonatal deaths. However, in a study of individual nutrition

rehabilitation in pregnancies of lower socioeconomic groups of women in Montreal, Canada, Higgins et al25 demonstrated that 100 g protein per day provided the best outcome as measured by reduced numbers of LBW infants in singleton pregnancies. More recent studies of high-protein intake during pregnancy have shown long-range negative impacts (eg, insulin resistance, hypertension, and higher adult BMI) in offspring.23,26

In some clinical cases, protein requirements are greater than normal. Pregnant women with complications arising from trauma, burn, or major surgery may benefit from increased protein delivery, and pregnant women receiving high-dose steroid therapy may require higher protein intake to offset catabolism associated with this therapy. There are little data to guide protein provision in the complicated pregnant patient. Therefore, as with energy, the clinician should plan to give patients additional protein during times of metabolic stress and monitor closely whether growth and development of the fetus are appropriate.

Carbohydrate

Carbohydrate is required in the oral diet or nutrition support regimen because some tissues (the brain and red blood cells) can only use glucose for energy. In pregnancy, patients also require carbohydrates as a source of energy to meet the demands to support weight gain. The IOM set the Recommended Dietary Allowance (RDA) for carbohydrate in pregnancy at 175 g/d. The fetus can use both glucose and ketoacids generated by the mother for energy, but fetal use of free fatty acids is limited.3

Carbohydrate has a greater effect on blood glucose levels compared with other macronutrients (see Chapter 3). In a normal pregnancy, consumption of a high-carbohydrate meal results in postprandial hyperglycemia and hyperinsulinemia, which provides a constant supply of glucose to the fetus.27 Pregnant women tend to have decreased premeal and fasting blood glucose levels, which likely reflects the constant glucose uptake by the placenta as well as altered hepatic gluconeogenesis.

Prolonged hyperglycemia may be seen in gestational diabetes as well as other conditions, such as metabolic stress; this problem may also affect women receiving steroid therapy. In pregnancy, prolonged hyperglycemia can lead to excess transfer of glucose across the placenta. During the second trimester, progesterone, estrogen, human placental lactogen, growth hormone, and cortisol levels all rise, which may lead to increased insulin resistance and decreased insulin sensitivity. These factors contribute to the development of gestational diabetes.28 Hyperglycemia in the pregnant woman will lead to fetal hyperglycemia and hyperinsulinemia, which are detrimental to the fetus. In the early stages of pregnancy, chronically elevated fetal blood glucose levels are associated with fetal anomalies and increased risk of miscarriage. In later stages of pregnancy, poor maternal glucose control is associated with increased risk of fetal macrosomia, which may result in birth trauma and an increased rate of cesarean deliveries.29–32 Poor maternal glucose control is also associated with increased risk of stillbirth,33 and hyperglycemia impairs oxygen delivery to the fetus.34 Given these complications, relatively tight glucose control is advocated. For women with diabetes (type 1 or gestational diabetes), the target fasting blood glucose is 95 mg/dL or lower, the 1-hour postprandial blood glucose target is

140 mg/dL or less, and the 2-hour postprandial blood glucose goal is 120 mg/dL or less.35 These targets are also important to follow for pregnant women requiring nutrition support.

Inadequate carbohydrate intake during pregnancy can also be harmful and may lead to ketonemia or ketonuria. Ketone bodies have a negative effect on embryogenesis36 and the behavior and intellectual development of offspring in childhood.37 When planning a nutrition support regimen, clinicians must aim to provide adequate carbohydrate to prevent ketonemia. In general, this goal may be achieved by providing the RDA for carbohydrate (175 g/d), but that amount of carbohydrate may not be sufficient for the metabolically stressed pregnant patient or in situations of multiple gestations.

Fat

Adequate fat intake in pregnancy supports fetal growth and development. The fetus has a significant increase in fat deposition in the second half of gestation, and fat accounts for 16% of the fetus' body weight at term.38 Appropriate essential fatty acid intake is important for fetal growth and lung maturation as well as production of fetal phosphatidylglycerol, pulmonary surfactant, and myelin. There is no formal recommendation for total fat intake in pregnancy, but a reasonable starting point would be approximately 20% to 35% of energy, as suggested by the IOM Dietary Reference Intakes (DRIs).3 In addition, the IOM set the Adequate Intake (AI) for linoleic acid at 13 g/d and the AI for α-linolenic acid at 1.4 g/d.3 The relevance of ω-3 fatty acids, particularly docosahexaenoic acid (DHA), during pregnancy has received significant attention because DHA plays an important role in fetal brain and central nervous system development, which occurs at a rapid pace during the third trimester of pregnancy.39 Proposed benefits of DHA supplementation include improved infant visual acuity, postnatal growth, cognitive development, and prevention of allergies and asthma; in the mother, DHA may potentially lower incidence of gestational hypertension and peripartum depression. A recent systematic review found that fish oil supplementation had no significant effect on markers for any of these potential benefits.40 However, consensus guidelines recommend at least 200 mg DHA in the diet for both pregnant and lactating women.41

Lipid metabolism changes during pregnancy, and transient hyperlipidemia is common. Free fatty acids, triglycerides, and cholesterol are all elevated during pregnancy, particularly during late stages of pregnancy.29,42 Of note, triglyceride levels may rise 150% and cholesterol may rise from 125% to 150% of prepregnancy levels without any adverse sequelae.43 Maternal hypertriglyceridemia results from several factors, including enhanced adipose tissue lipolysis, which increases the amount of substrate available to the liver for triglyceride synthesis; reduced lipoprotein lipase activity in extrahepatic tissues; and increased chylomicron formation from dietary fat intake.44

Fluid

Intravascular, interstitial, and intracellular fluid compartments increase during pregnancy. Adequate fluid should be provided to meet requirements needed to support these normal physiological changes. The AI for fluid for pregnant women is 3 L/d, with approximately 2.3 liters from beverages and the rest coming from water contained in food.45 An individual's fluid requirements may be greater or less than the AI, depending on the patient's volume status, need for fluid restriction (eg, the pregnant woman

with heart failure), or need for replacement of losses (eg, a patient with severe diarrhea with IBD). Care must be taken to avoid dehydration, which may be associated with a reduction in amniotic fluid volume. This reduction is reversible if treated appropriately, but oligohydramnios (amniotic fluid less than expected for gestational age) may lead to fetal deformation, umbilical cord compression, and death.46

Micronutrients

Clinicians may be most familiar with the need for increased folic acid during pregnancy, but requirements for practically all vitamins and minerals increase during pregnancy relative to the nonpregnant state. Tables 20-6 and 20-7 list vitamin and mineral requirements in normal pregnancy, respectively;47–51 requirements for healthy adults are more generally discussed in Chapter 8.

TABLE 20-6 Dietary Reference Intakes for Vitamins in Pregnancy and Lactation

	Pregnancy			Lactation		
Vitamin (Type of DRI)	Age ≤18 y	Age 19–30 y	Age 31–50 y	Age ≤18 y	Age 19–30 y	Age 31–50 y
A, mcg (RDA)	750	770	770	1200	1300	1300
D, IU (RDA)	600	600	600	600	600	600
E, mg (RDA)	15	15	15	19	19	19
K, mcg (AI)	75	90	90	75	90	90
Vitamin C, mg (RDA)	80	85	85	115	120	120
Thiamin (B_1), mg (RDA)	1.4	1.4	1.4	1.4	1.4	1.4
Riboflavin (B_2), mg (RDA)	1.4	1.4	1.4	1.6	1.6	1.6
Pyridoxine (B_6), mg (RDA)	1.9	1.9	1.9	2.0	2.0	2.0
Niacin, mg (RDA)	18	18	18	17	17	17
Pantothenic acid, mg (AI)	6	6	6	7	7	7
Biotin, mcg (AI)	30	30	30	35	35	35
Folate, mcg (RDA)	600	600	600	500	500	500
Vitamin B_{12}, mcg (RDA)	2.6	2.6	2.6	2.8	2.8	2.8

AI, Adequate Intake; DRI, Dietary Reference Intake; RDA, Recommended Dietary Allowance.

Source: Data are from references 47–51.

TABLE 20-7 Dietary Reference Intakes for Minerals in Pregnancy and Lactation

	Pregnancy			Lactation		
Mineral (Type of DRI)	Age ≤ 18 y	Age 19–30 y	Age 31–50 y	Age ≤ 18 y	Age 19–30 y	Age 31–50 y
Calcium, mg (RDA)	1300	1000	1000	1300	1000	1000
Magnesium, mg (RDA)	400	350	360	360	310	320
Phosphorus, mg (RDA)	1250	700	700	1250	700	700
Iron, mg (RDA)	27	27	27	10	9	9
Chromium, mg (AI)	29	30	30	44	45	45
Copper, mcg (RDA)	1000	1000	1000	1300	1300	1300
Iodine, mcg (RDA)	220	220	220	290	290	290
Manganese, mg (AI)	2	2	2	2.6	2.6	2.6
Selenium, mcg (RDA)	60	60	60	70	70	70
Zinc, mg (RDA)	12	11	11	13	12	12

AI, Adequate Intake; DRI, Dietary Reference Intake; RDA, Recommended Dietary Allowance.

Source: Data are from references 47–51.

Micronutrient Deficiencies

Inadequate micronutrient intake may have a profound impact on fetal growth and development, and may affect length of gestation. Vitamin A deficiency during pregnancy is strongly associated with growth restriction, eye abnormalities, and impaired vision in children.52 Women at particular risk for vitamin A deficiency include those with a history of fat malabsorption and those with a prior history of bariatric surgery.

Vitamin D deficiency is highly prevalent in pregnant women and can contribute to neonatal hypocalcemia and early onset of rickets (along with inadequate calcium intake).53 A recent study evaluating vitamin D supplementation in pregnancy found that women with vitamin D levels equal to or greater than 40 ng/mL had lower risk of preterm birth compared with those with levels of 20 ng/mL or less.54

Vitamin K deficiency is a cause of chondrodysplasia punctate (CDP). In a recent case series of 8 women (7 with hyperemesis gravidarum and 1 with Crohn's disease) with vitamin K deficiency, all 8 offspring had characteristics of CDP, which include stippled epiphyses, hypoplasia of the nasal cartilages, and abnormal distal digits.55 Risk factors for vitamin K deficiency during pregnancy include hyperemesis gravidarum, IBD, celiac disease, prior bariatric surgery, pancreatitis, liver disease, renal disease, use of medications that may interfere with vitamin K (coumarin derivatives, antibiotics, antiepileptics), autoimmune disorders, and alcohol use during pregnancy.55

Inadequate folic acid intake is a known risk factor for neural tube defects (NTDs). Since food manufacturers started fortifying flour with folic acid in the late 1990s, the incidence of NTDs has decreased by up to 50%.56 Supplementation with folic acid outside of the normal diet remains

important in prenatal care, particularly for women who have had a prior pregnancy with an NTD, women taking medications with antifolate activity, obese women (especially with history of bariatric surgery), women who are actively smoking or have significant exposure to passive smoking, and those with diabetes.17,56

Iron deficiency anemia is one of the most common deficiencies during pregnancy, with a reported prevalence of 38% of pregnant women.57 Women with IBD, celiac disease or have a history of bariatric surgery carry additional risk for iron deficiency. Iron deficiency during pregnancy has been associated with increased incidence of fetal growth restriction, premature birth, and fetal death.58 In addition, new research is emerging correlating maternal iron deficiency with impaired cognitive development in offspring.59 As previously stated, pregnant women should be screened for iron deficiency and receive adequate repletion (which may be oral or intravenous [IV] iron, depending on gastrointestinal [GI] function) if necessary.

Zinc deficiency may lead to preterm birth and may prolong labor.60 It may contribute to restricted fetal growth and development, central nervous system abnormalities, and congenital malformations.15,60–63

Iodine is crucial for brain development. Severe iodine deficiency is classically associated with cretinism, and mild iodine deficiency has been associated with developmental impairments.64 A recent study of 141 women living in Washington, DC, revealed marginal iodine status and evidence of mild hypothyroidism.65 Clinicians should be aware of this problem and ensure that patients achieve adequate iodine intake through use of fortified foods (eg, iodized salt) or appropriate supplements.

Micronutrient Toxicities

Micronutrient toxicities may also have an adverse effect on the fetus, with vitamin A being the main micronutrient of concern. Vitamin A intake in excess of 10,000 IU/d or 0.5 to 1.5 mg 13-cis retinoic acid (isotretinoin) per kg has been associated with a high incidence of spontaneous abortions and birth defects.66,67 Similar abnormalities can be caused by large daily doses of retinyl esters or retinol in amounts greater than 6,000 RE or 20,000 IU.52,68,69

Additional Micronutrient Supplementation Considerations in Pregnancy

DRIs are intended for healthy individuals with normal digestive and absorptive capacity (see Chapter 8). Individuals with underlying diseases or altered GI anatomy that may affect digestion and absorption may have different micronutrient requirements above and beyond the DRI. For pregnant women requiring nutrition support, EN formulations may not contain the same sources or combinations of vitamins and minerals found in foods, which may change exactly how much is absorbed. The DRIs for pregnancy are designed for women taking an oral diet who have normal intestinal absorption processes. Therefore, the appropriate dosing of micronutrients in PN may be different from the DRI levels; research in this area is lacking. Because of these concerns, pregnant women receiving nutrition support must be monitored very closely for any signs and symptoms of micronutrient deficiencies or excess.

Nutrition Support Therapy for the Pregnant Patient

Enteral Nutrition

EN has been used successfully in pregnant women. Indications for EN in this population are the standard ones: any situation in which the patient has a functional GI tract but cannot take adequate oral nutrition. Examples of situations when EN might be used in pregnancy include hyperemesis gravidarum, multiple gestation, trauma, or critical illness (see Complications and Specific Clinical Challenges in Pregnancy, later in this chapter).

Enteral Access

The selection of enteral access requires careful consideration of the duration of therapy as well as the type of feeding tube device (see Chapter 12). A nasoenteric tube, which can generally remain in place for 6 to 8 weeks, is an appropriate feeding tube for short-term EN. It carries the risk of reflux and aspiration in pregnant women for 2 reasons. First, gastric emptying is delayed and lower esophageal sphincter (LES) tone is decreased in pregnancy.70 Second, a nasoenteric tube will prevent the LES from closing completely, allowing for reflux of gastric contents into the esophagus. Maximum efforts should be taken to decrease the risk of aspiration, which could lead to serious complications such as pneumonia and even death (see Chapter 13).

Gastrostomy tubes or jejunostomy tubes may be considered for long-term EN.71–77 These tubes may reduce the risk of reflux and aspiration but are more invasive than nasoenteric tubes and pose other risks. Extrapolation from reports of other fluoroscopic procedures during pregnancy suggest that fluoroscopic tube placement practice is safe with appropriate radiation shielding.78–81 In a case series of 5 pregnant women with severe hyperemesis gravidarum who underwent surgical jejunostomy insertion between 12 and 26 weeks' gestation (mean 14 weeks), 1 patient required jejunostomy insertion for 2 consecutive pregnancies, for a total of 6 insertions. Five of six women gained weight, and all pregnancies ended with term deliveries (2 LBW infants). The only tube complications were late dislodgment in 2 patients (tubes were replaced via the established tract).81 In a case report, a woman with intractable hyperemesis had an open gastrostomy tube (for drainage and decompression) and feeding jejunostomy tube inserted at 26 weeks after 3 nasogastric feeding tubes failed in a 2-day period. Premature contractions began 30 minutes after the tubes were placed, and contractions were tocolyzed.77

Formula Selection

The process for selecting an enteral formula for the pregnant patient requiring EN is similar to the process for nonpregnant patients (see Chapter 11). A polymeric formula is appropriate for patients with adequate digestive and absorptive capacity. If the patient has heart failure, renal failure, or another complication leading to volume overload or need for a fluid restriction, a concentrated enteral formula may be selected. Because constipation is often a problem in pregnancy (25% to 45% of pregnant women experience this complication70), a fiber-containing formula should be considered. Clinicians should carefully review micronutrient delivery at the goal volume and compare the amounts provided to the

DRIs for pregnancy to ensure that micronutrient needs are met. Additional micronutrient supplementation may be required if the micronutrient delivery from formula will not meet the patient's needs or if the patient requires repletion of a deficiency.

Enteral Nutrition Infusion

Determining the appropriate infusion method will depend on the tube location and the patient's clinical status (see Chapter 10).

Enteral Nutrition Monitoring and Complications

Monitoring of EN and management of enteral feeding complications are covered in Chapters 10, 12, and 13. Recommendations in this chapter are appropriate for the pregnant woman receiving EN. The nutrition support clinician must consider interventions for complications carefully, as some interventions are not appropriate in pregnancy. For example, diarrhea is a common complication associated with EN. In the nonpregnant patient, antidiarrheals may be prescribed if the diarrhea is not caused by infection. Prior to prescribing antidiarrheal medications to a pregnant patient, the clinician should consult with a pharmacist and carefully evaluate the risks to the fetus. Use of loperamide in early pregnancy has been associated with increased risk of congenital malformations, hypospadias, placenta previa, large-for-gestational age fetus, and need for cesarean section.82 Bismuth subsalicylates and diphenoxylate with atropine are both contraindicated during pregnancy because they are known teratogens.70

As mentioned previously, constipation is a common problem in pregnancy. In addition to the use of a fiber-containing enteral formula and assuring adequate fluid intake, stool softeners may be required to treat this complication.

Parenteral Nutrition

Indications

As with any other patient requiring nutrition support, EN is the preferred mode of therapy. However, in some cases, EN is not feasible and PN must be used (see Chapter 14). For example, when EN is contraindicated in pregnant women, PN may be used in cases of severe hyperemesis gravidarum, IBD complications, intestinal stricture, or other clinical complications. ASPEN has recently published guidelines for PN use, which are applicable to pregnant women.83 PN has many risks, and the risks and benefits must be weighed carefully in the pregnant patient. However, fear of complications should not delay initiation of PN in a patient who truly requires it.

Safety of Parenteral Nutrition in Pregnancy

PN can be safe during pregnancy and can support healthy outcomes in women with underlying disorders that limit their ability to tolerate oral or enteral nutrition or digest and absorb nutrients.84–88 Two recently published reports recount the experiences of pregnant women with long-term PN requirements and their pregnancy outcomes. Theilla and colleagues87 focused on the safety of home PN during pregnancy in 9 pregnancies in 7 home PN-dependent patients (4 with short bowel syndrome and prior

home PN dependence for a mean of 6.4 years; 1 with antiphospholipid antibody syndrome with severe hyperemesis who started PN 2 months into the pregnancy; 1 with ulcerative colitis who started PN 3 months into the pregnancy; and 1 with anorexia nervosa who started PN 3 months into the pregnancy). Complications related to the home PN included 3 catheter-related infections in 2 women. Complications associated with pregnancy included dyspnea and palpitations in 1 patient during the first trimester; edema and cervical insufficiency in 2 patients, urinary tract infection in 1 patient, sciatica in 2 patients, and heartburn in 2 patients during the second trimester; and edema in 2 patients in the third trimester. There were no reports of hyperglycemia, and 1 patient had hypoglycemia after completing the PN cycle for the day, requiring extension of the cycle from 12 to 18 h/d. Overall, the women had appropriate weight gain and, in general, delivered normal weight infants without significant complications related to nutrition.

Billiauws and colleagues88 reported a case series of 21 pregnancies in 15 women with intestinal failure and PN dependence. They found that 67% of the patients had a complication related to the pregnancy, including preeclampsia, postpartum hemorrhage, and thrombosis. Half of the patients had a complication related to their underlying disease during the pregnancy, and 33% of the patients had a complication related to the PN. Negative infant outcomes included 45% of infants were LBW, 29% were hypotrophic, and 19% had other complications (3 cases of respiratory distress syndrome and 1 cardiopulmonary arrest). There was 1 intrauterine death of unclear etiology. Infants were followed for a median of 4 years, and no severe complications were reported in early childhood. Chronic intestinal pseudo-obstruction was suspected in 2 infants who were born to mothers with that condition. Continued monitoring of the offspring will be important to evaluate the impact of PN during pregnancy on long-term outcomes during growth and development.

Peripheral vs Central Parenteral Nutrition

Once the decision has been made to initiate PN, the route of delivery must be considered (see Chapter 14). For the pregnant patient, both peripheral PN and central PN have risks and benefits that must be considered. To reduce the risk of thrombophlebitis during infusion via peripheral vein, the maximum osmolarity of peripheral PN is usually 900 mOsm/L.89 Because of this restriction, the amino acid and dextrose concentrations are fairly low, and the patient must be able to tolerate a large volume of this solution to receive maintenance energy requirements. Therefore, peripheral PN may not provide adequate energy to support growth and development of the fetus. It could be used as a bridge therapy while central venous access is obtained to allow for central PN.

Central PN allows for provision of full energy and protein requirements in a reduced volume. The concentrated solution generally has an osmolarity greater than 900 mOsm/L and therefore requires central venous access for administration. A common central venous catheter used to administer PN for short-to-intermediate courses (eg, 2 to 12 weeks) is the peripherally inserted central catheter (PICC). It generally requires ultrasound for insertion and is simple to insert at the bedside (in contrast to tunneled catheters or implantable ports, which require insertion in interventional radiology or the surgical suite). PICCs seem less risky compared with other types of central venous access. However, in a retrospective review of 66 pregnant women with a total of 84 PICCs inserted, Cape and colleagues identified a high

complication rate, particularly for bacteremia (6.7 cases per 1000 PICC days) and thrombosis (2.7 cases per 1000 PICC days).90 This study does not imply that PICCs should never be used in pregnant women. Instead, clinicians should carefully select the most appropriate therapy and type of central venous access in this population, and take extra precautions if a PICC is required for any therapy.

Parenteral Nutrition Composition

As with any patient requiring PN, the final composition of a PN solution for a pregnant patient will be calculated based on her energy, protein, and fluid requirements. Chapter 15 reviews general principles for the composition of PN formulations. Additionally, there are some special considerations when calculating PN goals for pregnant women.

Hyperglycemia is a significant risk in pregnancy,28–34 and it is important to provide adequate carbohydrate to prevent ketonemia while avoiding hyperglycemia.3 Clinicians should monitor the patient's blood glucose closely. Regular insulin may be added to the PN to achieve the target blood glucose of equal to or less than 140 mg/dL to avoid complications.35 Adequate protein should be provided to support fetal growth and meet protein demands associated with the underlying disease or therapy. Lipid injectable emulsion (ILE) delivery should be calculated to ensure adequate provision of essential fats. In the United States, an ILE preparation that contains fish oil is now available (see Chapters 5 and 15). If the patient does not have a history of fish allergy, clinicians may want to consider using this product to ensure adequate provision of DHA.91 One recent case report used this ILE in a pregnant woman dependent on long-term PN because of short bowel syndrome.92

Standard multivitamin and trace element preparations should be provided, and electrolytes adjusted to meet metabolic needs. The clinician must recognize that IV preparations of these additives may not be adequate to meet 100% of pregnancy requirements; therefore, additional supplementation may be required. Nutrients of concern include vitamin D, vitamin K, folic acid, calcium, magnesium, iron, iodine, and selenium.

Parenteral Nutrition Complications

Chapter 17 extensively reviews PN complications. A pregnant woman can have the same complications as any other patient receiving PN.

As discussed previously, glucose control is especially important in pregnancy. To avoid fetal complications, clinicians should closely monitor blood glucose levels in pregnant women receiving PN and provide regular insulin if necessary to keep blood glucose levels in the desirable range. Regular insulin can be added to the PN admixture if the patient has significant insulin requirements.

Nutrition Monitoring

The monitoring of a patient's response to EN is reviewed in Chapter 10, and Chapter 14 addresses monitoring of patients receiving PN. A large part of nutrition support monitoring involves evaluating biochemical changes in response to the nutrition intervention. This assessment is challenging in pregnancy because alterations in blood volume and other pregnancy-related factors contribute to

changes in electrolytes, circulating proteins, vitamins, and minerals. These changes vary by trimester. Table 20-8 compares normal ranges for selected laboratory test results in the 3 trimesters of pregnancy with nonpregnant values. Abbassi-Ghanavati and associates93 provide a resource for many additional laboratory studies that may be evaluated during pregnancy.

TABLE 20-8 Selected Laboratory Values in Pregnancy by Trimester

	Normal Values			
	Nonpregnant	1st Trimester	2nd Trimester	3rd Trimester
Electrolytes and acid-base values				
Sodium, mEq/L	136–146	133–148	129–148	130–148
Potassium, mEq/L	3.5–5.0	3.6–5.0	3.3–5.0	3.3–5.1
Chloride, mEq/L	102–109	101–105	97–109	97–109
Bicarbonate, mmol/L	22–30	20–24	20–24	20–24
pCO_2, mm Hg	38–42	NR	NR	25–33
pO_2, mm Hg	90–100	93–100	90–98	92–107
Anion gap, mmol/L	7–16	13–17	12–16	12–16
pH	7.38–7.42 (arterial)	7.36–7.52 (venous)	7.40–7.52 (venous)	7.39–7.45 (arterial)
BUN, mg/dL	7–20	7–12	3–13	3–11
Creatinine, mg/dL	0.5–0.9	0.4–0.7	0.4–0.8	0.4–0.9
Calcium, mg/dL	8.7–10.2	8.8–10.6	8.2–9.0	8.2–9.7
Magnesium, mg/dL	1.5–2.3	1.6–2.2	1.5–2.2	1.1–2.2
Phosphate, mg/dL	2.5–4.3	3.1–4.6	2.5–4.6	2.8–4.6
Osmolality, mOsm/kg H_2O	275–295	275–280	276–289	278–280
Liver function tests and lipids				
Total bilirubin, mg/dL	0.3–1.3	0.1–0.4	0.1–0.8	0.1–1.1
Direct bilirubin, mg/dL	0.1–0.4	0–0.1	0–0.1	0–0.1
ALP, U/L	33–96	17–88	25–126	38–229
ALT, U/L	7–41	3–30	2–33	2–25

AST, U/L	12–38	3–23	3–33	4–32
Total protein, g/dL	6.7–8.6	6.2–7.6	5.7–6.9	5.6–6.7
Albumin, g/dL	4.1–5.3	3.1–5.1	2.6–4.5	2.3–4.2
Total cholesterol, mg/dL	<200	141–210	176–299	219–349
Triglycerides, mg/dL	< 150	40–159	75–382	131–453
Hematologic laboratory values				
Hemoglobin, g/dL	12–15.8	11.6–13.9	9.7–14.8	9.5–15
Hematocrit, %	35.4–44.4	31–41	30–39	28–40
MCV, mcm^3	79–93	81–96	82–97	81–99
WBC count, $\times 10^3/mm^3$	3.5–9.1	5.7–13.6	5.6–14.8	5.9–16.9
Lymphocytes, $\times 10^3/mm^3$	0.7–4.6	1.1–3.6	0.9–3.9	1.0–3.6
Platelets, $\times 10^9/L$	165–415	174–391	155–409	143–429
Serum iron, mcg/dL	41–141	72–143	44–178	30–193
TIBC, mcg/dL	251–406	278–403	NR	359–609
TS, %	22–46	NR	18–92	9–98
Ferritin, ng/mL	10–150	6–130	2–230	0–116

ALP, alkaline phosphatase; ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; MCV, mean corpuscular volume; NR, not reported; pCO2, partial pressure of carbon dioxide; pO2, partial pressure of oxygen; TIBC, total iron-binding capacity; TS, transferrin saturation; WBC, white blood cell. Source: Adapted with permission from reference 93: Abbassi-Ghanavati M, Greer LG, Cunningham FG. Pregnancy and laboratory studies. A reference table for clinicians. Obstet Gynecol. 2009;114:1326–1331. doi:10.1097/AOG.0b013e3181c2bde8.

Circulating proteins, primarily albumin and prealbumin, are poor indicators of nutrition status. Both are sensitive to inflammation, and low levels likely reflect severity of illness rather than malnutrition or poor response to nutrition therapy.94 In pregnancy, albumin levels decrease as a result of changes in volume status as well as a shift in production of gamma-globulin to alpha- and beta-globulins.95 Creatinine levels are lower in pregnancy than the nonpregnant population because of increased renal clearance. Pregnant women with a creatinine level equal to or greater than 0.9 mg/dL should be evaluated for possible developing renal insufficiency.96 It is unclear whether protein delivery should be modified when renal function is reduced. For women receiving PN with ILE, a baseline triglyceride level should be checked and compared with normal values for her trimester of pregnancy.

Total iron-binding capacity (TIBC), serum iron, hemoglobin, and hematocrit levels may be used to assess iron status. A transferrin saturation of 16% or a serum iron level of less than 60 to 70 mcg/dL may indicate iron deficiency during pregnancy.97 The National Research Council recommends that transferrin saturation in pregnancy be maintained above 20%.98 Iron may be affected by factors other than nutrition during critical illness (for example, anemia of chronic disease where iron is sequestered in the liver). Compared with TIBC, serum ferritin concentration more accurately reflects the body's iron stores, and it may help to differentiate iron deficiency from dilutional changes in pregnancy. A serum ferritin concentration of 12 mcg/L is classified as iron deficiency; however, concentrations less than 35 mcg/L may indicate deficiency during a singleton pregnancy; values for multiples are not known. If a patient has a depressed serum hemoglobin concentration, low mean corpuscular volume, and low mean corpuscular hemoglobin concentration, a serum ferritin level should be checked to confirm iron

deficiency. Generally, iron deficiency anemia may be indicated by serum hemoglobin and hematocrit levels less than 11.0 mg/dL and 33.0%, respectively, in the first trimester; 10.5 mg/dL and 32.0% in the second trimester; or 11.0 mg/dL and 33.0% in the third trimester.99 IV iron may be required to correct deficiency in patients who cannot take oral iron; Auerbach and Deloughery provide guidelines for dosing in various clinical conditions, including pregnancy.100

Clinicians may use urine studies as part of the nutrition monitoring process. Glomerular filtration increases significantly in pregnancy beginning in the first trimester. The increases may result in glucosuria, which may be present in more than 50% of pregnant women.4 Glucosuria is not necessarily related to maternal hyperglycemia, and urine glucose levels should not be used to diagnose diabetes or for monitoring glycemic status in pregnant women. The presence of ketones in the urine can be caused by inadequate hydration, hyperglycemia, or inadequate energy intake. Catabolic illness during pregnancy may also increase the risk of ketonuria. Monitoring urine ketones during the provision of nutrition support therapy is advisable so that energy and fluid intake from EN and/or PN may be adjusted appropriately. The presence of ketones should initially be checked daily and then as needed if weight loss, hyperglycemia, or another change in maternal status (eg, fever) might affect fluid requirements.

Nitrogen balance studies may help the clinician assess individual total nitrogen requirements (see Chapter 6), but published studies have demonstrated that nitrogen intake is often overestimated and nitrogen output can be underestimated.21 It can be difficult to obtain a complete urine collection unless the patient has a urinary catheter in place, and the correction for insensible losses may be over- or underestimated depending on the patient's other losses (eg, large-volume diarrhea, enterocutaneous fistula losses, or skin sloughing in conditions such as Steven Johnson syndrome). If the clinician elects to conduct a nitrogen balance study, a positive balance of 4 to 6 g nitrogen per day is ideal to support fetal growth and development. However, positive nitrogen balance may not be obtainable during the immediate period following acute illness, such as trauma or sepsis (see Chapters 23 and 24). Serial nitrogen balance studies (eg, weekly) could be monitored to evaluate trends in nitrogen balance.

Clinicians monitoring tolerance to EN and PN support should be familiar with normal changes in acid-base status (see Chapter 7) associated with pregnancy. During pregnancy, a chronic state of compensated respiratory alkalosis exists, and buffering capacity is decreased. The alteration is mostly caused by an increase in maternal respiratory rate and increased excretion of bicarbonate by the maternal kidneys; the result is that the maternal pH is maintained within normal limits. These changes facilitate the transfer of carbon dioxide from the fetus to the mother.

Transitional Feeding

In pregnancy, as in other conditions, the transition to EN or oral intake should be initiated and tolerated before the PN or EN is discontinued (see Chapters 10 and 14).

Lactation

Energy and Protein Requirements

Lactation is the process of producing nutritionally appropriate sustenance with immunologic benefit for the infant. It is a physiologically and metabolically demanding activity that occurs after the delivery of an infant. Energy is expended for production of breast milk, and increased protein intake is required to ensure adequate protein content. The average "cost" of lactation (often referred to as the milk energy output) is approximately 500 kcal/d in the first 6 months postpartum and 400 kcal/d in the second 6 months postpartum (Table 20-9).3 The milk energy output is calculated from production and energy density of human milk. The IOM suggests a mild degree of energy reduction to promote postpartum weight loss during the first 6 months of lactation. Milk production is in response to demand, and production is generally reduced in the second 6 months postpartum. Protein needs during lactation are also increased (Table 20-9). As previously stated, consensus guidelines recommend at least 200 mg DHA in the diet for lactating women.41

TABLE 20-9 Energy and Protein Requirements for Lactation

	Requirement
Energy	• First 6 months postpartum: Prepregnancy EER + 330 kcal[a] • Second 6 months postpartum: Prepregnancy EER + 400 kcal[b]
Protein	• 1.3 g/kg/d *or* • Add 25 g/d to maintenance protein requirements

EER, Estimated Energy Requirement (see Table 20-4 for EER equations).

[a]330 kcal = 500 kcal for milk energy output – 170 kcal for weight loss.

[b]400 kcal is for milk energy output; no adjustment is made to support weight loss.

Source: Data are from reference 3.

Composition of Breastmilk and Micronutrient Considerations

The nutrient content of breastmilk is not uniform. Lawrence and Lawrence have provided nutrient analysis of human breastmilk from well-nourished women, which changes in the initial month postpartum.101 Nutrition content of breastmilk will vary based on maternal intake. If a mother was nutritionally compromised during her pregnancy, that may lead to suboptimal breastmilk quality.

Micronutrient requirements during lactation are summarized in Tables 20-6 and 20-7, earlier in the chapter. Lactating women may need to increase their intake of vitamin B12 and vitamin D to ensure adequate levels in breast milk. Women at risk for low vitamin B12 levels in breastmilk include impoverished women whose diet is low in animal protein, those with unsupplemented vegan diets, and

those with a history of bariatric surgery (particularly those with poor adherence to vitamin supplementation).102–104 The vitamin D concentration in breast milk of women taking 400 IU vitamin D per day in pregnancy is relatively low, leading to vitamin D deficiency in breastfed infants. The vitamin D activity in normal lactating women is known to be in the range of 5 to 80 IU, depending on the method of assay. The American Academy of Pediatricians and the IOM have endorsed supplementation with vitamin D to the nursing infant.105 Compliance to this practice is poor, ranging from 2% to 19%.105 In a US study supplementing nursing mothers with 400, 2400, or 6400 IU vitamin D3 daily for 6 months showed supplementation with 6400 IU/d safely supplied breast milk with adequate vitamin D to meet the infant requirements and offered an alternative strategy to direct infant supplementation.105 Breastmilk is low in vitamin K and iron.106,107 Infants who are exclusively breastfed and who do not receive intramuscular vitamin K at birth are at risk for hemorrhagic disease of the newborn.106,108 The exclusively breastfed preterm infant requires iron supplementation; term breastfed infants should not require iron supplementation until 4 to 6 months of age.109,110

Nutrition Support During Lactation

There is little information in the literature to guide nutrition support therapy for women who require nutrition support during lactation. In 2 recent reports of PN-dependent women with short bowel syndrome who had been maintained on PN through pregnancy and lactation, the women were able to support adequate growth and development of their infants with lactation.86,92

Complications and Specific Clinical Challenges in Pregnancy

Hyperemesis Gravidarum

Hyperemesis gravidarum is a complication distinct from the typical “morning sickness” associated with pregnancy. Occasional nausea and vomiting may occur in 85% of all pregnancies. In contrast, hyperemesis gravidarum is severe, intractable nausea and vomiting complicated by dehydration, electrolyte imbalance, ketosis, nutrition deficiencies and at least 5% weight loss; it affects 0.3% to 3% of total pregnancies.111,112 The etiology of hyperemesis gravidarum is not fully understood, and research continues to identify causes and appropriate treatments. A recent case-control study found that women with hyperemesis gravidarum were more likely to report a history of allergies, anxiety disorder, dental cavities, depression, gynecologic disorder, immune disorder, migraine headaches, motion sickness, premenstrual syndrome, and temporomandibular joint disorder compared to those without hyperemesis gravidarum.113 This knowledge may assist with risk screening. Symptoms start at 6 to 8 weeks of gestation and often resolve by 20 weeks, but nausea and vomiting can persist into the third trimester in about one-quarter of cases.111,114

Women with hyperemesis gravidarum are at risk for Wernicke’s encephalopathy, acute kidney injury, liver dysfunction, and esophageal rupture. In addition, limitations in oral intake because of severe vomiting can contribute to the development of malnutrition. Maternal deaths related to hyperemesis gravidarum have been reported.115 Risks to the fetus include higher risk of LBW, intrauterine growth restriction, preterm delivery, fetal and neonatal death, and neurodevelopmental delay.115

A recent systematic review provides guidance for managing hyperemesis gravidarum.111 Initial management generally starts with basic interventions of small, frequent meals comprised of low-fat, high-carbohydrate foods and the avoidance of trigger foods and foods with strong odors. If these interventions are unsuccessful, treatment may include supplemental vitamin B6, ginger, and acupressure. The next line of therapy would be combined vitamin B6/doxylamine, antihistamines, dopamine antagonists, serotonin antagonists, and IV fluids with or without diazepam. Finally, the last line of therapy would be corticosteroids, EN (or PN in severe cases), gabapentin, or transdermal clonidine (see Practice Scenario 20-1).93,116

Practice Scenario 20-1

Question: How do you decide when to initiate nutrition support for a patient with severe hyperemesis gravidarum?

Scenario: A 30-year-old woman who has experienced persistent severe nausea and emesis throughout the entire course of her pregnancy presents in her 17th week of gestation with weight loss, ongoing nausea and vomiting, and severe fatigue. The patient's height is 160 cm, and her pregravid weight was 56.8 kg, meaning her prepregnancy body mass index (BMI) was 22.2 and her prepregnancy ideal body weight was 52.3 kg (per the Hamwi formula). Her current weight is 48.1 kg. She had previously been admitted at week 14 with dehydration and weight loss (then weighing 50.8 kg) and was discharged after receiving 3 days of intravenous hydration and being able to tolerate a single meal of 2 slices of dry white toast and a cup of decaffeinated tea. Since being discharged, she was seen in the outpatient infusion clinic for hydration 2 days per week.

Physical examination shows that the patient has pale conjunctiva, and her oral cavity is dry. She has moderate temporal muscle and clavicular wasting; severe fat wasting at the triceps and prominent ribs. No edema is noted.

Her diet recall documents minimal oral intake since discharge 3 weeks ago. At best, she was only able to sip water throughout the day and eat plain white bread or a few saltine crackers daily. She is unable to tolerate her prenatal vitamin. Pertinent laboratory test results include the following:

- Hemoglobin, 9.7 g/dL (nonpregnancy normal: 12–15.8 g/dL; second trimester normal: 9.7–14.8 g/dL)
- Hematocrit, 29% (nonpregnancy normal: 35.4%–44.4%; second trimester normal: 30%–39%)
- Mean corpuscular volume, 79 mcm3 (nonpregnancy normal: 79–93 mcm3; second trimester normal: 82–97 mcm3)
- Serum iron: 38 mcg/dL (nonpregnancy normal: 41–141 mcg/dL; second trimester normal: 44–178 mcg/dL)
- Total iron-binding capacity, 293 mcg/dL (nonpregnancy normal: 251–406; second trimester normal: not reported; first trimester normal: 278–403)

Intervention: Dextrose-containing intravenous fluid is initiated to hydrate patient until a nasogastric tube can be inserted. Once the nasogastric tube is placed, continuous enteral nutrition (EN) is initiated with an isotonic enteral formula. The patient is at risk for refeeding syndrome; therefore, EN is advanced slowly while serum levels of potassium, magnesium, and phosphorus are closely monitored, with aggressive repletion if levels are low. Supplemental thiamin and folic acid are provided for the first 3 to 5 days of feeding. The patient is monitored closely for signs and symptoms of heart failure.116 Aggressive antiemetic therapy is provided during the initiation and advancement of enteral nutrition. Oral iron will be started once nausea and vomiting are controlled.

Answer: Because the patient is severely malnourished, nutrition support (EN in this case) should be started as soon as appropriate access can be obtained.

Rationale: This patient started out with a healthy BMI and her target weight gain was 25 to 35 pounds (11.4 to 15.9 kg). She has lost approximately 15% of her pregravid weight and now has a BMI of 18.8, with overt signs of fat and muscle wasting. At this point in her pregnancy, she should have gained approximately 2.3 kg from her pregravid weight, with a target weight of 59.1 kg at week 17 of her pregnancy. Using this weight, she is 19% below where she should be at this stage of her pregnancy; therefore, she is at high risk for refeeding syndrome. Her appearance and assessment of her laboratory values are consistent with iron deficiency. She can be categorized with severe malnutrition in the context of chronic disease because she has had hyperemesis gravidarum for more than 3 months, has had prolonged inadequate energy intake meeting less than 75% of her estimated needs for more than 1 month, has lost 15% of her pregravid weight in approximately 4 months, and has severe fat wasting and moderate muscle wasting. In addition, she is iron deficient. The patient requires initiation of EN to stabilize her weight, with the eventual goal to support appropriate weight gain and correction of nutrition deficiencies. If the patient demonstrates intolerance of EN for a prolonged period of time (eg, more than 7 days) and is still unable to tolerate and oral diet, parenteral nutrition should be considered.

For some women, the severity of hyperemesis gravidarum has prompted termination of the pregnancy; in a survey of 808 women with hyperemesis gravidarum, 15.2% had at least 1 termination because of hyperemesis gravidarum, and 6.1% had multiple terminations.117 Another survey of 610 women, 377 with hyperemesis gravidarum and 233 without, 18% of women with hyperemesis gravidarum reported posttraumatic stress symptoms associated with their pregnancies, and compared with those without hyperemesis gravidarum, reported significantly more negative outcomes, including inability to breastfeed, missed time from work or school, lost job (or had to leave employment), and experienced marital and financial difficulties.118

In addition to the negative impact on the mother, hyperemesis gravidarum poses risks for the fetus. Women with hyperemesis gravidarum tend to have smaller infants overall, have more SGA infants, and shorter gestations.115,119–121 In a literature review of Wernicke's encephalopathy as a result of hyperemesis gravidarum, 16 of 49 cases experienced spontaneous abortion and 2 of 49 cases had fetal

death, for a 37% fetal loss rate. The authors suggested that thiamin deficiency may have played a role in this high fetal loss rate.122

Nutrition support clinicians can play a major role in the management of hyperemesis gravidarum. Severe vomiting has been associated with thiamin depletion; therefore, it is essential that patients are given IV thiamin along with IV fluid (particularly if dextrose-containing IV fluids are used) to prevent Wernicke's encephalopathy or Wernicke-Korsakoff syndrome (Practice Scenario 20-2). Thiamin repletion (generally 100 mg/d) should be provided with IV fluids.112,122 An IV multivitamin could also be included, as the patient has likely had inadequate micronutrient intake for a prolonged period of time. Van Stuijvenberg and colleagues123 documented that the intake of most nutrients by women with hyperemesis gravidarum fell below the 50% of the DRI, and 60% of patients had suboptimal levels of thiamin, riboflavin, vitamin B6, and vitamin A.

Practice Scenario 20-2

Question: How do you prevent an adverse neurologic outcome when initiating nutrition support in a patient with severe intractable hyperemesis gravidarum?

Scenario: The insertion of a nasogastric tube in the patient from Practice Scenario 20-1 is delayed because of lack of availability in interventional radiology. She continues to have severe nausea and vomiting, and she continues to receive hydration with intravenous (IV) fluid containing 5% dextrose, infusing at 125 mL/h. She is prescribed an oral prenatal vitamin but promptly vomits after taking it. On hospital Day 2, she becomes confused and starts to exhibit short-term memory loss. Physical examination reveals nystagmus and gait ataxia that was not present on her admission examination.

Intervention: The patient is given 100 mg thiamin intravenously and prescribed 100 mg IV thiamin daily for the next 2 days.

Answer: Dextrose or other carbohydrate repletion should not proceed until supplemental thiamin is provided first. The classic triad of Wernicke's encephalopathy caused by thiamin deficiency is confusion, ophthalmoplegia, and ataxia. If a patient with hyperemesis gravidarum develops these symptoms, prompt thiamin replacement should be provided.

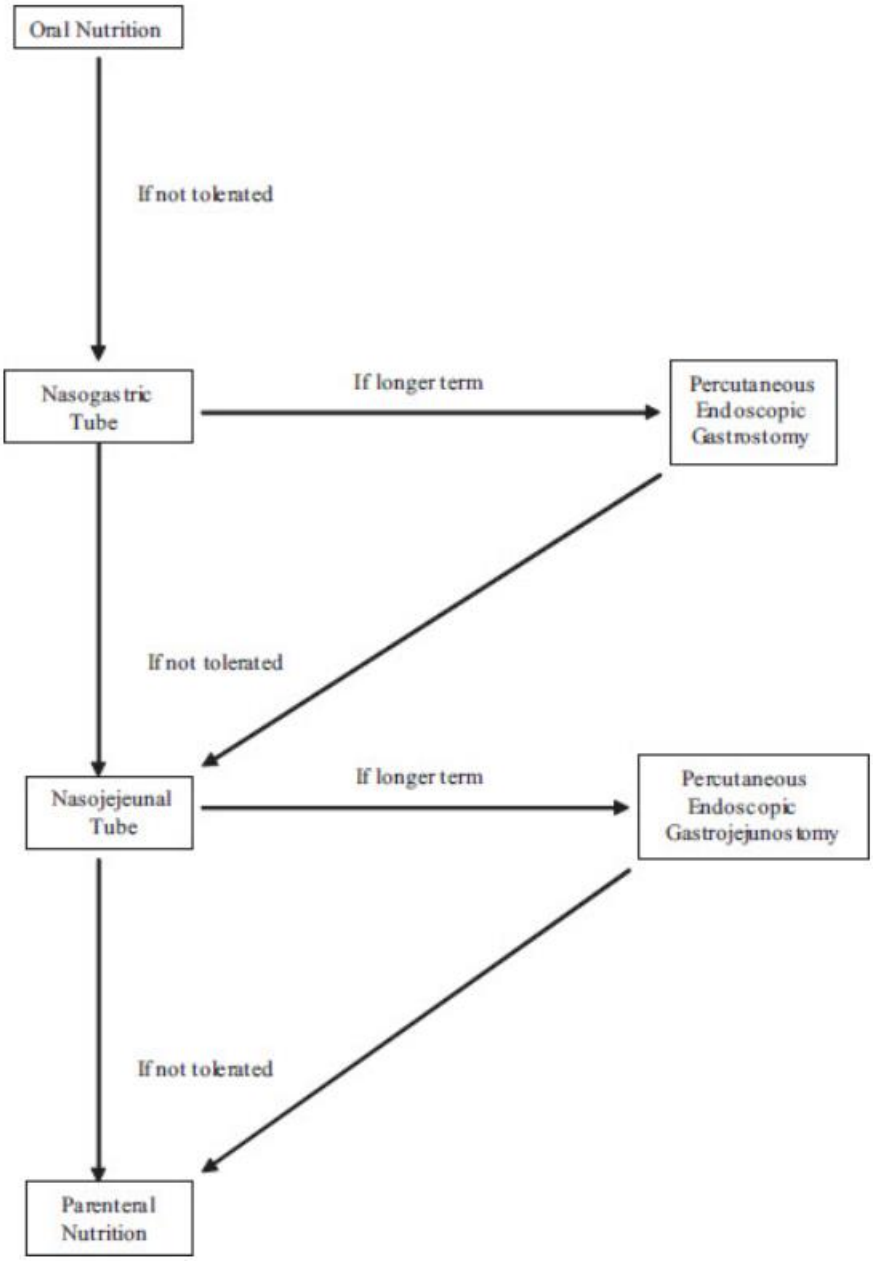
Rationale: Patients with prolonged severe vomiting are at risk for Wernicke's encephalopathy. This condition is usually precipitated by provision of glucose without prior or concurrent thiamin supplementation.

If the patient's response to the therapies outlined in the recent systematic review by McParlin et al111 mentioned previously are minimal, nutrition support initiation should be considered. The comprehensive nutrition assessment will help guide decision-making regarding when to consider EN vs PN. Ideally, EN would be the starting point for nutrition support. However, if a patient is severely

malnourished and well below her pregravid weight with little nutrition reserve, it may be prudent to initiate PN early as a bridge to obtaining enteral access and transitioning to EN.

The literature to support the use of EN as a way to improve nausea and vomiting with hyperemesis gravidarum is limited to individual case reports and small case series.78,124–126 The MOTHER trial (Maternal and Offspring outcomes after Treatment of HyperEmesis by Refeeding) is in progress to evaluate early nasogastric tube feeding to optimize treatment of hyperemesis gravidarum.127 Once the patient has stopped vomiting and electrolytes are stable, a small-bore feeding tube may be inserted and gastric feedings with an isotonic enteral formula can be initiated at a low rate with slow advancement to the calculated goal as long as nausea is not worsened and there is no vomiting or diarrhea.126 Gastric residual volumes (GRVs) should not be checked in patients with a small-bore feeding tube because of the risk of tube clogging (see Chapter 13). As long as the patient can report nausea, fullness, or other GI discomfort, there should be no need to check GRVs. Antiemetics can be used concurrently with EN to minimize retching and decrease the risk of tube dislodgment and aspiration. Vaisman and colleagues78 noted that it took 48 hours of nasojejunal feeding to reduce vomiting, and complete cessation occurred after an average of 5 days of enteral feeding. Lord and Pelletier128 reported success with nasogastric feeding in a series of 26 patients with hyperemesis gravidarum. The patients received intermittent EN over 4 to 6 gravity-drip feedings via a small-bore nasoenteric feeding tube. The mean time to resolution of emesis was 4.5 days and the mean time to stabilize and promote weight gain was 3.6 days. The mean duration of EN was 7 weeks. Of interest, the patients required frequent replacement of the nasogastric feeding tubes, with a report of 2.7 feeding tubes per patient.128 In general, nasojejunal feeding should be considered in patients with poor tolerance to gastric feeding.126 For patients requiring long-term enteral access, a percutaneous endoscopic gastrostomy with or without jejunal extension tube or direct feeding jejunostomy may need to be considered.71–76 If the patient is unable to tolerate EN or has a contraindication to enteral access, PN should then be considered. For patients with severe malnutrition, clinicians may want to consider PN earlier in the clinical course, particularly if there are delays in obtaining enteral access (see Figure 20-1).

FIGURE 20-1 Algorithm for Preference of Route of Nutrition Support in Hyperemesis Gravidarum



If severe malnutrition is present, parenteral nutrition should be considered earlier in the patient's course to allow for correction of deficiencies while enteral access options are pursued.

Management of the Pregnant Trauma Patient

Medical and nutrition support of pregnant trauma patients are especially challenging because catecholamines released in response to stress cause increased nutrient catabolism and vasoconstriction of the placental vasculature, thereby reducing the nutrient and oxygen supplies to the fetus. The nutrition needs to support maternal illness together with demands of the growing fetus are difficult to estimate. Requirements for nutrients are likely to be altered by trauma, but the degree of alteration depends on the nature and extent of the injury. In the few published case reports of pregnant trauma

patients receiving nutrition support, various methods for estimating energy requirements in the absence of indirect calorimetry were used.75,129–132 In these cases, energy delivery ranged from 2000 to 3000 kcal/d. Indirect calorimetry is a valuable tool for determining the resting energy expenditure of the maternal-fetal unit so that under- or overfeeding can be prevented. If indirect calorimetry is not available, traditional equations that estimate the needs of critically ill patients can be used with 200 to 300 kcal/d added for pregnancy; this pregnancy energy deposition is slightly below the recommendations to support weight gain in a healthy pregnancy because the energy expenditure from activity while recovering from trauma would most likely be low and it is important to avoid overfeeding the critically ill patient.133 Weight gain goals would remain the same as in a healthy pregnancy. However, accurate weights can be difficult to obtain in the intensive care unit, where weight gain may reflect volume resuscitation, rather than true weight gain. The initial estimation for protein requirements can be calculated by using the same methods for nonpregnant patients, beginning with 1.5 to 2.0 g/kg pregravid weight.133

As with any other critically ill patient, EN is preferred over PN. Methods to insert enteral feeding tubes have been discussed previously in this chapter; pregnant patients requiring mechanical ventilation may have an orogastric tube inserted for EN. The guidelines for enteral formula choice in critical illness from ASPEN and the Society of Critical Care Medicine should be followed; a specialty enteral formula is likely not necessary unless the patient has significant organ dysfunction, such as acute kidney injury, and requires an electrolyte modified enteral formula.133 A multivitamin with minerals should be provided daily as well as additional folic acid; additional iron may also be required. Glucose control should be managed as discussed previously. Because of the risk for bowel obstruction with the use of insoluble fiber use in critically ill patients, a soluble fiber supplement and appropriate stool softeners and laxatives should be used to ensure regular stool output.

Other Considerations in Pregnancy

With improvements in therapies for IBD, short bowel syndrome, other GI motility disorders, chronic pancreatitis, cystic fibrosis, and genetic metabolic disorders, patients are living longer and clinicians may encounter long-term EN or PN patients who become pregnant. With little in the literature to guide management of these patients, nutrition support clinicians should work closely with the obstetrician to determine the optimal route of feeding, implementation of the nutrition plan, and close monitoring of the patient's nutrition status and fetal growth.

Conclusion

Nutrition support during pregnancy poses many challenges to the nutrition support clinician, particularly given the limitations in data available to guide the assessment and management process for these high-risk patients. Careful assessment of nutrition status, close monitoring of response to nutrition therapy, and frequent communication with the patient's obstetrician is important to promote positive outcomes for the patient and the fetus.