Identifying Malnutrition in Preterm and Neonatal Populations: Recommended Indicators

PRETERM INFANTS AND NEONATES are more vulnerable to times of nutrition deficits than at any other time in the life cycle. The risk of malnutrition is related to reduced nutrient stores at birth, immature nutrient absorption and use, organ immaturity, delayed advancement of parenteral and enteral feeds due to cautious advancement, and dependence on health care providers to accurately identify and effectively provide needed nutrients during a period of rapid growth and development. Complications of prematurity such as necrotizing enterocolitis and chronic lung disease can contribute to the development of malnutrition.

It is well accepted that malnutrition results in poor growth. Growth less than expected as well as calorie and protein intake below that recommended for age are endorsed indicators for pediatric malnutrition.[1] Research indicates a link between poor growth in preterm infants and subsequent neurocognitive development up to age 19 years.[2-16] Although poor growth may be due to medical complications of prematurity, malnutrition is often a cause. Extrauterine growth restriction is reportedly common in neonatal intensive care units (NICUs) among infants born younger than 31 weeks of gestation.[17-19] The degree of growth restriction combined with increased percent body fat and decreased percent lean body mass in preterm infants at term vs term infants suggests that current practices are not consistently promoting optimal growth and body composition in preterm infants.[20] Poor growth post discharge is also common.[21]

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PURPOSE

The Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition have established recommended criteria for the identification and documentation of malnutrition related to undernutrition for both adult and pediatric populations, citing a need for standardized sets for diagnostic characteristics.[1,22] These recommended indicators can be used to identify malnutrition in most settings, including inpatient acute care settings. The criteria that have been published to assist in early identification and documentation of pediatric malnutrition are intended for use in infants aged beyond 37 weeks of corrected gestation and older than age 30 days. Therefore, these criteria do not apply to preterm infants or neonates up to age 1 month. The purpose of this article is to identify a set of basic indicators that can be used to diagnose and document malnutrition related to undernutrition in preterm and neonatal populations. These recommended indicators would be intended for use in neonatal critical care units and inpatient hospital settings as well as after discharge for infants who remain younger than 37 weeks of corrected gestation/postmenstrual age.

Likewise, the goal of this article is to provide a uniform definition of malnutrition for preterm infants and neonates to close the gap. In medical contexts, newborn or neonate refers to an infant during the first 28 days after birth. The terms apply to premature, full-term, and postterm infants. For the purpose of this article, preterm infants are defined according to the World Health Organization (WHO) criteria as those born at younger than 37 weeks of gestation.[23] Neonates are those infants born at 37 weeks of gestation or greater with a current age of 28 days or younger.[24]

All infants beyond this age range are included in the intended population of pediatric consensus definitions for subsequent identification of malnutrition. Deficits in nutrient intake as well as growth will be used as criteria to identify neonatal malnutrition. Specific nutrition intervention strategies to correct growth deficits are beyond the scope of this article.

The indicators of malnutrition for preterm infants and neonates in Table 1 were developed by a group of eight experienced neonatal dietitians following a methodology similar to that of the pediatric malnutrition consensus statement.[1] The group used the pediatric consensus statement as a guideline to determine the recommended indicators and cutoffs for mild, moderate, and severe malnutrition. The indicators selected reflect a literature review and the experience of the committee.

DATA USED IN NEONATAL MALNUTRITION IDENTIFICATION

The data used to assess for the presence of malnutrition in a preterm infant or neonate is similar to those used for pediatric populations. Evaluation of nutrient intake, anthropometric measurements, and rate of growth (ie, growth velocity) are used to determine whether an infant is malnourished. Accurate assessment data must be

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Table 1. Primary indicators of neonatal malnutrition

Indicator	Mild malnutrition	Moderate malnutrition	Severe malnutrition	Use of indicator
Primary indicators requiring 1 indicator				
Decline in weight-for-age *z* score[a]	Decline of 0.8-1.2 SD[b]	Decline of >1.2-2 SD	Decline of >2 SD	Not appropriate for first 2 wk of life
Weight gain velocity[a]	<75% of expected rate of weight gain to maintain growth rate	<50% of expected rate of weight gain to maintain growth rate	<25% of expected rate of weight gain to maintain growth rate	Not appropriate for first 2 wk of life
Nutrient intake	≥3-5 consecutive days of protein/energy intake ≤75% of estimated needs	≥5-7 consecutive days of protein/energy intake ≤75% of estimated needs	>7 consecutive days of protein/energy intake ≤75% of estimated needs	Preferred indicator during the first 2 wk of life
Primary indicators requiring 2 or more indicators				
Days to regain birth weight	15-18	19-21	>21	Use in conjunction with nutrient intake
Linear growth velocity[a]	<75% of expected rate of linear gain to maintain expected growth rate	<50% of expected rate of linear gain to maintain expected growth rate	<25% of expected rate of linear gain to maintain expected growth rate	Not appropriate for first 2 wk of life May be deferred in critically ill, unstable infants Use in conjunction with another indicator when accurate length measurement available
Decline in length-for-age *z* score[a]	Decline of 0.8-1.2 SD	Decline of >1.2-2 SD	Decline of >2 SD	Not appropriate for first 2 wk of life May be deferred in critically ill, unstable infants Use in conjunction with another indicator when accurate length measurement is available

[a]Expected weight gain velocity, expected linear growth velocity, and *z* scores can be determined using the online calculator PediTools (www.peditools.org).
[b]SD=standard deviation.

obtained and then compared with appropriate reference standards (eg, growth charts and comparative standards for nutritional requirements). The 2013 Fenton preterm growth chart or the 2010 Olsen intrauterine growth curves should be used for infants born at 36 6/7 weeks of gestation or earlier.[25,26] The WHO child growth standards should be used for infants born at 37 0/7 weeks of gestation and older. The Centers for Disease Control and Prevention National Health and Nutrition Examination Survey Anthropometry Procedures Manual can be used to ensure correct technique for accurate measurements.[27] Information on the development and use of premature infant growth charts is included in Figure 1 and Table 2. Recommended energy and protein intakes are discussed in the Nutrient Intakes section.

Growth Assessment at Birth

Birth anthropometric characteristics provide an important benchmark for evaluating subsequent changes in nutritional status in preterm infants or neonates and determining goals for discharge.[44] For preterm infants, the comparison of birth weight with a standard is complicated by several factors. Birth weight and other anthropometric measurements at birth

Growth Standards vs References

Evaluation of weight, length, and head circumference involves plotting growth on an appropriate growth chart. Growth charts can be either standard or reference charts. Standard charts describe how infants from low-risk pregnancies grow under ideal environment and health conditions. Reference charts describe growth in a particular time and place and include high- and low-risk pregnancies.

Growth charts commonly used for preterm infants[25,26] are not standards.[28] Villar and colleagues[29] discuss recommendations for ideal standards. International premature infant growth standards have been developed but are not widely used. These growth standards omit infants with prenatal growth restriction and begin at 27 weeks, which is too late for many preterm infants.[30,31] Giuliani and colleagues[31] discuss how the international standards will overcome the methodologic and conceptual weaknesses associated with current preterm growth curves.

Extrauterine vs Intrauterine Growth Charts

Both extrauterine and intrauterine charts have been developed. Extrauterine growth charts were published in the 1980s and 1990s.[32-35] Their usefulness is limited by small sample sizes,[33,34] categorization by birth weight instead of gestational age,[32-35] and changes in growth patterns due to changes in nutrition management over time. More recent charts have been developed using Swedish data.[36]

Intrauterine Charts

Intrauterine growth charts were developed in the 1960s and 1970s.[37,38] Swedish growth charts by Niklasson and Albertsson-Wikland[39] are Babson-style fetal-infant charts that use an exponential *y*-axis, making plotting challenging. More recently, Olsen and colleagues[26] published intrauterine growth charts and Fenton[40] updated the Babson and Benda chart with more recent data and a different format. During 2013, the Fenton growth charts were revised to include more recent data, smooth the disjunction with the World Health Organization (WHO) growth chart, develop sex-specific charts, and rescale the *x*-axis to include actual age instead of completed weeks.[25] The cross-sectional data used to construct intrauterine growth charts do not represent intrauterine growth or the postnatal growth of preterm infants, and physiologic postnatal weight loss is not represented in the charts. Isolette or room temperature, stress, feeding intolerance, insensible water loss, sepsis, morbidities, and medical interventions that alter energy expenditure and nutrient losses influence growth. Many preterm infants will be defined as growth-restricted even when catch-up growth has occurred due to weight loss from postnatal diuresis.[29] Using intrauterine growth data does not consider that factors contributing to premature birth may influence birth weight and that neonatal intensive care unit environments are different from intrauterine environments.[28]

Intrauterine growth charts are generally considered the best choice to assess weight gain at birth and during the neonatal intensive care unit stay because they represent intrauterine growth as best estimated.[41] The 2013 Fenton preterm growth chart or Olsen intrauterine curves are the best widely available growth charts to assess weight gain at this time. It is important to choose one and be consistent. Table 2 summarizes information regarding the development of the Olsen and Fenton curves. It is important to keep in mind that growth charts show growth trends over time but not specific percentiles.

Use of Growth Charts in the Electronic Medical Record

Many electronic medical records plot growth on the Olsen or Fenton growth charts and the WHO growth charts. Because the WHO growth charts do not account for postnatal diuresis, preterm infants should be switched from a preterm growth chart to the WHO growth chart after age 42 weeks.[42] PediTools (http://www.peditools.org/) provides a calculator to determine an infant's exact weight percentile and *z* score using Olsen, Fenton, and WHO growth data. Downloadable calculators on the Fenton chart are available at http://u.calgary.ca/fenton.

Figure 1. Development and selection of growth charts for use with preterm infants.

Table 2. Comparison of extrauterine growth curves for use in neonatal intensive care unit settings[a]

Variable	Olsen and colleagues[26]	Fenton and colleagues[25]
Sample size	257,855	3,986,456
Sample location	248 US hospitals in 33 states from 1998-2006	Germany, United States, Italy, Australia, Scotland, and Canada from 1991-2007
Gestational age (wk)	23-41	22-50
Additional information	Infants defined as small for gestational age by Olsen curves have been found to be at higher risk of poor outcomes[43]	Smoothed the data between the preterm and World Health Organization estimates
Additional Information	Separate sex-specific validation samples	Smoothing assumption between the preterm and postterm references validated[25]
Sex-specific	Yes	Yes

[a]Data from these charts are used in assessing weight gain and linear growth velocity and decrease in weight and length-for-age *z* scores.

are influenced by maternal characteristics, the intrauterine environment, and duration of gestation. Second, the cause of preterm birth may influence intrauterine growth. In addition, it may not be possible to accurately determine gestational age, especially when early pregnancy dating from early prenatal care or ultrasound is not available.[20,28] Intrauterine growth curves are used to circumvent these issues.[20,28]

Growth assessment begins at birth by identifying whether an infant is small for gestational age (SGA), appropriate for gestational age (AGA), or large for gestational age (LGA) or has experienced intrauterine growth restriction (IUGR). SGA is defined as a *z* score below −1.28 (<10th percentile) for gestational age, AGA is a *z* score between −1.28 and 1.28 (10th to 90th percentile), and LGA is a *z* score >1.28 (>90th percentile). By definition, therefore, 10% of infants should be born SGA and 10% born LGA when the given NICU population sample is normally distributed. It is important to recognize that many infants born SGA or LGA grow appropriately at a rate commensurate with their predetermined genetic potential.

By contrast, IUGR is defined as a pathologic process that causes weight to be less than the genetically predicted weight. Thus, all IUGR infants are not SGA.[44] IUGR is diagnosed by intrauterine growth failure with normal head circumference (HC) and/or Doppler velocimetry abnormalities. Symmetric growth restriction (restricted weight and length measurements with restricted HC when severe enough) occurs during the first trimester and is due to exposure to a toxin or a genetic, metabolic, or infectious disorder while asymmetric growth restriction (restriction of weight only) occurs during the second or third trimester and can be due to maternal vascular disorders or repeated courses of antenatal steroids.[44,45] Maternal smoking and malnutrition may also contribute to IUGR.[42,44,46-49]

Diagnosis of IUGR or SGA is associated with higher risk for mortality or neurodevelopmental impairment and poor growth.[45,50-56] Infants with known IUGR or antenatal nutrient deficits are at higher risk for postnatal malnutrition. Infants born SGA without IUGR may also be at higher risk for malnutrition due to limited nutrient reserves. Therefore, SGA and IUGR infants should be monitored more frequently.

Postnatal Growth Assessment

Weight. Weight and change in weight are the primary indicators for evaluation of infant malnutrition due to the rapid rate of weight gain in preterm infants/newborns and the ease in completing accurate weight measurements. Three methods of utilizing weight to screen for malnutrition are discussed below. The first method—days to regain birth weight—is used over the first few weeks of life when weight loss is expected due to postnatal diuresis. The second method—growth velocity—allows for short-term assessment in growth after the infant has regained birth weight. The final method—change in weight-for-age *z* score—is indicated for longer-term assessment of growth and nutritional status (>2 weeks).

Days to Regain Birth Weight. Most infants, both term and preterm, demonstrate an initial postnatal diuresis. Postnatal diuresis results in a loss of 7% to 20% of birth weight during the first 3 to 5 days of life.[57] Therefore, weight gain or change in weight *z* scores should not be used for the first 2 to 3 weeks of life. It is generally expected that infants will regain birth weight by age 7 to 14 days, although not all infants regain birth weight by this time.[58-62]

Optimal water balance and nutrition mitigates the duration of weight loss and poor growth after birth.[57,63,64] Postnatal weight loss may be due in part to inadequate nutrition, and delayed return to birth weight may be indicative of malnutrition.

Table 1 under primary indicators requiring more than one indicator provides criteria for using return to birth weight to diagnose malnutrition. It should be used in conjunction with nutrient intake.

Growth Velocity. The general consensus is that goal growth for preterm infants is growth comparable to fetal growth. This rate of growth has been defined in some publications as 15 to 16 g/kg/day or 25 to 35 g when a weight of 2,000 g is attained.[63,65] In reality, this growth rate may underestimate current fetal growth because it does not consider the change in growth velocity as birth gestation and postnatal age increase.[20] Several publications have shown that a weight gain of 15 to 20 g/kg/day is insufficient to prevent postnatal growth retardation, whereas a growth velocity of 20 to 30

g/kg/day has been associated with improved neurodevelopmental outcomes, reduction of extrauterine growth restriction, and maintenance or improvement in a premature infant's birth *z* score.[7,17] These studies used either gestational age or birth weight as inclusion criteria but most likely include infants with very low birth weight. Determination of optimal weight gain in grams per kilogram per day is complicated by the fact that the method of calculating weight gain influences the results.[63,66,67] Although many NICUs may express weight gain goals in grams per kilogram per day, it is recommended that grams per day be used to identify malnutrition.

The amount of weight gain needed to maintain weight *z* score varies with age, weight *z* score, and sex, so weight goals should be adjusted weekly. Because the American Academy of Pediatrics recommends growth at intrauterine growth rates and the best rate of catch-up growth is unknown, catch-up growth is not prescribed. Weight gain goals can be established using an online preterm growth calculator, such as available at www.peditools.org, that provides the amount of weekly weight gain needed to maintain current growth metrics.

Clinical judgment will be important in determining weight gain goals and will require evaluation of an infant's medical condition, growth, and nutrient intake. Consideration of genetic potential is needed when determining growth goals for SGA and LGA infants. An infant who loses weight with the initiation of diuretic therapy may indeed not be malnourished.

The WHO Child Growth Standards website provides weekly weight gain goals for the 5th, 10th, 25th, and 50th percentiles for the first month of life for birth weight categories between 2,000 g and ≥4,000 g (http://www.who.int/childgrowth/standards/w_velocity/en/). Although the median can be used as a goal, a range of velocities is compatible with health.

Peak growth velocity occurs from 28 days of life to 2 months of corrected age.[68-70] Growth goals should be determined on an individual basis. Precise growth at the 50th percentile is rare because only 6% of infants will be at the 50th percentile due to the shape of the bell curve. Weight gain goals for SGA infants should take into consideration that many are genetically small. For LGA infants, whereas some will be genetically large, others—particularly from mothers with poorly controlled diabetes—will demonstrate regression toward the mean over time. Whether an infant's larger size is due to larger parent size should be taken into consideration when determining weight gain goals.

Table 1 provides criteria for using growth velocity to diagnose malnutrition. The indicator for decline in growth velocity is the same as the pediatric consensus statement for identification of pediatric malnutrition.

Change in Weight-for-Age *z* Scores. Once postnatal diuresis is complete, an infant should begin to gain weight and ideally will develop a growth track that parallels fetal growth. Greer and Olsen[20] suggest that AGA and SGA infants should maintain a rate of weight gain and linear growth consistent with the birth percentile. Whether or not preterm infants should return to their birth weight *z* score is complicated by the fact that the birth measurement includes body water that is naturally lost during the transition to extrauterine life, and the loss of this water leads to lower placement in birth percentiles.[70,71] Ziegler and Carlson[70] state that a decline from birth weight during diuresis that exceeds 0.6 standard deviations (SD) or 10 percentile points is unphysiologic. Rochow and colleagues[71] demonstrated that preterm infants transitioned to a growth trajectory parallel to the Fenton 2013 growth chart at a weight-for-age *z* score 0.8 SD below their birth *z* score.

Table 1, under primary indicators requiring one indicator, provides criteria for using change in weight-for-age *z* score to diagnose malnutrition. The indicator for decline in weight *z* score is based on the study by Rochow and colleagues.[71] This large, international longitudinal observational study reported that infants with uncomplicated postnatal adaptation transitioned to a weight gain trajectory 0.8 SD below birth at day of life 21. The cutoffs for mild, moderate, and severe malnutrition also reflect the very rapid expected rate of weight gain of preterm infants and neonates. The pediatric consensus statement includes an indicator for percent of expected weight gain for diagnosing malnutrition. It is also included as a recommended indicator for preterm infants and neonates to minimize extrauterine growth failure.

Length

Evaluating growth using weight alone does not identify weight gain that is not proportional or weight gain that is lower or exceeds linear growth.[63,72] Nutritional factors influence the degree of pre- and postdischarge linear growth faltering in preterm infants, which is negatively associated with cognitive development.[11]

The relationship between length, brain development, and neurodevelopmental outcome is well established.[10,11,13,73,74] Furthermore, the importance of length is reinforced by the fact that preterm infants at term, including late-preterm infants, have less lean body mass and similar fat mass at hospital discharge than term infants.[75-78] The association of faltering linear growth and stunting with a similar fat mass suggests that a decline or deceleration of length *z* scores obtained from accurate length measurements is a valuable indicator of malnutrition in preterm infants.

Linear growth is dependent on fat-free mass accretion and adequate protein and micronutrient intake. Therefore, assessment of linear growth may be used in conjunction with nutrient intake in the identification of malnutrition. Length measurements may be deferred between birth and day of life 14 and for infants who are intubated or require minimal stimulation.

Length assessments are only useful when the measurements are accurate. Length measurements using common techniques such as a nonstandard length board or a tape measure are often inaccurate compared with measurements using recommended measurement techniques.[79]

Table 1 under primary indicators requiring more than one indicator provides recommendations for using length as an indicator of malnutrition. The expert committee decided to use the same cutoffs for mild, moderate, and severe malnutrition as was used for weight. The expert committee agreed that use of an indicator that reflects lean body mass accretion was important and recommends its use in

combination with another indicator when accurate length measurements are available.

Body Composition

In preterm infants and neonates, differentiating between fat mass, fat-free mass, and fluid status is influenced by lack of standards and means of assessment. Available methods for determining body composition in preterm infants such as air displacement plethysmography, total body electrical impedance analysis, dual energy x-ray absorptiometry, and magnetic resonance imaging are not yet practical in clinical settings.[68]

Body Mass Index

Evidence that body mass index (BMI) accurately identifies disproportionate growth in neonates is inconclusive. In a small study of preterm and term infants, BMI was significantly correlated with percent body fat measured by air displacement plethysmography.[80] In contrast, Demerath and colleagues[81] reported that BMI is not a good proxy for relative fatness or leanness in neonates. It explained 43% of the variation in fat mass with high estimation errors in term infants and only 27% of the variation in percent body fat at birth in premature infants born at 30 to 36 weeks of gestation. Thus, more research is needed to support BMI as a marker of malnutrition in neonates.

Although BMI curves for premature infants have been developed, BMI is not recommended as an indicator of malnutrition.[82] The curves were developed to be used in conjunction with other growth measures rather than as a replacement for weight- or length-for-age curves.[82] BMI does not identify infants who are proportionately stunted.[44]

Midupper Arm Circumference

Midupper arm circumference (MUAC) provides information regarding body composition and may be useful as an indicator of nutritional status.[83] A decrease in the MUAC measurement may indicate a reduction in either or both muscle mass and fat mass. Arm circumference measurements are less affected by fluid status changes than other areas of the body and may be a more accurate measure in the presence of edema.[1] Serial MUAC measurements on preterm infants are positively correlated with weight, length, and HC and increase linearly with gestational age.[32] In a small sample of infants, Daly-Wolfe and colleagues[80] reported MUAC is a significant covariate of percent body fat in preterm infants. Research is needed to determine the utility of MUAC as an indicator of nutritional status for preterm infants.

For both term and preterm infants, serial MUAC measurements may be useful in tracking growth when obtaining accurate weight, length, and HC measurements is not feasible. However, recommendations are not provided for using MUAC due to lack of availability of references for preterm infants.

Head Circumference

Head growth velocity, as with weight and length, can decline with inadequate nutrient intake. HC measurements reflect brain size.[84] Head growth is thus an important indicator of neurodevelopment outcomes in preterm and term infants and should be measured weekly. Online growth calculators available at www.peditools.org can be used to determine weekly head growth goals for preterm infants and neonates.

HC at birth plotting 2 SD below the mean (<2.3rd percentile) has been classified as microcephaly,[85] whereas 2 SD above with mean (>97.7th percentile) is classified as macrocephaly.[86] However, the definition of microcephaly is not consistent in the literature. Some authors define microcephaly as >2 SD below the mean and others >3 SD.[87,88] Both of these conditions could indicate an underlying pathology. HC growth that varies significantly from an expected growth pattern may indicate complications of prematurity (eg, intraventricular hemorrhage with hydrocephalus) or other brain anomalies. Changes in fluid status, such as significant volume overload with body edema or dehydration, can affect the accuracy of a head measurement. In these circumstances, including the HC as part of a nutrition assessment should be deferred.

HC growth is believed to be spared during periods of undernutrition during infancy. In a sample of 416 infants born at 32 weeks of gestation or less, 57% weighed less than the 10th percentile and 49% had lengths less than the 10th percentile, whereas only 6% had a HC less than the 10th percentile.[62] Extremely-low-birth-weight infants may demonstrate slowing of HC growth from inadequate nutrient intake before 36 weeks of gestation. In a study of nutritional adequacy and HC growth, 24% of infants with cumulative energy and protein deficits at 4 weeks had HC measurements more than 2 SD below the mean, whereas none of the infants who were adequately nourished (no energy or protein deficit) had HC measurements below the mean at 36 weeks of postmenstrual age.[89]

This randomized control study compared a control parenteral nutrition regimen with an enhanced regimen providing 11% more protein and 7% more calories in 150 infants aged younger than 29 weeks and 1,200 g at birth. Infants in the enhanced parenteral nutrition group at 28 days had HC measurements that averaged 5±0.37 mm greater than the control group. The HC remained greater at 36 weeks of corrected age.

Faltering HC growth may support the diagnosis of moderate to severe malnutrition based on weight and length. A head growth velocity that falters independently of weight and length velocity should be investigated for causes other than inadequate nutrient intake as head growth during the hospital stay may be more reflective of immaturity-related morbidity and smallness at birth.[90] Thus, we do not recommend the use of HC as a primary, independent indicator of malnutrition. In addition, for preterm infants postdischarge head growth may be a better predictor of cognitive outcomes than head growth during the hospital stay.[91]

Nutrition-Focused Physical Exam

Body composition measurements, particularly longitudinal measurements of fat-free mass and fat mass can be used to study the effects of nutrition on growth and development during the critical period of early infant development. Weight gain, the most commonly used clinical tool for guiding nutrition management in premature infants, fails to differentiate between proportionate gains in fat

Observation	Possible clinical significance
Color	
Pallor (washed-out, whitish)	• Birth asphyxia • Shock (altered perfusion) • Anemia (iron and/or vitamin deficiency • Chronic disease • Patent ductus arteriosus
Plethora (deep, rosy red)	• Polycythemia • Overoxygenated • Overheated
Jaundice	• Yellowish: Indirect hyperbilirubinemia • Greenish: Direct hyperbilirubinemia
Central cyanosis (bluish skin, tongue, and lips)	• Low oxygen saturation, might be congenital heart disease or lung disease (concern for gut perfusion)
Acrocyanosis (bluish hands and feet only)	• Cold stress • Hypovolemia
Mottling (lacy red pattern)	• Normal variation • Cold stress • Hypovolemia • Sepsis
Fluid status	
Periorbital or generalized edema and bulging fontanel	• Overhydration • Protein deficiency
Dry mucous membranes, sunken fontanel, lack of tears, and poor skin turgor	• Dehydration
Integrity	
Dermatitis	• Essential fatty acid, B vitamin, or zinc deficiency
Flaky paint dermatitis	• Protein deficiency
Poor wound healing	• Essential fatty acid, vitamin A, or zinc deficiency
Texture	
Scaly, dry	• Essential fatty acid, vitamin A, or zinc deficiency
Excessive initial peeling	• Postterm: Normal variant

Figure 2. Nutrition-focused physical exam: Clinical assessment of skin.[93] Reprinted with permission from the Academy of Nutrition and Dietetics.

mass and lean mass. Fat-free mass and fat mass considered separately are true estimates of nutritional status of the individual infant when compared with a reference. Because body composition measurements are yet to become a part of bedside practice, reference data for newborns and infants are scarce.[92]

Macronutrient and micronutrient deficiency often do not present with the same symptoms in preterm infants as found in adults and older children. For example, thiamine deficiency in preterm infants does not present with altered mental status as in adults but may present as lactic acidosis.

Assessment and documentation of fluid status should be included in the identification of malnutrition in this population. Conditions such as hydrocephalus and renal or cardiac anomalies can be marked by abnormal fluid accumulation that should be noted/observed and taken into account because correction of these issues may influence weight gain velocity. Clinical judgment is essential in these cases.

A nutrition-focused physical exam by a trained neonatal registered dietitian nutritionist includes observation of the premature infant or neonate, taking into consideration the norm in body composition for gestational age. Typical fat and muscle stores, along with skin integrity, change significantly with each increasing week in gestational age. Observation of an infant includes assessment of fat and muscle stores for wasting, abdominal protuberance, and skin integrity. Input from the physician or neonatal nurse practitioner can be obtained for muscle tone in a critically ill infant. Figure 2 describes skin assessment and its clinical significance.[93]

ASSESSMENT OF NUTRIENT INTAKE

Nutrient Goals

Variations in growth rates among NICUs are due to differences in nutrition practices[58,59,94-100] as well as different approaches in calculating growth rates.[66] Monitoring growth to identify inadequate growth early is one strategy for improving growth.[44] Infants with very low birth weight who received increased amounts of protein, energy, fat, essential fatty acids, and vitamin A until discharge had greater weight gain velocity, increased HC, enhanced white matter maturation, and improved visual perception.[98-100]

Many review articles and expert opinions have identified goals for energy and protein intakes in premature infants based on weight and/or gestational age (see Table 3). An infant aged 2 weeks and weighing 700 g has different energy and protein needs than the same infant at age 3 months. These energy and protein goals will change over time as an infant advances in gestational age and weight. In addition, nutrient goals may need to be modified based on individualized

Table 3. Recommended parenteral and enteral energy and protein intakes

	Parenteral		Enteral	
Infant age (wk)	Energy goals (kcal/kg)	Protein goals (g/kg)	Energy goals (kcal/kg)	Protein goals (g/kg)
Preterm[101,102] <34 0/7	85-111	3-4	110-130	3.5-4.5
Late preterm[103] 34 0/7-36 6/7	100-110	3-3.5	120-135	3-3.2
Term[101,102] ≥37 0/7	90-108	2.5-3	105-120	2-2.5

medical and environmental factors influencing energy expenditure, nutrient use, and individual needs for growth. Tudelhope and colleagues[104] discuss special considerations for SGA infants.

Evaluating Nutrient Intake after Birth

Intake inadequacies are common in the first weeks of life in premature infants. Numerous studies have shown improved nitrogen balance and enhanced growth in weight, length, and HC when early energy and protein intakes are increased through the implementation or modification of feeding protocols.[17,27,105,106] For this reason, the assessment of adequacy of nutrient intake may assist in the determination of malnutrition for this population. When nutrient intake is examined by nutrition phase rather than chronologically by week, the highest rate of growth failure occurs during the transition period from parenteral to enteral nutrition compared with the parental nutrition–only and enteral nutrition–only phases.[107] This likely reflects a decrease in protein intake and in the protein to energy ratio.

During the early weeks of hospitalization, short-term changes in weight typically reflect postnatal fluid shifts instead of malnutrition. Evaluating adequacy of nutrient intake compared with established goals is a recommended component in identifying malnutrition in preterm infants at this time. During the early stages of postnatal life, the nutrient intakes of preterm infants are typically prescribed by a health care provider and provided either parenterally or enterally. These methods of feeding make the process of assessing the quantity and adequacy of intake relatively straightforward. Assessing intake becomes more complex as the infant transitions to oral intake (particularly breastfeeding) and as nutrient requirements are modified by changes in medical status. Therefore, during the first 2 weeks of life, neonatal nutritional status is best assessed by examining nutrition intakes relative to recommendations. Similar to criteria for diagnosis of malnutrition in adult populations, consecutive days of protein and energy intake ≤75% of estimated needs will be used to determine the degree of malnutrition.[22] As infants mature, nutritional status assessment requires an assessment of adequacy of growth. Therefore, during early life, neonatal nutritional status is best assessed by examining nutrition intakes relative to recommendations. As infants mature, nutritional status assessment requires an assessment of adequacy of growth.

Criteria for identifying malnutrition using adequacy of intakes are outlined in Table 1 under primary indicators requiring two or more indicators. Cutoffs for the nutrient intake section were determined by expert consensus taking into consideration that intervention for inadequate nutrient intake should occur early.

CONCLUSIONS

The recommended indicators for identification and documentation of malnutrition in preterm infants and neonates were developed by a committee of experienced NICU registered dietitian nutritionists using a literature review and group consensus. The methodology was similar to that of the consensus statement of the Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition on pediatric malnutrition.[1] The indicators are the same with the exception of BMI and MUAC, which were deemed to be inappropriate for preterm infants and neonates. The cutoff for the decline in weight *z* score in the pediatric consensus statement was judged to be too high for preterm infants and neonates due the extremely rapid expected rate of growth. Inadequate nutrient intake was modified from the adult consensus statement to include a time frame of 3 to 7 days of inadequate intake reflecting not only the high nutrient requirement to support a very rapid expected rate of growth, but also the increased ability to accurately access intake. Days to regain birth weight, decline in linear growth velocity, and decline in length-for-age *z* score require two indicators to make the diagnosis of malnutrition. Only one indicator needs to be met to make a diagnosis of malnutrition using weight gain velocity, decline in weight-for-age *z* score, or nutrient intake. The indicator for which accurate information is available and is most appropriate for the timing of the assessment should be selected. The indicators may change as additional research is completed and more information becomes available. Diagnosing malnutrition in this population will require clinical judgment because medical status can influence the recommended indicators of malnutrition.

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