Academy of Nutrition and Dietetics

POCKET GUIDE TO

Neonatal Nutrition

THIRD EDITION

Pediatric Nutrition Practice Group

Editors

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Preface

This pocket guide for neonatal nutrition evolved from a collaboration of leaders in the field of neonatal nutrition that spanned several decades, beginning in 1985 with the publication of *Nutritional Care for High Risk Newborns*. Sharon Groh-Wargo, Melody Thompson, and Janice Hovasi Cox, editors of *Nutritional Care for High-Risk Newborns*, second and third editions; and the *Pocket Guide to Neonatal Nutrition*, first and second editions; dedicated their careers to caring for the smallest and most fragile patients—premature infants. Their work in clinical care, research, and education has benefited patients, families, dietitians, and the varied health care professionals in the neonatal intensive care unit.

Since the publication of the second edition of the *Academy of Nutrition and Dietetics Pocket Guide to Neonatal Nutrition*, the responsibility of this storied text has been passed to a new group of editors who are honored to fill the shoes of their predecessors and mentors.

This third edition of the *Academy of Nutrition and Dietetics Pocket Guide to Neonatal Nutrition* contains updated information in the key areas of neonatal nutrition: nutrition assessment, parenteral nutrition, enteral nutrition, and discharge/follow-up. This text also provides updates to typical disease states seen in the neonatal intensive care unit (NICU), such as necrotizing enterocolitis, neonatal abstinence syndrome and neonatal opioid withdrawal syndrome, and short bowel syndrome and intestinal failure. The third edition includes several new chapters and appendixes including:

- dedicated chapters on neurologic disorders (Chapter 12) and metabolic disorders (Chapter 13),
- discussion of the late preterm infant (Chapter 17),
- essential parenteral and enteral calculations (Appendix B),
- enteral product overview (Appendix C), and
- nonstandard enteral feeding calculations (Appendix D).

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We thank the authors, reviewers, and Academy of Nutrition and Dietetics team who worked on the *Academy of Nutrition and Dietetics Pocket Guide to Neonatal Nutrition*, third edition, throughout the first year of the COVID-19 pandemic. In a time of much uncertainty, they worked diligently to update this valued resource utilizing evidence-based practice and thoughtful clinical perspective.

Terminology to Describe Human Milk Feedings

Expressed human milk (EHM) refers to human milk produced by the biological parent of the infant and is the term we will use throughout this text for consistency. Other terms commonly used to describe this type of human milk include expressed breast milk (EBM), mother's own milk (MOM), and mother's/maternal breast milk (MBM).

Breastfeeding refers to the method of feeding an infant directly at breast.

Donor human milk (DHM) refers to human milk processed by a human milk bank or company. Donor breast milk (DBM) and donor milk (DM) are other terms commonly used to describe this type of human milk.

Our choices of terminology in this text reflect typically used industry terms and allow for distinction of the types of human milk used in the neonatal intensive care unit environment.

It is important to be thoughtful about the use of gendered language in a clinical setting to reflect the diversity of individuals who lactate and include the transgender and gender-nonconforming community. For example, not all lactating individuals may identify as mothers, and there are individuals who prefer the term *chestfeeding* over *breastfeeding*. Selection of appropriate terminology in the clinical setting should be done with this in mind.

CHAPTER 1

Nutrition Assessment

Melody Thompson, MS, RDN, LD

Introduction

Nutrition assessment in infants includes the following components:

- anthropometric assessment;
- biochemical assessment;
- clinical assessment; and
- dietary intake assessment (parenteral, enteral, and oral).

In addition, infant nutrition assessment includes classification of gestational age (GA) and size for gestational age.

A nutrition screen—often completed by a neonatal intensive care unit (NICU) nurse or dietetic technician, registered—may be used to focus registered dietitian nutritionist (RDN) resources. Screening should be completed within 24 hours of admission.[1,2] See Box 1.1 (page 2) and Figure 1.1 (page 3) for examples of screening criteria and a screening tool, respectively.[3,4] An RDN then completes an assessment of infants meeting designated criteria. Neonatal nutritionists may want to lead the development or revision of unit-specific screening tools and nutrition assessment priorities, considering NICU feeding protocols (to prevent or delay nutrition risk) and RDN staffing.

BOX 1.1 Ohio Neonatal Nutritionists Screening Criteria for Identifying Hospitalized Infants at Highest Nutritional Risk

<1 Week of age

>15% weight loss from birth weight
<1 kg at birth

1 to 2 Weeks of age

<70 kcal/kg/d
Any continued weight loss

>2 Weeks of age

Intake <80% expected energy requirement

- <70 kcal/kg/d (all intravenous)
- <85 kcal/kg/d (intravenous/enteral)
- <100 kcal/kg/d (all enteral)

<15 g/kg/d weight gain (<36 weeks' gestational age) or <½ expected g/d weight gain (>36 weeks' gestational age)

Prealbumin[a] <8.0 mg/dL, or albumin <2.5 g/dL
Blood urea nitrogen <7 mg/dL
Direct bilirubin >2.0 mg/dL
Serum phosphorus <4 mg/dL
Alkaline phosphatase >600 U/L

>2 Months of age

Any of the above for >2 weeks of age plus:

- no source of dietary iron
- continued total parenteral nutrition

Any infant with newly diagnosed necrotizing enterocolitis, bronchopulmonary dysplasia, cholestasis, osteopenia, cardiac disorders, neurologic problems, gastrointestinal surgical anomalies, or metabolic aberrations

Any infant with birth weight <1.5 kg (and current weight <2 kg) and receiving full feedings but not receiving fortified human milk or preterm formula

[a] Include as criteria only if screening can be done in a time-efficient manner for entire unit; use values only as guide—compare with institutional normal ranges; although not reliable during inflammatory states, may indicate the infant with increased nutrition needs.
Adapted with permission from Thompson M. Establishing and developing the position of the neonatal nutritionist. In: Groh-Wargo S, Thompson M, Cox JH, eds. *Nutritional Care for High-Risk Newborns*. Precept Press; 2000:605. See source 3.

Affix patient label here	**Neonatal nutritional screening tool** *To be completed on admission and weekly (every Monday)*

Gestation at birth: **Birth weight:**

1. Assess growth

Current weight:		Current centile:		Birth centile:	
Current OFC:		Current centile:		Birth centile:	
Current length:		Current centile:		Birth centile:	

2. Determine risk category

		Check all that apply
High risk	*Any one of:*	
	• Preterm <28 weeks at birth	
	• Extremely low birth weight < 1,000 g	
	• Infant establishing feeds after episode of NEC or GI perforation	
	• Infant with severe congenital GI malformation eg, gastroschisis	
Moderate risk	*Any one of:*	
	• Preterm 28–31^{+6} weeks, otherwise well	
	• IUGR (weight <9th centile) and AREDFV <35 weeks	
	• Very low birth weight 1,000–1,500 g	
	• Illness or congenital anomaly which may compromise feeding	
Low risk	*Any one of:*	
	• Preterm 32–36^{+6} weeks, otherwise well	
	• IUGR (weight < 9th centile) and AREDFV >35 weeks	
	• Well Term Infant ≥37 weeks	

3. Determine the need for nutrition team review

The nutrition team should review any infant meeting the following criteria:

	Check all that apply
• High risk infants according to criteria above	
• Not regained birth weight by 2 weeks of age	
• >15% weight loss at any time	
• Weight gain <10g/kg/day from 2 weeks of age onwards	
• NEC or GI surgery at any time	

Name of person completing assessment: ____________________ Signature: ____________________

If completing admission assessment, please file in the baby's nursing folder, next to the nutrition flow charts

If completing a weekly assessment, please place this form in the nutrition screening box

FIGURE 1.1 Neonatal nutrition screening tool example

OPFC, occipitofrontal circumference; AREDFV, absent or reversed end-diastolic flow velocity; GI, gastrointestinal; IUGR, intrauterine growth restriction; NEC, necrotizing enterocolitis Reproduced with permission from Johnson MJ, Pearson F, Emm A, Moyses HE, Leaf AA. Developing a new screening tool for nutritional risk in neonatal intensive care. *Acta Paediatrica*. 2015;104(2):e90-e93. doi:10.1111/apa.12855. See source 4.

The screening tool shown in Figure 1.1 was developed and retrospectively validated (90% sensitivity, 75% specificity) in an NICU in the United Kingdom.[4] Only infants identified as high risk in section two of the tool and those in section three were seen by the NICU nutrition support team. This tool was developed for its ease of use by nursing staff. As such, it lacks information on nutrient intake, which, according to the definition of neonatal malnutrition, is the only indicator used in the first 2 weeks of life.[5] The growth assessment uses percentiles and not *z* scores. These are limitations of the use of this tool.

Newborn Classification of Gestational Age and Birth Weight

Newborn infant maturity and intrauterine growth are classified by GA, birth weight (BW), and weight for gestational age using terminology in Box 1.2.

GA can be estimated by maternal dates and by early (first or early second trimester) ultrasound examination (if available). The GA is also determined in the NICU by examining the infant's physical and neurological development via a reliable standardized instrument called the New Ballard score (available online at www.ballardscore.com).[6] The GA classifies the infant as preterm, term, or postterm.

These classifications of GA, BW, and size for age can help guide or anticipate clinical care needs. For example, babies who are postterm, small for gestational age (SGA), or large for gestational age (LGA) are more likely to have hypoglycemia, polycythemia, birth asphyxia, and specific syndromes or anomalies than are term babies who are appropriate for gestational age. Prematurity is also associated with a host of potential morbidities, many of which are discussed in this pocket guide.

The extrauterine growth restriction (EUGR) designation requires careful evaluation of the individual infant's intake and overall growth trajectory. Extrauterine growth restriction has recently been described as a misnomer for preterm infants because it does not consider initial fluid weight loss and is based on weight only, using an arbitrary percentile cutoff that would include those who are genetically destined to be small. Of additional concern is that assigning this designation can risk

BOX 1.2 Gestational Age and Birth Weight Classifications

Gestational age (GA)

Preterm/premature <37 weeks' GA

Late preterm ≥34 to <37 weeks' GA

Term 37 to 42 weeks' GA

Postterm >42 weeks' GA

Birth weight (BW)

Normal BW 2,500 to 4,500 g (5 lb, 8 oz to 8 lb, 8 oz)

Low birth weight (LBW) <2,500 g (5 lb, 8 oz)

Very low birth weight (VLBW) <1,500 g (3 lb, 5 oz)

Extremely low birth weight (ELBW) <1,000 g (2 lb, 3 oz)

Size for age

Small for gestational age (SGA) <10th percentile BW for GA

Appropriate for gestational age (AGA) 10th to 90th percentile BW for GA

Large for gestational age (LGA) >90th percentile BW for GA

Intrauterine growth restriction (IUGR) or fetal growth restriction (FGR) <10th percentile estimated fetal weight

Extrauterine growth restriction (EUGR) <10th percentile weight for corrected GA at hospital discharge

the infant being fed more than is needed nutritionally.[7] Careful consideration of genetic potential (eg, parental size) and watchful intervention to provide optimal nourishment and avoid overfeeding may be warranted for infants assigned the EUGR designation.

Anthropometric Assessment

Postnatal growth—with consistent and comprehensive monitoring—is an important health care outcome measure for high-risk infants. Anthropometric measurements are rapid, inexpensive, and noninvasive to obtain.

Measurement of body weight, length, and head circumference (HC) is the predominant method used to monitor infant growth, detect growth abnormalities, and assess nutritional status in infants. Measurements are plotted on growth curves for comparison with established reference data. Serial measures of growth are compulsory for assessing response to nutrition support in hospitalized infants. Satisfactory postnatal growth is associated with shortened lengths of hospitalization and improved cognitive development.[8,9]

Weight

The nude infant is weighed, in grams, on a regularly calibrated, digital scale.

Uses and Interpretation

Body weight comprises the total mass of the infant's lean tissue, fat, and extracellular and intracellular fluid compartments. As GA increases, extracellular fluid volume decreases and lean tissue and fat mass increase. Initial postnatal weight loss is attributed to contraction of body water compartments and catabolism of endogenous stores before energy and nutrient needs are met.[10] Consider the following when assessing postnatal weight changes:

- Expected initial postnatal weight loss ranges between 5% and 14%, with greater loss found in the smallest, most immature infants, and those with restricted fluid intake.[11,12]
- Initial weight loss reaches its nadir by 5 days of life.[12]
- Birth weight is optimally regained by 2 weeks but may take longer to reach in infants with extreme prematurity or severe illness.[12,13]

Two commonly used methods of comparing a preterm infant's growth with growth standards are the *z* score method and the growth velocity (GV) model.[14] The first method involves using the BW *z* score as the goal; nutrition prescriptions can be adjusted in continued pursuit of this goal. An online calculator, PediTools (https://peditools.org), can predict desired weights to maintain this *z* score as the infant grows.[15] This approach, however, does not take the initial fluid weight loss into account, so the infant may be fed to grow in a nonphysiologic way.[16]

The GV model uses a GV goal of 15 to 20 g/kg/d for infants from 23 to 36 weeks' GA.[17] Actual GV can be calculated using the following equation:

$$\text{GV (g/kg/d)} = \frac{[1{,}000 \times (W_n - W_1)]}{\{(D_n - D_1) \times [\frac{(W_n + W_1)}{2}]\}}$$

where W is weight in grams, D is day, 1 refers to the beginning of the time interval chosen, and n is the end of that time interval in days. For example, here is how to calculate GV for an infant who weighs 1,100 g on day 12 and 1,400 g on day 26:

$$\text{GV} = \frac{[1{,}000 \times (1{,}440 - 1{,}100)]}{\{(26 - 12) \times [\frac{(1{,}440 + 1{,}100)}{2}]\}}$$

$$\text{GV} = \frac{1{,}000 \times 340}{14 \times 1270}$$

$$\text{GV} = \frac{340{,}000}{17{,}780}$$

$$\text{GV} = 19.1 \text{ g/kg/d}$$

This equation, which uses average weight in the denominator, is more accurate than methods using BW or other weights in the denominator.

In addition to these methods, a novel approach to assess growth is called the individualized growth trajectory, which is supported by investigators who are concerned that cross-sectional charts reflecting intrauterine growth do not allow for the initial weight loss seen after birth.[16,18,19] Expecting an infant to continue along the same birth *z* score is likely not physiologic and promotes unhealthy growth. The individualized growth trajectory approach combines physiologic changes and growth goals for different stages, which include intrauterine growth until birth, physiologic postnatal fluid weight loss and weight nadir (at approximately 1 week of age), stable growth along a new trajectory (typically 0.8 *z* scores below the birth *z* score) parallel to the former predicted trajectory using BW, and transition to term-equivalent growth. Whether following the individualized growth trajectory will minimize future cardiometabolic risk associated with abnormal body composition (increased fat or decreased lean body mass) frequently seen in former preterm infants at term-corrected age is unknown. A free online calculator for individualized postnatal growth trajectories for preterm infants is available at growthcalculator.org.[20]

Weight gain cannot accurately reflect lean body mass changes, especially when edema or dehydration is present. This is a limitation to using weight gain as an independent indicator of postnatal growth. Additional factors contributing to insufficient or excessive weight gain are listed in Box 1.3.

Length

Obtaining an accurate linear measurement using an infant length board requires two people. One person holds the infant's head against the fixed headboard; the other measurer gently flattens the infant's knees and guides the footboard toward the infant's flat feet. Although not recommended, in some clinical settings, infant length is estimated using a tape measure, sacrificing accuracy for expediency.

Uses and Interpretation

Weekly length measurements have the following advantages over the measurement of weight in that length more accurately reflects lean tissue mass, length is not influenced by fluid status, and length is a better indicator of long-term growth. Factors that may contribute to poor length gain include nutrient insufficiencies (eg, protein, minerals, energy), severity of illness, feedings withheld, systemic steroids, genetic conditions, and congenital anomalies.[9,21]

Expected incremental gain in crown-heel length in low-birth-weight (LBW) infants is approximately 1 cm/wk.[18,19]

Limitations

Length is often more difficult to accurately determine—requiring a length board and two measurers—than either weight or HC.[22]

BOX 1.3 Insufficient or Excessive Weight Gain

Factors that may contribute to poor weight gain (<15 g/kg/d)

Insufficient fluid, energy, or nutrient intake

Improper preparation of feeding

Feeding intolerance (eg, feedings held, abnormal stools, regurgitation)

Acidosis

Hypoxia

Hyponatremia

Anemia

Chronic diuretic administration

Temperature instability or cold stress

Increased metabolic rate; increased work of breathing

Sepsis or infection

Factors that may contribute to excessive weight gain (>35 g/d)

Excessive fluid, energy, or nutrient intake

Improper preparation of feeding

Chronic systemic steroid administration (in addition to excessive weight gain, this treatment may contribute to the loss of lean mass and decrease in linear growth)

Head Circumference

The largest occipital frontal circumference, HC is measured with a flexible, nonstretchable tape measure.

Uses and Interpretation

When monitoring HC, the following should be noted:

- During the first postnatal week, HC may decrease by approximately 0.5 cm due to extracellular fluid space contraction.
- Head circumference is monitored weekly; mean gain in LBW infants is 1 cm/wk, with velocity decreasing as the infant

approaches term.[18,19] PediTools may be used as a resource to help determine individual goals.[15]

- More frequent assessment may be indicated for infants with microcephaly or macrocephaly or with suspected abnormal increases in HC (>1.25 cm/wk).

Limitations

Cerebral edema, hydrocephalus, compression due to the administration device for nasal continuous positive airway pressure, scalp intravenous (IV) access, presence or absence of hair, or the addition or removal of external apparatus may interfere with accuracy of HC measurements.

Body Proportionality

Body proportionality measures in neonates include weight-for-length, body mass index (BMI; calculated as weight divided by length squared), and the ponderal index (weight divided by length cubed). The accuracy of the infant's length measurement is of utmost importance in these equations—particularly in the BMI and ponderal index when the length measurement is squared or cubed—because any potential measurement error is magnified.

Weight-for-length curves are available on World Health Organization (WHO) growth charts for term infants; these charts have weight and length curves on one side and HC and weight-for-length curves on the opposite side. For preterm infants, BMI has been reported to be more appropriate to assess body proportionality than using either weight for length or the ponderal index.[23] Sex-specific BMI charts for preterm infants have been developed and validated.[24] An infant's BMI can be calculated using PediTools or manually—using the equation (g/cm^2) × 10—and plotted on the appropriate BMI curve. Longitudinal BMI charts are also available for use with infants remaining in the NICU.[25]

Uses and Interpretation

Although determining BMI can be useful when assessing symmetry of growth, interpretation is difficult in preterm infants who have low lean mass and delayed length growth.[7] Body proportionality interpretation should be approached with caution and only when the length measurement is known to be accurate.

Regional Anthropometry

At term-corrected age, preterm infants have a higher proportion of body fat and lower proportion of lean mass than do their term-born counterparts. Body composition can be measured by air displacement plethysmography, bioelectrical impedance, isotope dilution techniques, magnetic resonance imaging, and a combination of manual measurements of skinfolds and circumferences called regional anthropometry. These methods can be used to estimate fat mass, fat-free mass, and distribution of body fat.[26,27] Although regional anthropometry is gaining traction, it is not routinely assessed in many NICUs. It is used primarily in research settings.

Uses and Interpretation

Skinfolds (to assess subcutaneous fat) and limb circumferences, or the ratios and formulas derived from these measurements, have potential as predictors of body composition, growth, and metabolic complications for infants who are overgrown or undergrown. These measurements may be most useful in patients with conditions such as ascites or large hydrocephalus, or who are conjoined twins; and in patients with plaster casts and other conditions in which body weight alone may be misleading.

Well-established standard values that are validated against a reference body composition method are not available. However, the infant's own measurements can be compared over time during hospitalization.

Limitations

Examiner measurement-technique variability, as well as critical illness, hydration status, and positioning of infants, can make these measurements invalid or unreliable. The use of calipers to measure skinfolds may not be feasible in extremely immature infants who have delicate, easily punctured skin.

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