Fifteen-minute consultation: ABCDE approach to nutritional assessment in preterm infants

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ABSTRACT

The last 20 years has seen dramatic improvements in the survival of preterm infants due to improved antenatal and neonatal care. Closer attention to nutrition means early parenteral nutrition and mother's own milk are considered as standard of care. Many uncertainties remain however, such as optimal macronutrient intakes for longer term cognitive and metabolic outcomes, and the optimal probiotic regime to reduce the risk of necrotising enterocolitis. Nutrition involves macronutrients and micronutrients, immunonutrients, microbiomic aspects and nutrient delivery. It is also clear that there are behavioural and psychological aspects, and strongly held beliefs for parents and professionals that affect practice. While many healthcare professionals (HCPs) are aware of several key nutritional concepts on the neonatal intensive care unit (NICU), many HCPs lack a concise, systematic approach. This article provides a brief approach to nutritional assessment for use on the NICU summarised as ABCDE: A—anthropometry, B—biochemistry, C—clinical, D—dietary intakes, E—environment and evaluation.

INTRODUCTION

A number of principles and concepts guide nutrition in preterm infants. The most obvious is that they have limited nutrient stores and high demands (see table 1). At 24 weeks of gestation, 85%–90% of an infant's weight is water, meaning a 500 g preterm infant only has around 50–60 g 'dry tissue'.[1] Preterm infants have no fat stores and very little stored energy as glycogen in muscles and liver. Minerals only account for around 1% of body weight. The main component of body weight is protein, but in the absence of sufficient dietary energy this will be catabolised to provide energy.[2] Organs suffering catabolic loss of protein may not function optimally: liver protein synthesis may be impaired; diaphragmatic muscle may be weakened. Survival without exogenous dietary energy could be estimated by assuming no more than 20% of body protein could be catabolised before irreversible metabolic decompensation. A 500 g infant with total 50 g dry lean mass could convert no more than 10 g protein (20%) into just 50 kcal of energy. Resting energy expenditure in a preterm infant is around 50 kcal/kg/day, meaning death from malnutrition would occur within 2–3 days without dietary supply.

At 24 weeks of gestation, fetal protein accretion is approximately 2 g/kg/day, but to enable similar accretion ex utero requires around 3.5 g/kg/day dietary protein due to inevitable nitrogen losses in urine, stool and secretions, as well as metabolic 'inefficiency'.[2] A similar protein intake in an adult would require the consumption of 20 beef burgers per day. Energy requirements in preterm infants are around 110–135 kcal/kg/day. To place this in context, a Tour de France cyclist consumes around 7000 kcal/day or around 100 kcal/kg/day (see figure 1). Newborn preterm infants therefore expend 20% more energy than the most energy-intense sporting activity known to man! Unfortunately, many healthcare professionals are unaware of these dramatic aspects, how to determine nutrient requirements or calculate macronutrient supply. Patient monitors on the neonatal intensive care unit (NICU) provide second-by-second feedback on cardiorespiratory status, but no such colourful monitoring devices or alarms exist for nutritional status.

Nutrition is a 'complex intervention' with multiple interacting elements, often with a long lag time between exposure and functional effects,[3] but can be grouped

Table 1 Key concepts in neonatal nutrition

Key nutritional concept	Explanation or example
1. Body composition and limited stores.	Most preterm infants have no energy (fat) stores and limited stores of every nutrient.
2. High demand and high losses.	Energy expenditure is higher than at any other life stage. There are high losses of nitrogen in urine, or fat in stool due to malabsorption or short gut, etc.
3. Not too little, not too much.	Although demand is high, nutrient provision in excess of metabolic capacity may cause harm. During critical illness dietary supply needs reducing.
4. Life course perspective.	Nutritional status depends on maternal pre-pregnancy, placental, fetal and neonatal factors; nutritional status as an infant determines adult metabolic and cognitive outcomes.
5. One brain for life.	Focus of neonatal care must be on protecting the brain and avoiding harm due to malnutrition.
6. Nutrients do not function in isolation.	Nutrient intakes must be balanced and provide every macronutrient and micronutrient; high protein without sufficient energy is wasted.
7. We live in a microbial world.	Gut microbes produce nutrients such as vitamins and fatty acids, as well as affecting risk of NEC and sepsis.
8. NEC is deadly.	More preterm infants die from NEC than childhood leukaemia; long-term cognitive outcomes following NEC are worse than for meningitis.
9. Mother's own milk (MOM) is always best.	There is a dose–response relationship between MOM exposure and *every* key neonatal morbidity.
10. Team makes the dreamwork.	Multidisciplinary teams and a holistic approach involving parents are key to improving nutritional status.

NEC, necrotising enterocolitis.

into four key areas: nutrients, functional components, microbiomic aspects and sociobehavioural and technical aspects (see figure 2).

THE NUTRITIONAL ASSESSMENT

When conducting nutritional assessment think of the interacting elements shown in table 2, appreciate that nutrients do not function in isolation and that there may be 'trade-offs': breast milk is often associated with slower weight gain than formula, but improved developmental and cognitive outcomes, the so-called 'breastfeeding paradox'.[4] Studies of individual nutrient supplements such as docosahexaenoic acid[5] or iodine[6] may give the impression that there are some nutrients that are more important than others. However, normal growth and development requires every single macronutrient and micronutrient to be provided in a balanced diet: very few studies have ever shown neurodevelopmental benefits from the supplement of a single nutrient. Despite concerns regarding later metabolic risks of rapid growth in early life,[7] the most important adverse outcome following preterm birth is neurocognitive impairment, so remember that preterm infants have 'one brain for life'. There are multiple potential mechanisms that link nutrition to brain outcomes some of which are summarised in table 3. Given the importance of good nutritional status it is helpful to have a simple practical approach that can be used in a busy NICU. The ABCDE approach has been widely used[8] (see table 4) and is summarised in more detail below.

A—Anthropometry

Anthropometry requires minimal training and accurate equipment. Weight must be regularly monitored, every 1–3 days depending on clinical circumstances.

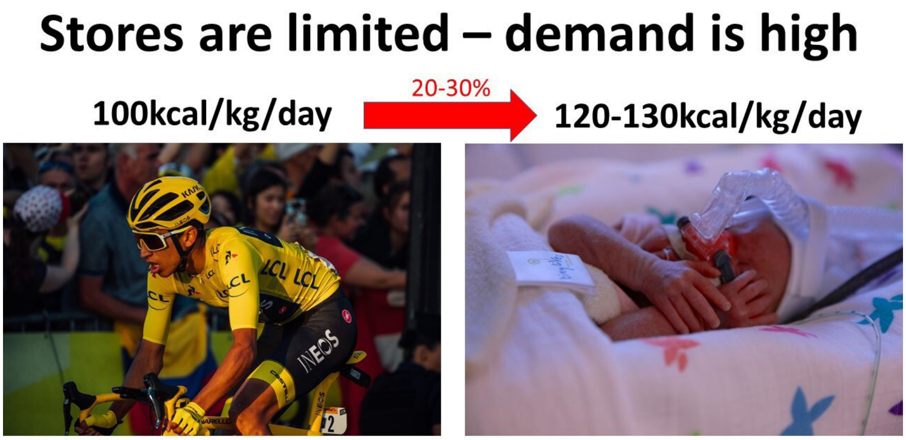
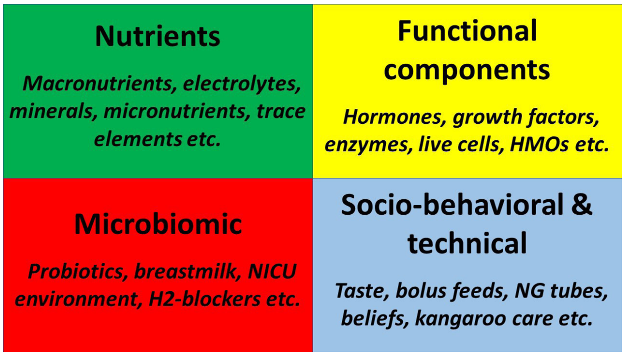


Figure 1 Energy expenditure in preterm infants. Credits: left panel, Ineos Grenadiers/Russ Ellis; right panel: Tiny Lives Charity with parental permission.



Nutrients

Macronutrients, electrolytes, minerals, micronutrients, trace elements etc.

Functional components

Hormones, growth factors, enzymes, live cells, HMOs etc.

Microbiomic

Probiotics, breastmilk, NICU environment, H2-blockers etc.

Socio-behavioral & technical

Taste, bolus feeds, NG tubes, beliefs, kangaroo care etc.

Figure 2 Nutritional components. HMO, human milk oligosaccharide; NG, nasogastric; NICU, neonatal intensive care unit.

Head circumference and length can be measured weekly. Plot all measures on a valid growth chart either by hand or ideally by using electronic medical record software. There is no need to calculate body mass or ponderal index, or measure body composition, but regular inspection of centile tracking to ensure weight/length are proportional is informative. Most infants lose some weight in the first few days due to the inevitable contraction of extracellular fluid, but most infants should then maintain that weight centile during NICU stay (that is slightly lower than their birth centile). Weight, head or length gain in g/kg/day or cm/week can be calculated (see table 5 for suggested guides) but these rates change during the third trimester so tracking an infant's centile on a growth chart is always preferable. Change in centile position or SD score from birth to discharge[9] may be useful for NICU audit and interhospital comparisons.[10]

B—Biochemistry and bloods

There are no useful biochemical tests of global nutritional status, and serum total protein and albumin are unhelpful nutritional indicators because of long plasma half lives. Furthermore, homeostatic mechanisms will ensure that plasma concentrations of many nutrients such as calcium will be maintained despite whole body depletion. Monitor glucose and electrolytes at least daily in the first few days, thereafter, measure one to two times weekly depending on clinical status.[11] Measure serum phosphate during parenteral nutrition (PN) in the first few days as low levels (<1.8 mmol/L) are commonly seen with higher amino acid intakes especially if growth restricted[12]: adding extra phosphate is simple and effective, but also ensure adequate calcium intake. Watch haemoglobin concentrations as infants with significant anaemia may not grow optimally. Serum ferritin is a useful indicator of iron status: iron supplements are not needed if ferritin is >300 ng/mL.[13] Only infants on prolonged PN (over 3–4 weeks) or with liver impairment require measurement of trace elements or vitamins.[14] Infants on steroids or diuretics need careful attention to bone mineral status. Low serum phosphate after the first 1–2 weeks may indicate inadequate phosphorus intakes (commonly seen with unfortified breast milk) and is more useful than alkaline phosphatase which may be normal despite profound mineral loss, or be appropriately raised where there is active bone growth.[15] A degree of mineral bone deficiency is inevitable in most preterm infants and many will also need extra calcium (provided as supplements or in breast milk fortifiers).[16] There is no benefit in routinely measuring vitamin D: all preterm infants require supplementation.

C—Clinical examination and status

There are few visible signs of malnutrition in preterm infants which is why it is so easy to allow them to become malnourished. However, the occasional baby may have poor wound healing due to zinc deficiency.[17] Consider how individual infant's needs may differ: severe lung disease may need additional energy, additional losses due to intestinal stoma may require more sodium and minerals and higher needs due to malabsorption may occur with short bowel syndrome. Infants should be

Table 2 Nutrition grouped into four interacting areas on the NICU

Nutrition group	Explanation
Nutrients	This includes all macronutrients (protein, lipids, carbohydrates and water), electrolytes, minerals, micronutrients and trace elements.
Functional components	Immunonutrients or other components especially those present in human milk such as human milk oligosaccharides (HMOs), milk fat globule membrane, lactoferrin and live cells, etc. None of these are in PN and few are present in formula milk.
Microbiome	The gut microbiome may be impacted by use of probiotics, H2 blockers, milk type and NICU practices such as skin to skin. Gut microbes both metabolise dietary nutrients and produce nutrients and metabolites such as vitamins, short-chain fatty acids and signalling molecules, and therefore affect risk of disease, for example, NEC, and growth.
Sociobehavioural and technical	This is a broad group that includes beliefs and attitudes of staff on the NICU, support for breast milk expression, gastric tube placement, bolus versus continuous feeds, when to initiate direct feeding from the breast, maternal beliefs and mental health, all of which may affect breastfeeding duration.

NEC, necrotising enterocolitis; NICU, neonatal intensive care unit; PN, parenteral nutrition.

Table 3 Potential mechanisms linking nutrition to brain outcomes in preterm infants

Potential mechanism	Example or explanation
Nutrients for tissue substrate	Every macronutrient and micronutrient is needed to accrete lean tissue and especially to build 'one brain for life'.
Energy to drive the system	Energy is needed for tissue synthesis (growth and repair) and mainly comes from dietary fat and carbohydrate. However, dietary and body protein will be catabolised when energy demands are not met by the diet.
Signalling and growth factors	Dietary intakes of protein and energy affect levels of endogenously produced IGF-1, which in turn modulates brain growth and differentiation. IGF-1 and other hormones and growth factors which impact on brain growth are also key components of breast, but not formula, milk.
Gene expression	Vitamin D, iron, DHA, choline, folate and many other dietary components have epigenetic effects (eg, DNA methylation) with potential long-lasting impacts on cognitive and metabolic outcomes.
Microbial gut-brain axes	Gut microbial populations are directly affected by quality and quantity of enteral intakes. These microbes produce metabolites which impact on neural (central and enteric nervous systems), gastrointestinal (eg, gastric emptying) and inflammatory activity.
Disease reduction	Breast milk reduces the risk of NEC and sepsis, both of which damage white matter due to cytokine release and result in worse long-term brain outcomes. This may be due to interactions between multiple rather than single components in human milk.

DHA, docosahexaenoic acid; IGF, insulin-like growth factor; NEC, necrotising enterocolitis.

examined to determine the degree of oedema and whether this may contribute to 'inappropriate' weight gain. Infants who are acutely sick due to necrotising enterocolitis (NEC) or sepsis may not have the metabolic capacity to process high amino acid intakes and may also develop hyperglycaemia or hyperlipidaemia.[18] Although no good trials exist, reducing nutrient intakes to 50%–70% for 1–3 days while carefully monitoring serum glucose, sodium and inflammatory response may be prudent.

D—Dietary intake

Develop a simple table for your NICU with the energy and protein contents of all commonly used PN solutions, milks and fortifiers. Calculate the actual (not prescribed) protein intake over the preceding 24 hours by summating the protein received in PN, milk and fortifiers. Aim for protein 3–3.5 g/kg/day if PN, and around 3.5–4.5 g/kg/day if enterally fed. Calculate the actual total energy intake by summating all the energy in carbohydrates (4 kcal/g), lipids (9 kcal/g) and protein (4 kcal/g) aiming to provide 110–135 kcal/kg/day.[19] Target the lower range for more mature babies, and the upper range in the most immature, enterally fed infants. Some infants may need higher intakes. If standardised solutions are used there is no need to calculate micronutrient intakes unless the infant is especially complex.

Table 4 ABCDE approach to assessing nutritional status

Assessment	Typical key elements
Anthropometry	Weight, length and head circumference measured regularly and plotted correctly on an appropriate growth chart.
Biochemistry	Concentrations of glucose, electrolytes, Hb, minerals.
Clinical	Examination (rashes, wasting, etc), oedema, note-specific conditions (stoma) or diseases (cardiac, renal, lung, etc).
Dietary intake	Calculate preceding 24-hour dietary intakes of protein and energy from parenteral and enteral sources including supplements.
Environment and evaluation	NICU processes and environment (noise, light, seating, etc), parent involvement, maternal support, multidisciplinary team planning.

Hb, haemoglobin; NICU, neonatal intensive care unit.

E—Environment and evaluation

Consider the wider environment: Is the NICU quiet enough to facilitate kangaroo care? Is the mother receiving support for breast milk expression?[20] Do dietary intakes meet the needs? What does the growth chart look like? Discuss your evaluation with the clinical team including nurses, pharmacists, dietitians, doctors and other members of the multidisciplinary team. Explain the rationale for the use of any supplements and fortifiers and provide an interpretation of the growth trajectory for parents.

NUTRITIONAL ASSESSMENT IN THE FUTURE

The ABCDE approach can be completed at the bedside and used for every infant on the NICU. Currently, this could be facilitated as a short document (see online supplemental material 1) but could be incorporated into electronic medical records. Despite the importance of good nutritional status for all infants, technical advances in NICU care rarely address nutrition. Newer software could record dietary intakes by simply scanning the bar code for the fluid (PN or milk) and calculate nutrient intakes by multiplying by the volume delivered on a syringe pump. Intakes could be presented graphically. In the next 10 years, we may see

Table 5 Typical growth parameters in healthy preterm infants

Growth parameter	24–30 weeks	32–36 weeks	Comments
Weight gain (fractional)	18–21 g/kg/day	~15 g/kg/day	Fractional rate slows during third trimester equivalent.
Weight gain (absolute)	10–30 g/day	30 g/day	Absolute rate increases and large variability depends on infant size.
Head gain	0.8–1 cm/week	<0.8 cm/week	Change in head shape (flattening) ex utero artificially 'increases' apparent growth.
Length gain	1.2–1.4 cm/week	1 cm/week	Measurement error large unless accurate technique and equipment.

the integration of metabolomic techniques using stool and urine to predict disease such as NEC,[21] as well as bedside assessment of energy expenditure and body composition. Until then, pen, paper and a calculator are all that are needed.

Test your knowledge

1. The primary aim of nutritional management is to
    A. Normalise serum measures or concentrations
    B. Improve nutritional status
    C. Maximise weight gain
    D. Ensure infants stay on their birthweight centile
2. During acute illness (eg, sepsis or necrotising enterocolitis) nutritional management should
    A. Increase macronutrient intakes to avoid protein catabolism
    B. Maintain nutrient intakes but with less fluid intakes
    C. Reduce amino acid, but maintain lipid and carbohydrate intakes
    D. Consider reducing macronutrient intakes temporarily
3. Which of the following are correct?
    A. Protein yields around 9 kcal/g energy
    B. Lipids yield around 9 kcal/g energy
    C. Carbohydrates yield around 4 kcal/g energy
    D. Protein requirements in preterm infants are around 3.5–4 g/kg/day
    E. Energy requirements in preterm infants are around 90–110 kcal/kg/day
4. Which of the following are correct?
    A. Serum protein or albumin is a useful indicator of protein intakes
    B. Serum calcium is a useful marker of calcium intake
    C. Serum phosphate is a useful marker of phosphorus intake
    D. Serum ferritin is a useful marker of iron requirements
5. Human breast milk contains
    A. Insulin-like growth factor 1
    B. Lactoferrin
    C. Human milk oligosaccharides
    D. Docosahexaenoic acid
    E. Insulin

Answers to the quiz are at the end of the references.

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Answers to the multiple choice questions

1. (a) False; (b) True; (c) False; (d) False.
2. (a) False; (b) False; (c) False; (d) True.
3. (a) False; (b) True; (c) True; (d) True; (e) False.
4. (a) False; (b) False; (c) True; (d) True.
5. (a) True; (b) True; (c) True; (d) True; (e) True.

Nutrition & Growth assessment

Affix patient label

Completed by: Mia Dawson Role: B6 nurse Date: 26/05/2021

	Birth	***Centile**	**Most recent**	**Centile**	**Weight gain**
Date	16/04/2021		26/04/2021		*Average over last week*
Weight	1020 grams		1020 grams		g/kg/day
Head	35.4 cm		35.7 cm		cm/week
Length	forgot! cm		cm		cm/week

**Record to nearest centile e.g. <10th, >2nd etc.*

BIOCHEMISTRY	**mmol/L**	**Date**	**Comment**
Sodium	136mmol	26/04	Did have extra in PN
Phosphate			
***** Hb	106		Transfused yesterday
*****			

*Consider: *Hb, urea, albumin, calcium, CRP, alk phos, specific micronutrient levels*

DIET: actual intakes in last complete 24hr period Working weight: ________ kg

PARENTERAL	***Volume (mL)**	**ml/kg A**	**Calories/mL B**	**Kcal/kg/day A x B**	**Protein/mL C**	**g/kg/day A x C**
11% Standard			0.53		0.022	
Other						
Lipid/SMOF			1.8		0	

MILK[$]	***Volume (mL)**	**ml/kg A**	**Calorie/mL B**	**Kcal/kg/day A x B**	**Protein/mL C**	**g/kg/day A x C**
EBM	148	140	0.65	91kcal	0.012	1.68g
Fortified EBM			0.80		0.022	
GP1			0.80		0.030	
NP1			0.80		0.025	
Term / PJ			0.67		0.018	
Other						
Total intakes PN + Milk				91kcal		1.68g

[$] If no enteral intake for >2 weeks d/w dietician & consider measuring micronutrient concentrations

Author: www.neonatalresearch.net

Valid until January 2023

Nutrition & Growth assessment

Affix patient label

Completed by: Mia Dawson Role: B6 nurse Date: 26/05/2021

CLINICAL

Condition		Comment
Acute sepsis/NEC	Decrease AA	did have Staph epi infection ; now better
Stoma / increased losses		normal
Established CLD/BPD		no
Rashes / poor wound healing		
Other		

Current Rx (circle): [✓ Probiotic] Sodium [✓ Dalavit] [✓ Phosphate] Calcium Iron Fortifier Other*

**e.g. additional vitamins e.g. ADEK, H2-blocker/PPI, Urso, Loperamide, Colestyramine*

EVALUATION & ENVIRONMENT

A – Growth Acceptable / [✓ Sub-optimal] **Growth chart** (Badger) updated [✓ Yes]/No

Comment/action: lost weight

B - Bloods Acceptable / Sub-optimal **Tests ordered:** [✓ U&E] [✓ Bone] LFT Micronutrients

C – Clinical *Additional comments:* looks well

D – Diet Acceptable / Sub-optimal **Rx to start:** Probiotic [✓ Na$^+$] PO^{4-} Dalavit [✓ BMF] Iron

Routine supplements	When to start
Probiotic (Labinic)	>20-30mls/kg/d of milk tolerated
Dalavit	>100mls/kg/d of milk tolerated (no need to wait until ‘full feeds’)
*Breastmilk fortifier	Full feeds of breastmilk for >2 days
*Iron	Full feeds of breastmilk AND >3 weeks age AND no transfusion in last 7 days

* *needed when breastmilk is >50% of intake by volume*

E – Environment

Action / process	Comment
Mother actively supported with BM expression?	BF team visited last week – ask to return
If continuous feeds, can bolus be started?	yes?
Is the baby demonstrating ‘feeding cues’?	no
Would specialist dietic referral help?	no

Weight ↓		Intakes	Parenteral	Enteral or mix
<30w: 17-21/kg/day		**Energy**	90-110kcal/kg/day	110-135kcal/kg/day
>32w: 15/kg/day		**Protein**	3.5g/kg/day	3.5-4.5g/kg/day

Growth is best assessed when plotted on growth chart and time periods of at least 1 week

NUTH PN ↓	Calorie/mL	Protein/mL	Milk ↓	Calorie/mL	Protein/mL
5% TPN	0.27	0.018	**NP2**	0.75	0.02
7.5% TPN	0.37	0.018	**SMA GP 2**	0.73	0.019
12.5% TPN-Fort	0.59-0.61	0.022-0.029	**Neocate LCP**	0.67	0.018

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