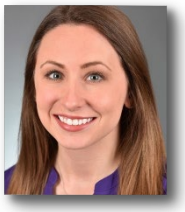
Optimizing Enteral Nutrition in the Critically Ill Term Infant with Congenital Heart Disease

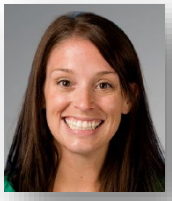
Presenters:

Emily Finnan, MS, RDN, LDN, CNSC Clinical Nutrition Specialist II, Boston, MA

Kimberly I. Mills, MD, MPH, Assistant in Cardiology, Department of Cardiology, Assistant Professor of Pediatrics, Harvard Medical School

Live event date: March 26 & 27, 2024 - *Recording on NutriciaLearningCenter.com*





Learning Objectives:

- Discuss the unpredictable nutrient needs and etiology of growth failure in term infants with congenital heart disease (CHD)
- Review the initiation and advancement of enteral nutrition support in patients with CHD
- Summarize evidence-based recommendations on determining energy and protein requirements for critically ill term infants with CHD
- Review a case study of a critically ill term infant with CHD on an Energy and Nutrient Dense Formula (ENDF)

Notes:

Nutricia North America supports the use of human milk wherever possible.

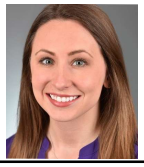
NUTRICIA
LIFE-TRANSFORMING NUTRITION

Thank you for joining!
The webinar will begin shortly

Optimizing Enteral Nutrition in the Critically Ill Term Infant with Congenital Heart Disease

DOWNLOAD HANDOUT:

Kimberly I. Mills, MD, MPH
Assistant in Cardiology,
Department of Cardiology
Assistant Professor of Pediatrics,
Harvard Medical School



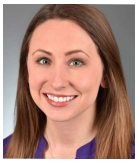
Emily Finnan,
MS, RDN, LDN, CNSC
Clinical Nutrition Specialist II
Boston, MA

1

NUTRICIA
LIFE-TRANSFORMING NUTRITION

Optimizing Enteral Nutrition in the Critically Ill Term Infant with Congenital Heart Disease

Kimberly I. Mills, MD, MPH
Assistant in Cardiology,
Department of Cardiology
Assistant Professor of Pediatrics,
Harvard Medical School



Emily Finnan,
MS, RDN, LDN, CNSC
Clinical Nutrition Specialist II
Boston, MA

Moderator
Carolyn Ricciardi,
MS, RD
Medical Science Liaison
MidAtlantic and Northeast

2

NLC
NUTRICIA LEARNING CENTER

Nutricia North America supports the use of breast milk wherever possible

3

Disclosures

- Dr. Mills
  Current Consultant for Astarte Medical
  Compensated educational seminars with Mead-Johnson
  Past consultant for CosMed / Inno-CC
  Past Ad-hoc Scientific Advisory Board Member for Nutricia
- Emily Finnan
  - No disclosures

4

Objectives

1. Discuss the unpredictable nutrient needs and etiology of growth failure in term infants with congenital heart disease (CHD)
2. Review the initiation and advancement of enteral nutrition support in patients with CHD
3. Summarize evidence-based recommendations on determining energy and protein requirements for critically ill term infants with CHD
4. Review a case study of a critically ill term infant with CHD on an Energy and Nutrient Dense Formula (ENDF)

5

Gap in CHD Representation

Guidelines for the Provision and Assessment of Nutrition Support Therapy in Pediatric Critically Ill Patient: Society of Critical Care Medicine and American Society of Parenteral and Enteral Nutrition
Mehta, et al.

- Focused on critically ill children but excluded term infants

Nutritional support for children during critical illness: European Society of Pediatric and Neonatal Intensive Care (ESPNIC) metabolism, endocrine and nutrition section position statement and clinical recommendations
Tume, et al.

- Included term infants, but no specific focus on infants with CHD

[1]Mehta et al. *JPEN*. 2017. [2] Tume et al. *Intensive Care Med*. 2020.

6

Gap in CHD Representation

- 2017 SCCM/ASPEN Guidelines[1]
  - Focused on critically ill children but excluded term infants
- 2020 ESPNIC Guidelines[2]
  - Included term infants
  - No specific focus on infants with CHD

Neonatal Cardiac Care Collaborative (NeoC3)[3]

Nutrition Section

[1]Mehta et al. *JPEN*. 2017. [2]Tume et al. *Intensive Care Med*. 2020. [3]Mills et al. *Pediatrics*. 2022.

7

Nutritional Considerations for the Neonate With Congenital Heart Disease

Kimberly I. Mills, MD; Jae H. Kim, MD, PhD; Kristi Fogg, MS, RD, LDN; Nimrod Goldshtrom, MD; Eric M. Graham, MD; Jasmeet Kataria-Hale, MD; Scott W. Osborne, MD; Mayte Figueroa, MD

Mills KI, Kim JH, Fogg K, Goldshtrom N, Graham EM, Kataria-Hale J, Osborne SW, Figueroa M. Nutritional Considerations for the Neonate With Congenital Heart Disease. Pediatrics. 2022 Nov 1;150(Suppl 2):e2022056415G. doi: 10.1542/peds.2022-056415G. PMID: 36317972.

8

NeoC3 Nutrition Section

- Multidisciplinary nutritional support specialists
- Generated 6 clinical questions commonly debated among clinicians
- Comprehensive literature review 2000-2019
- Study Population:
  - Critically ill neonates (≥ 37 weeks estimated gestational age & <28 days old) and infants (>28 days old) up to 6 months of age with CHD
  - NOT preterm infants
  - Structural, myopathic or arrhythmic diagnoses

NeoC3 = Neonatal Cardiac Care Collaborative

9

Clinical Questions:

Q1a. What is the most accurate method to determine REE in infants with CHD?
Q1b. If IC is unavailable, what other methods are available to determine REE in infants with CHD?
Q2a. What are the recommended energy and protein requirements for infants with CHD?
Q2b. How do energy requirements in infants with CHD evolve during preoperative, perioperative and postoperative disease states?
Q3a. Is EN safe in preoperative infants with CHD?
Q3b. Is EN safe in infants with CHD utilizing vasopressors or inotropes?
Q3c. Is EN safe in infants with CHD when umbilical lines are in situ?
Q3d. Are fortified feeds safe in infants with CHD?
Q3e. Is EN safe in infants with CHD on mechanical support (ECMO or VAD)?
Q4a. How do we advance EN in infants with CHD?
Q4b. Is there an advantage to gastric versus post-pyloric enteral feeds in infants with CHD?
Q4c. Are there any benefits to feeding human milk as opposed to formula in infants with CHD?
Q4d. Are there special nutritional considerations for infants with CHD suffering from chylous effusions?
Q4e. Is there a subset of infants with CHD at risk for aspiration?
Q4f. Are there predictive risk factors in infants with CHD to determine need for surgical feeding tube placement?
Q5a. What is the indication for initiation of PN in infants with CHD?
Q5b. What is the optimal timing for initiation of PN in infants with CHD?
Q5c. What formulation of intravenous lipid emulsion should be initially prescribed for infants with CHD?
Q5d. What are the complications associated with PN utilization?
Q6. Does nutritional status impact the clinical outcomes of infants with congenital heart disease?

10

WHY IS NUTRITION IMPORTANT IN INFANTS AND CHILDREN?

The first 1000 days [1]

- Critical period of brain growth and development
- Inadequate nutrition

1 Georgieff MK et al, Acta Paediatr. 2018:107:1310-21
2 Ross et al., Am Heart J 2020:224:85-97

11

WHY IS NUTRITION IMPORTANT IN INFANTS AND CHILDREN?

The first 1000 days [1]

- Critical period of brain growth and development
- Inadequate nutrition

Inadequate Nutrition Support [1]

- Cognitive developmental delays
- Decreased growth potential
- Decreased immune function

1 Georgieff MK et al, Acta Paediatr. 2018:107:1310-21
2 Ross et al., Am Heart J 2020:224:85-97

12

WHY IS NUTRITION IMPORTANT IN INFANTS AND CHILDREN?

The first 1000 days [1]
- Critical period of brain growth and development
- Inadequate nutrition

Inadequate Nutrition Support [1]
- Cognitive developmental delays
- Decreased growth potential
- Decreased immune function

Lower HAZ and WAZ in neonates with CHD are associated with[2]**:**
- Increased mortality
- Infection
- Longer hospitalizations
- Adverse surgical outcomes

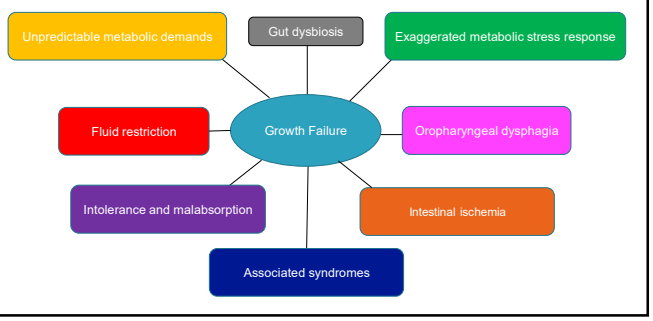
1 Georgieff MK et al, Acta Paediatr. 2018:107:1310-21
2 Ross et al., Am Heart J 2020:224:85-97

13

ETIOLOGY OF GROWTH FAILURE IN INFANTS WITH CHD IS MULTIFACTORIAL

14

Etiology of Malnutrition



15

ENERGY AND PROTEIN GOAL DETERMINATION

16

CALORIE AND PROTEIN NEEDS: NEONATES WITH CHD

Recommended energy requirement for healthy term neonates[4]:
90-120 kcal/kg/d

Minimum recommended protein requirement for critically ill neonates[1]:
"…recommend a minimum protein intake of 2-3 g/kg/d."

[1]Mehta et al. Pediatr Crit Care Med. 2017. [4]Pediatric Nutrition. American Academy of Pediatrics. 2020.

17

CALORIE AND PROTEIN NEEDS: CHILDREN WITH CHD

ASPEN Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Pediatric Critically Ill Patient[1]

Recommended energy requirement for critically ill children:
"…We suggest that measured energy expenditure by IC be used to determine energy requirements and guide prescription of the daily energy goal."

Minimum recommended protein requirement for critically ill children:
"…we recommend a minimum protein intake of 1.5 g/kg/d. Protein intake higher than this threshold has been shown to prevent cumulative negative protein balance in RCTs."

IC = indirect calorimetry; RCT = randomized controlled trials
[1]Mehta et al. Pediatr Crit Care Med. 2017.

18

DETERMINATION OF ENERGY REQUIREMENTS

Resting Energy Expenditure in Children With Cyanotic and Noncyanotic Congenital Heart Disease Before and After Open Heart Surgery

Yaron Avitzur, MD*¶; Pierre Singer, MD†; Ovdi Dagan, MD‡; Eran Kozer, MD**; Dana Abramovitch, RD*; Gabriel Dinari, MD*; and Raanan Shamir, MD*§

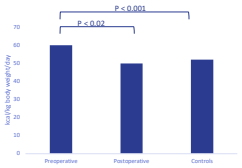
- No difference in REE between cyanotic vs. acyanotic
- ⬆ REE preop CHD vs. postop/controls
- Measured REE significantly different than calculated

Indirect calorimetry measurements of the study groups

	Cyanotic		Noncyanotic	
	Day −1	Day 5	Day −1	Day 5
REE (kcal/kg/d)	57 ± 13	59 ± 10	58 ± 9	62 ± 10

Measured REE vs calculated RR using prediction equation

	Before surgery (kcal/kg/d)	5 days after surgery (kcal/kg/d)
Differences in individual measurements – WHO vs measured REE	-6 to 27	-11 to 29
Differences in individual measurements – Schofield vs measured REE	-22 to 24	-18 to 6



CHD = congenital heart disease, REE = resting energy expenditure

Avitzur et al. JPEN. 2003

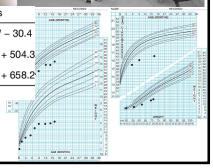
19

DETERMINATION OF ENERGY REQUIREMENTS

Indirect calorimetry = "gold standard" to evaluate nutrition needs
-Several limitations for use-

Age (years)	Girls	Boys
<3	58.317 × W – 31.1	59.512 × W – 30.4
3–10	20.315 × W + 485.9	22.706 × W + 504.3
10–18	13.384 × W + 692.6	17.686 × W + 658.2

W = weight in kg. +/- stress factor?



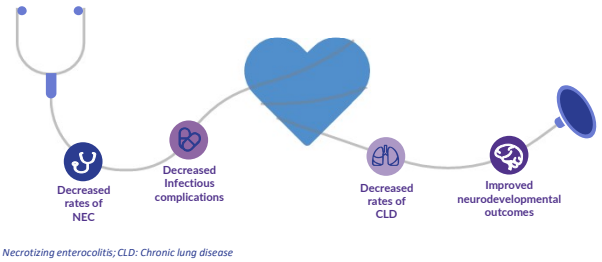
Veldscholte K, et al. Pediatric Medicine. 2020;3:18.

20

ENTERAL NUTRITION INITIATION AND ADVANCEMENT IN INFANTS WITH CHD

21

BENEFITS OF ENTERAL NUTRITION

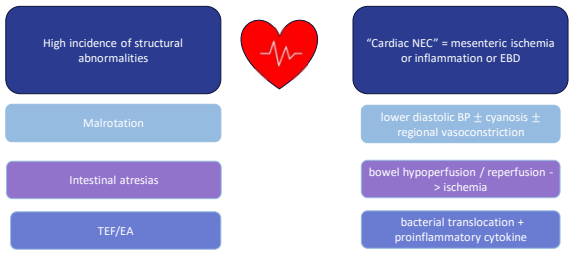


NEC: Necrotizing enterocolitis; CLD: Chronic lung disease

Ballard O, Morrow AL. Human milk composition: nutrients and bioactive factors. Pediatr Clin North Am. 2013;60(1):49–74; Cortez J, Makker K, Kraemer DF, Neu J, Sharma R, Hudak ML. Maternal milk feedings reduce sepsis, necrotizing enterocolitis and improve outcomes of premature infants. J Perinatol. 2018;38(1):71–74; Hair AB. Breast feeding associated with reduced risk of bronchopulmonary dysplasia. J Pediatr. 2016;174:279; Meier PP. Human milk and clinical outcomes in preterm infants. Nestle Nutr Inst Workshop Ser. 2019;90:163–174

22

CONCERNS WHEN INTRODUCING ENTERAL NUTRITION IN INFANTS WITH CHD



[7]Johnson et al. *Pediatr Cardiol.* 2011.

23

PREOPERATIVE FEEDS: PROTECTIVE EFFECTS OF HUMAN MILK

Human Milk use in the Pre-Operative Period is Associated with Less Risk for Necrotizing Enterocolitis in Neonates with Complex Congenital Heart Disease

Acacia Cognata, MD MSPH[1,2,5], Jasmeet Kataria-Hale, MD[1,2,5], Pamela Griffiths, MD[1,4], Shiraz Maskatia, MD[1,7], Danielle Rios, MD, MS[1,2,5], Andrea O'Donnell, RD[1,2,5], Dantin J. Roddy, MD[1,3,5], Amy Mehollin-Ray, MD[4,5], Joseph Hagan, ScD[1,2,5], Jennifer Placencia, PharmD[1,2,5], Amy Hair, MD[1,2,5]

Pre-operative feeding exposures

Risk Factor	N (%)
Any Feeds	363 (66.5)
Receiving > 100 ml/kg/d	139 (25.5)
Received feed by N	139 (38.3)
Exclusive Unfortified BMD	198 (54.5)
Received Fortification	63 (17.4)
Received any Formula	151 (41.6)
Feeds started with UAC in place	184 (50.7)

Bivariate Associations with Stage II/III NEC in the Post-Operative Period

Risk Factor	Odds Ratio	95% CI	P- Value
< 37 weeks gestation	6.62	1.80-23.91	0.004
Feeds > 100 ml/kg/d	4.53	1.26-16.31	0.02
Received any fortified feeds	3.99	1.04-15.3	0.04
Patient with BV w/ ductal dep pulmonary blood flow	3.75	1.03-13.56	0.04

Multivariate Regression Model

Risk Factor	Odds Ratio	95% CI	P- Value
Exclusively Unfortified BM Diet	0.17	0.04-0.84	0.03
Cardiac Lesion: BV w/ductal Dep L	3.27	1.07-9.96	0.04

- HM significantly decreases risk for NEC
- Feeds > 100/kg/d associated with NEC

HM = human milk, NEC = necrotizing enterocolitis
[10]Cognata et al. *J Pediatr.* 2019.

24

POSTOPERATIVE FEEDS: WHEN TO INITIATE

- Early EN initiation (~4-6 hrs) is feasible
- Macronutrient intake improved
- No difference in clinical outcomes

Feasibility of initiating early enteral nutrition after congenital heart surgery in neonates and infants*

Rajat Kalra, Rohit Vohra*, Malti Negi, Reena Joshi, Neeraj Aggarwal, Mridul Aggarwal, Raja Joshi

Early enteral nutrition therapy in congenital cardiac repair postoperatively: A randomized, controlled pilot study

Manoj Kumar Sahu, Anuradha Singal*, Ramesh Menon, Sarvesh Pal Singh, Alka Mohan*, Mala Mauraf, Divya Singh*, V. Devagourou*, Sachin Talwar*, Shiv Kumar Choudhary*

Table 2: Comparison of per-and post-operative parameters of infants undergoing corrective cardiac surgery

Variables	Control group (n=25)	Intervention group (n=25)	P
CPB duration (min)	118.3±53.1	110.4±54.4	0.50
AoXCl (min)	85.0±97.7	70.1±43	0.24
Mortality (n)	2/25	1/25	-
Ventilation duration (h)	153.6±149	123.2±107	0.20
LOIS (days)	13.2±8.9	11±8.13	0.14
LOHS (days)	16.5±8.8	14.1±7.03	0.17
Sepsis (culture positives) (n)	5/25	3/25	-

Comparison of macronutrient consumption by infants postoperatively in Cardiac Surgical Intensive Care Unit for 10 days

Macronutrients	Energy (kcal/day)		Protein (g/day)		Fat (g/day)		Carbohydrates (g/day)	
Group	Control	Intervention	Control	Intervention	Control	Intervention	Control	Intervention
Day 1	67.6 ± 18.5	87.8±29.6	1±0.2	1.3±0.5	2.1±1	3.8±1.4	8.7±2.4	12.4±3.5
Day 2	68.1±9.6	98.8±28.2	1±0.3	1.5±0.5	2.1±1	4.4±1.5	8.8±2.3	13.2±3.1
Day 3	65.6 ± 26.5	110.2±36.4	0.96±0.4	1.7±0.67	2.9±1.5	5±1.9	8.6±2.8	14.4±4.1
Day 4	77.5± 31.7	100±41	1.1±0.5	1.7±0.78	3.5±1.7	5±2.3	10±3.5	14±6.5
Day 5	75.5 ± 36.5	117.7±46.5	1.1±0.6	1.9±0.89	3.5±2	5.5±2.5	4.5±3.9	15.1±5
Day 6	83.9 ± 27.0	124.1±51.8	1.2±0.5	2.0±0.9	3.8±1.7	6±2.7	10.8±2.8	16.1±5.4
Day 7	74.3 ± 32.9	124.1±57.4	1.2±0.5	2.1±1	3.9±1.6	6.1±2.9	9.3±3.4	15.8±6.4
Day 8	78 ± 33.2	128.6±48.6	1.3±0.4	2.1±0.9	4±1.5	6.1±2.6	9.9±3.5	16.2±5.3
Day 9	83 ± 32.7	138.3±48	1.4±0.4	2.3±0.8	4.4±1.4	6.6±2.5	10.6±3.3	17.2±5.5
Day 10	87.1 ± 38.3	127.2±56.1	1.5±0.5	2.1±1	4.7±1.6	5.9±3	10.8±3.9	16.2±6.3
P	<0.001		<0.001		<0.001		<0.001	

EN = enteral nutrition
[11]Sahu et al. *Ann Card Anaesth.* 2016. [12]Kalra et al. *Clin Nutr ESPEN.* 2018.

25

POSTOPERATIVE FEEDS: WHAT TO INITIATE

Tolerability and Effects of the Use of Energy-Enriched Infant Formula After Congenital Heart Surgery: A Randomized Controlled Trial

Vanessa Adriana Scheeffer, MD[1,4,5]; Claudia Pires Ricachinevsky, MD[2]; Alessandra Thais Freitas[2]; Francis Salamon[2]; Flavia Feijó Nunes Rodrigues, MS[1]; Tamires Goldani Brondani, MD[2]; Andrea Tomasi Sutil, MD[1]; Cristina Helena Targa Ferreira, PhD, MD[1,4,5]; Ursula da Silveira Matte, PhD[6]; and Themis Reverbel da Silveira, PhD, MD[1,5]

SEs	Intervention	Control	Odds Ratio (CI 95%)	P-value
Diarrhea	6 (20.6)	0	0 (0.00-0.7)	0.01
Diarrhea NGT	3			
Diarrhea PO	3			

Outcomes	Intervention	Control	P-value
Weight ZS	-1.57 ± 0.2	-2.69 ± 0.2	0.042
ICULOS	7.95 ± 1.42	10.26 ± 1.99	0.35
HLOS	14.4 ± 1.84	20.19 ± 2.56	0.057
MV-D	90.3 ± 23.5	108.4 ± 26.3	0.65

Comparison of wieght variation rate during 30 days in EE-formula and S-formula

- Energy-enriched EN may be safe and effective in infants following cardiac surgery
- Energy-enriched was associated with self-limited diarrhea

EN = enteral nutrition
[13]Scheeffer et al. *JPEN.* 2020.

26

POSTOPERATIVE FEEDS: WHAT TO INITIATE

High-Energy Enteral Nutrition in Infants After Complex Congenital Heart Surgery

Ping Ni[1], Xi Chen[1], Yueyue Zhang[1], Mingjie Zhang[1], Zhuoming Xu[1*†] and Wenyi Luo[2*†]

- Early initiation of high-energy EN may be safe and effective in infants following cardiac surgery
- High-energy EN initiation was not associated with increased feeding intolerance

TABLE 2 | Feeding related outcomes and clinical outcomes.

	Intervention group (n = 40)	Control group (n = 40)	P-Value
Primary outcome			
Caloric attainment rate	31 (77.5%)	18 (45.0%)	0.003
Secondary outcomes			
Milk intake (ml/kg/day)	50.2 ± 12.5	49.8 ± 11.3	0.881
Average calorie intake (kcal/kg/day)	50.2 ± 12.5	33.4 ± 7.6	<0.001
Average protein intake (g/kg/day)	1.1 ± 0.4	0.9 ± 0.2	0.011
Diarrhea	4 (10.0%)	2 (5%)	0.675
Fecal occult blood	1 (2.5%)	5 (12.5%)	0.201
Mechanical ventilation [h]	35.0 (14.9, 88.0)	81.0 (34.7, 136.3)	0.008
ICU stay (day)	7.0 (4.3, 8.8)	7.0 (5.3, 11.5)	0.263
Hospital stay after operation (day)	13.5 (10.3, 19.8)	15.0 (10.0,19.0)	0.579
Pneumonia	1 (2.5%)	10 (25.0%)	0.003
Pressure ulcer	2 (5.0%)	5 (12.5%)	0.432
Chylothorax	5 (12.5%)	5 (12.5%)	1.000

EN = enteral nutrition
[13]Ni et al. *Front Pediatr.* 2022.

27

POSTOPERATIVE FEEDS: WHAT TO INITIATE

With EHMD:
-Improved weight gain velocity
-Decreased incidence of NEC

A Randomized Trial of an Exclusive Human Milk Diet in Neonates with Single Ventricle Physiology

Cynthia L. Blanco, MD[1], Amy Hair, MD[2], Lindsey B. Justice, DNP[3], Dantin Roddy, MD[4], Krista Bonagurio, RD[1], Patricia K. Williams, MD[5], Desiree Machado, MD[6], Bradley S. Marino, MD[7,8], Annie Chi, MD[9], Cheryl Takao, MD[10], Erin E. Gordon, DO[11], Amir Ashrafi, MD[12], Nicole Cacho, DO, MPH[13], Jay D. Pruetz, MD[10], John M. Costello, MD, MPH[7,14], and David S. Cooper, MD, MPH[15], on behalf of the Cardiac Neonate Nutrition Study Group*

Table II.
Safety and other event data for all patients

Adverse events	Control (n=52)	Exclusive human milk (n=55)	P Value
NEC (stage >2)	3 (5.8)	1 (1.8)	.35
NEC + suspected NEC	8 (15.4)	2(3.6)	0.4
Sepsis	4 (7.7)	2 (3.6)	0.42
CHB	1(1.9)	1(1.8)	>.9
Diaphragm paralysis	1(1.9)	1(1.8)	>.9
Tracheostomy	1(1.9)	1(1.8)	>.9
Postoperative neurological injury	1(1.9)	3(5.5)	0.61
Mechanical circulatory support	5(9.6)	5(9.1)	>.9
Unplanned reoperation	5(9.6)	6(10.9)	>.9
Other morbidity	6(11.5)	9(16.4)	.66
Mortality (all cause)	1(4.5)	2(14.3)	.54
Wound infection	2(3.8)	3(5.5)	>.9
Wound Vac	1(1.9)	3(5.5)	.61
Other events			
ICU Length of stay (days)	39 (32-53)	41 (36-75)	.87
Days from first feed	22 (15-29)	24(22-29)	.71
TPN Days	11(10-14)	13 (10-20)	.41
Hospital length of stay (days)	50(43-79)	62(51-114)	.67
Surgery to EOS (days)	26(19-34)	30 (27-33)	.96

EHMD = exclusive human milk diet, NEC = necrotizing enterocolitis
[14]Blanco et al. *J Pediatr.* 2023.

28

FEEDING PRACTICE IN INFANTS WITH CHD:
STANDARDIZED FEEDING ALGORITHMS IMPROVE OUTCOMES

Reducing variation in feeding newborns with congenital heart disease
Janet M. Simsic, MD | Kirby-Rose Carpenito, RD | Kristin Kirchner, RD | Stephanie Peters, PNP-AC | Holly Miller-Tate, RN | Brian Joy, MD | Mark Galantowicz, MD

Enteral feeding algorithm for infants with hypoplastic left heart syndrome poststage I palliation
Nancy J. Braudis, RN, MS, CPNP; Martha A.Q. Curley, RN, PhD, FAAN; Karen Beaupre, RN, BSN; Kristi C. Thomas, RN, MS; Gina Hardiman, RD; Peter Laussen, MBBS; Kimberlee Gauvreau, ScD; Ravi R. Thiagarajan, MD, MPH

Improved Nutrition Delivery and Nutrition Status in Critically Ill Children With Heart Disease

1. Reduce rate and severity of NEC
2. Decreased time on parenteral nutrition
3. Decreased duration of mechanical ventilation & infectious complications
4. Decreased LOS and improve anthropometrics

NEC = necrotizing enterocolitis, LOS = length of stay
[15]Simsic et al. *Congenit Heart Dis.* 2017. [16]Braudis et al. *PCCM.* 2009. [17]Kaufman et al. *Pediatrics.* 2015.

29

CONCLUSIONS

- Utilize estimating equations (Schofield) and follow impact with serial anthropometrics to prescribe energy intake
- Energy requirements:
  - ↑ Higher in children with CHD preoperatively
  - ↓ Low in children with CHD during perioperative phase
- Malnutrition is:
  - Common
  - Associated with adverse clinical outcomes
  - Multifactorial in children with CHD

30

CONCLUSIONS

- "Cardiac NEC" = mesenteric ischemia
- Preoperative feeds are often safe and potentially beneficial
- "NEC" risk factors include:
  - Single ventricle heart disease
  - Feeds > 100mL/kg/d
  - Formula exposure
  - Prematurity
- High-energy or energy-enriched formulas are well tolerated
- Exclusive human milk diet may improve weight gain and decrease incidence of "NEC"

31

NUTRITION CHALLENGES FOR THE INFANT WITH CHD

HOW CAN WE OVERCOME THEM?

32

WHAT IS AN ENDF?

- 30 kcal/oz infant formula to support high energy needs and fluid restriction
- 2.6 g of protein per 100 kcals
- Lower osmolality
- Ready to feed/sterile
- Nutritionally complete
- Can be used to supplement infants consuming BM
- Well-tolerated and supports growth

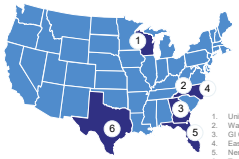
ENDF = energy- and nutrient-dense formula
ASPEN Practice Tool 2022

33

GROW-IN STUDY: LONG-TERM US CLINICAL TRIAL IN INFANTS WITH GROWTH FAILURE

Design

- Prospective, open-label, multi-center study
- Up to 16-week intervention
- Assessments at 0, 2, 4, 8, 12, and 16 weeks



1. University of Wisconsin
2. Wake Forest University
3. GI Care for Kids
4. East Carolina University
5. Nemours
6. Texas Children's Hospital

Study Population

- Infants 1- 8 months old with growth failure due to cardiac and non-cardiac diagnoses

Outcomes

1 – Growth 2 –Tolerance 3 – Safety

1. Nutricia North America.CHCHCH https://clinicaltrials.gov/ct2/show/NCT03563391.

34

GROW-IN STUDY: POPULATION CHARACTERISTICS

Variable	Result
Gender: n (%) male female	 16 (61.5%) 10 (38.5%)
Gestational age*	37.4 ± 3.2
Age at Visit 1**	22.2 ± 10.5
WAZ at birth (mean)	-0.19
WAZ at baseline (mean)	-2.92

N=26 Per Protocol subjects. WAZ = weight-for-age z-score *Median weeks **Mean Weeks.
1. Goday, et al. JPEN J Parenteral Enter Nutr. 2021;45:S224-5(P143). 2. Goday, et al. Children's Hospital of Philadelphia. 2021.

35

GROW-IN STUDY: FORMULA COMPOSITION

Study Formula Composition	
Concentration	30 kcal/fl oz
Protein/100 kcal	2.6 g
% En as Protein	10.3%
Osmolality, mOsm/kg	360
Nutritionally complete for term infants with FTT	✓

WHO expert guidance:

~9-12% to promote accelerated **weight gain of 5-10 g/kg/d**[1]

En = Energy. 1. World Health Organization; Food and Agriculture Organization of the United Nations. Protein and amino acid requirements in human nutrition. 2007.

36

GROW-IN STUDY RESULTS: ANTHROPOMETRICS

Weight-for-age:	Length-for-age:	Weight-for-length:	Head circumference:
+0.86 ±0.74 mean WAZ from baseline (p=0.0001)	+0.25 ±0.61 mean HAZ from baseline (p=0.003)	+0.77 ±0.81 mean WHZ from baseline (p=0.0001)	+0.54 ±0.68 mean HCZ from baseline (p=0.0001)

1. Goday, et al. JPEN J Parenteral Enter Nutr. 2021;45:S224-S(P143). 2. Goday, et al. Children's Hospital of Philadelphia. 2021.

37

GROW-IN STUDY: RATE OF CATCH-UP GROWTH

Percentage of infants who achieved weight gain velocity >WHO median:

- **83%** At ≥1 time point
- **67%** For overall study period
- **13%** Met criteria for "early success"*

No difference in time to meeting weight gain velocity target by presence of CHD

*Early success = WHZ ≥0 or weight velocity > +2 z-score for age at two consecutive visits: transitioned to lower energy-density formula. Two infants in the PP group withdrew early and are not included. 1. Goday, et al. JPEN J Parenteral Enter Nutr. 2021;45:S224-S(P143). 2. Goday, et al. Children's Hospital of Philadelphia. 2021.

38

GROW-IN STUDY: ENERGY INTAKE REACHED TARGET RANGE

Total energy intake:
123±32 kcal/kg/d

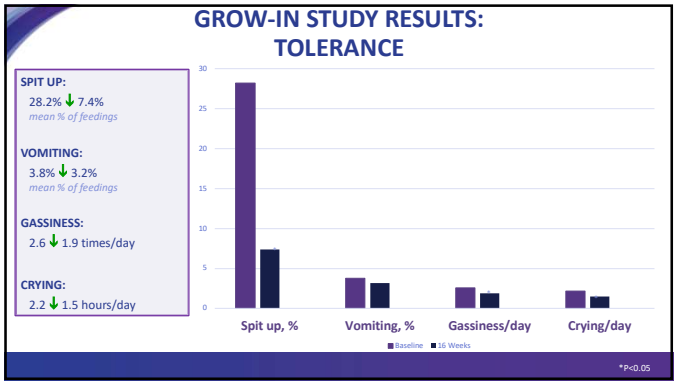
ENDF intake:
116±32 kcal/kg/d

94.3%
average energy intake from ENDF

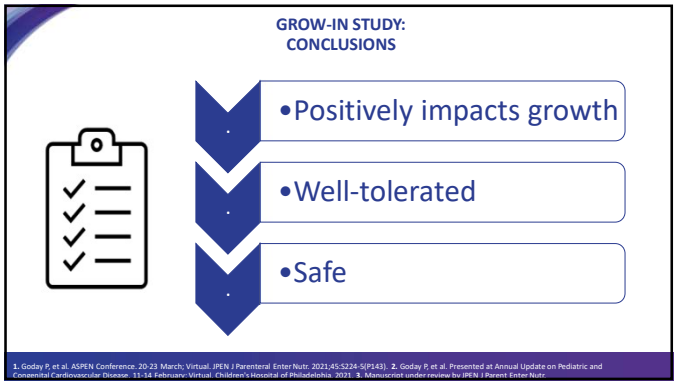
WHO expert guidance → **105-126 kcal/kg/d** to promote accelerated **weight gain of 5-10 g/kg/d**[1]

CHD = congenital heart disease; HCZ = head circumference z-score. WHO = World Health Organization. 1. World Health Organization; Food and Agriculture Organization of the United Nations. Protein and amino acid requirements in human nutrition. 2007. 2. Goday, et al. JPEN J Parenteral Enter Nutr. 2021;45:S224-S(P143). 3. Goday, et al. Children's Hospital of Philadelphia. 2021.

39



40

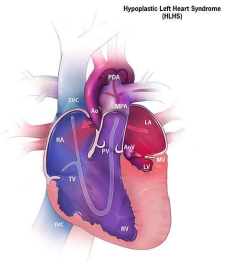


41

42

Case Study - Background

- Baby S term male prenatally known hypoplastic left heart syndrome (HLHS) with mitral atresia, aortic atresia, intact atrial septum.
  - Severe form of HLHS
  - Born appropriate of gestational age (3.32 kg)



1.Vlahos, JE et al. Circulation. 2004.
2. Feinstein JA et al. J Am Coll Cardiol. 2012.

43

Case Study – Surgical History

- Day of life (DOL) two: s/p cath atrial septal stent and pulmonary artery flow restrictors
- Two weeks of age: s/p OR Atrial septectomy, left atrium, endocardial fibroelastosis resection and removal of atrial stent
- Three months of age: s/p OR Stage 1 palliation

44

Case Study – Nutrition History

- Parenteral nutrition (PN) from DOL 1 until four months of age
  - Had been on/off trophic feeds (maternal breast milk)
- Around 3.5 months started to reliably advance with maternal breast milk (unfortified) and std dilution term infant formula
  - Slowly advanced volume and calorie density (via concentration and formula fortification), as PN slowly weaned

45

Case Study – Enteral Nutrition

- After 1 month of full enteral feeding, concern for growth faltering
- Current Regimen: Std term infant formula concentrated to 26 kcal/oz provided continuous via NJT at 132ml/kg/d
  - Provided: 114 kcal/kg/d, 2.4g/kg/d protein
  - No concerns for intolerance

46

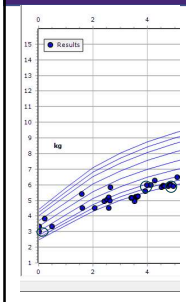
Case Study - Growth

	Weight, %ile	Weight, Z-score	Length, %ile	Length, Z-score	HC, %ile	HC, Z-score	Wt/length, %ile	Wt/length, Z-score
Birth	48	-0.05	86	1.12	6	-1.54	7	-1.46
4 mons of age , PN dc	13	-1.11	4	-1.72	14	-1.06	52	0.05
5 mons of age, 1 mon on std inf formula	2	-1.94	2	-1.94	18	-0.89	18	-0.92

- Growth: 11g/d x 1 week; 14g/d x 1 month
- Goal: 15g/d to maintain self at 2%ile, goal 30g/d for catch up

47

Case Study - Growth



	Weight, %ile	Weight, Z-score
Birth	48	-0.05
4 mons of age , PN dc	13	-1.11
5 mons of age, 1 mon on std inf formula	2	-1.94

48

Case Study – Increasing Calories

- Option A: Increasing Volume
  - Baby S on ~30ml/kg/d of IV medications
    - This + feeds = ~160ml/kg/d
  - Medical team would like to decrease volume Baby S receives
- Option B: Increasing Caloric Density
  - No tolerance issue presently. Concern often from team increasing formula by concentration > 26 kcal/oz d/t risk of NEC in single ventricle
    - ? Increase osmolality ; ~424 mOsm/kgH2O at 28 kcal/oz by concentration of std term infant formula

49

Case Study – Trial of ENDF

- Trial of energy-nutrient dense formula (ENDF)
  - Ready to feed, lower osmo 360 mOsm/kgH20
  - Even higher calorie, 30 kcal/oz. Able to fluid restrict further

50

Case Study – Trial of ENDF

- As already on increased caloric density formula, no transition. Baby S changed to ENDF
- New regimen: Continuous feeds via NJT at reduced volume 125ml/kg/d with 30 kcal RTF ENDF
  - Provides 125 kcal/kg/d, 3.3g/kg/d protein
  - 10% increase in calories, 5% decrease in fluid

51

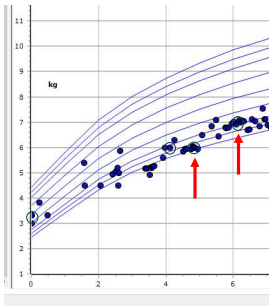
Case Study – Growth

	Weight, %ile	Weight, Z-score	Length, %ile	Length, Z-score	HC, %ile	HC, Z-score	Wt/length, %ile	Wt/length, Z-score
Birth	48	-0.05	86	1.12	6	-1.54	7	-1.46
4 mons of age , PN dc	13	-1.11	4	-1.72	14	-1.06	52	0.05
5 mons of age, 1 mon on std inf formula	2	-1.94	2	-1.94	18	-0.89	18	-0.92
6 mon of age, 1 mon on ENDF	12	-1.16	2	-2.10	41	0.22	52	0.04

- Growth: 33g/d x 1 month

52

Case Study – Growth



	Weight, %ile	Weight, Z-score
Birth	48	-0.05
4 mons of age , PN dc	13	-1.11
5 mons of age, 1 mon on std inf formula	2	-1.94
6 mon of age, 1 mon on ENDF	12	-1.16

53

Case Study – Follow-Up

- Remained on ENDF for 3 months
- ENDF was well tolerated
  - One 4-day period Baby S changed to std dilution term infant formula due to bloody stools increasing GT output
  - Concern for GJT malfunction, was able to directly change back to ENDF

54

Take Away

- Case of ENDF in high-risk, single ventricle population
- Allowed for improved growth, while fluid restricting
- Overall, no intolerance or GI complications observed

55

THANK YOU

Nutricia Learning Center
is provided by
Nutricia North America

56

REFERENCES

Centers for Disease Control. Congenital Heart Defects Learn about Congenital Heart Defects | CDC Accessed 9/14/2021

Cui Y, Li L, Hu C, Shi H, Li J, Gupta RK, Liang H, Chen X, Gong S. Effects and Tolerance of Protein and Energy-Enriched Formula in Infants Following Congenital Heart Surgery: A Randomized Controlled Trial. JPEN J Parenter Enteral Nutr. 2018 Jan;42(1):196-204. doi: 10.1002/jpen.1031. Epub 2017 Nov 3. PMID: 29505140.

Floh AA, Nakada M, La Rotta G, Mah K, Herridge JE, Van Arsdell G, Schwartz SM. Systemic inflammation increases energy expenditure following pediatric cardiopulmonary bypass. Pediatr Crit Care Med. 2015 May;16(4):343-51. doi: 10.1097/PCC.0000000000000357. PMID: 25651049.

Goday P, et al. ASPEN Conference. 20-23 March; Virtual. JPEN J Parenteral Enter Nutr. 2021;45:S224-5(P143).

Goday P, et al. Presented at Annual Update on Pediatric and Congenital Cardiovascular Disease. 11-14 February; Virtual. Children's Hospital of Philadelphia. 2021.

Georgieff MK, Ramel SE, Cusick SE. Nutritional influences on brain development. Acta Paediatr. 2018 Aug;107(8):1310-1321. doi: 10.1111/apa.14287. Epub 2018 Mar 22. PMID: 29468731; PMCID: PMC6045434.

Giannone PJ, Luce WA, Nankervis CA, Hoffman TM, Wold LE. Necrotizing enterocolitis in neonates with congenital heart disease. Life Sci. 2008 Feb 13;82(7-8):341-7. doi: 10.1016/j.lfs.2007.09.036. Epub 2008 Jan 9. PMID: 18187159.

Kataria-Hale J, Osborne SW, Hair A, Hagan J, Pammi M. Preoperative Feeds in Ductal-Dependent Cardiac Disease: A Systematic Review and Meta-analysis. Hosp Pediatr. 2019 Dec;9(12):998-1006. doi: 10.1542/hpeds.2019-0111. PMID: 31744846.

Li J, Zhang G, Herridge J, Holtby H, Humpl T, Redington AN, Van Arsdell GS. Energy expenditure and caloric and protein intake in infants following the Norwood procedure. Pediatr Crit Care Med. 2008 Jan;9(1):55-61. doi: 10.1097/01.PCC.0000298756.82286.23. PMID: 18477914.

McElhinney DB, Hedrick HL, Bush DM, Pereira GR, Stafford PW, Gaynor JW, Spray TL, Wernovsky G. Necrotizing enterocolitis in neonates with congenital heart disease: risk factors and outcomes. Pediatrics. 2000 Nov;106(5):1080-7. doi: 10.1542/peds.106.5.1080. PMID: 11061778.

Mehta NM, Skillman HE, Irving SY, Coss-Bu JA, Vermilyea S, Farrington EA, McKeever L, Hall AM, Goday PS, Braunschweig C. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Pediatric Critically Ill Patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition. Pediatr Crit Care Med. 2017 Jul;18(7):675-715. doi: 10.1097/PCC.0000000000001134. PMID: 28691958.

Nordenström K, Lannering K, Mellander M, Elfvin A. Low risk of necrotizing enterocolitis in enterally fed neonates with critical heart disease: an observational study. *Arch Dis Child Fetal Neonatal Ed*. 2020;105(6):609-614. doi:10.1136/archdischild-2019-318537.

Puri K, Allen HD, Qureshi AM. Congenital Heart Disease. Pediatr Rev. 2017 Oct;38(10):471-486. doi: 10.1542/pir.2017-0032. PMID: 28972050.

Ross FJ, Radman M, Jacobs ML, Sassano-Miguel C, Joffe DC, Hill KD, Chiswell K, Feng L, Jacobs JP, Vener DF, Latham GJ. Associations between anthropometric indices and outcomes of congenital heart operations in infants and young children: An analysis of data from the Society of Thoracic Surgeons Database. Am Heart J. 2020 Jun;224:85-97. doi: 10.1016/j.ahj.2020.03.012. Epub 2020 Mar 19. PMID: 32353587.

Schill CJ, Graham EM, Atz AM, Bradley SM, Kavarana MN, Zyblewski SC. Preoperative Feeding Neonates With Cardiac Disease. World J Pediatr Congenit Heart Surg. 2017 Jan;8(1):62-68. doi: 10.1177/2150135116668833. PMID: 28033074; PMCID: PMC5796765.

57

Nutritional Considerations for the Neonate With Congenital Heart Disease

Kimberly I. Mills, MD; Jae H. Kim, MD, PhD; Kristi Fogg, MS, RD, LDN; Nimrod Goldshtrom, MD; Eric M. Graham, MD; Jasmeet Kataria-Hale, MD; Scott W. Osborne, MD; Mayte Figueroa, MD

Mills KI, Kim JH, Fogg K, Goldshtrom N, Graham EM, Kataria-Hale J, Osborne SW, Figueroa M. Nutritional Considerations for the Neonate With Congenital Heart Disease. Pediatrics. 2022 Nov 1;150(Suppl 2):e2022056415G. doi: 10.1542/peds.2022-056415G. PMID: 36317972.

58

Feedback, Please! And Certificate of Attendance

1. Access survey and provide feedback to receive Certificate of Attendance:

Aim your smartphone camera at this → QR code

OR

access the survey at: https://www.surveymonkey.com/r/CHD24

2. Find the **event code** at end of survey

3. Visit www.NutriciaLearningCenter.com
Enter **event code** into your NLC Dashboard
Certificate of Attendance added to your NLC profile!

Nutricia Learning Center is provided by Nutricia North America

For questions on this webinar or Nutricia's products, please email: NutritionServices@nutricia.com or call: **1-800-365-7354**

59