CONGENITAL HEART DEFECTS: NUTRITION CONSIDERATIONS FOR INFANTS

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Welcome to this self study module titled “Congenital Heart Defects and Nutrition Considerations for Infants”

DISCLOSURES

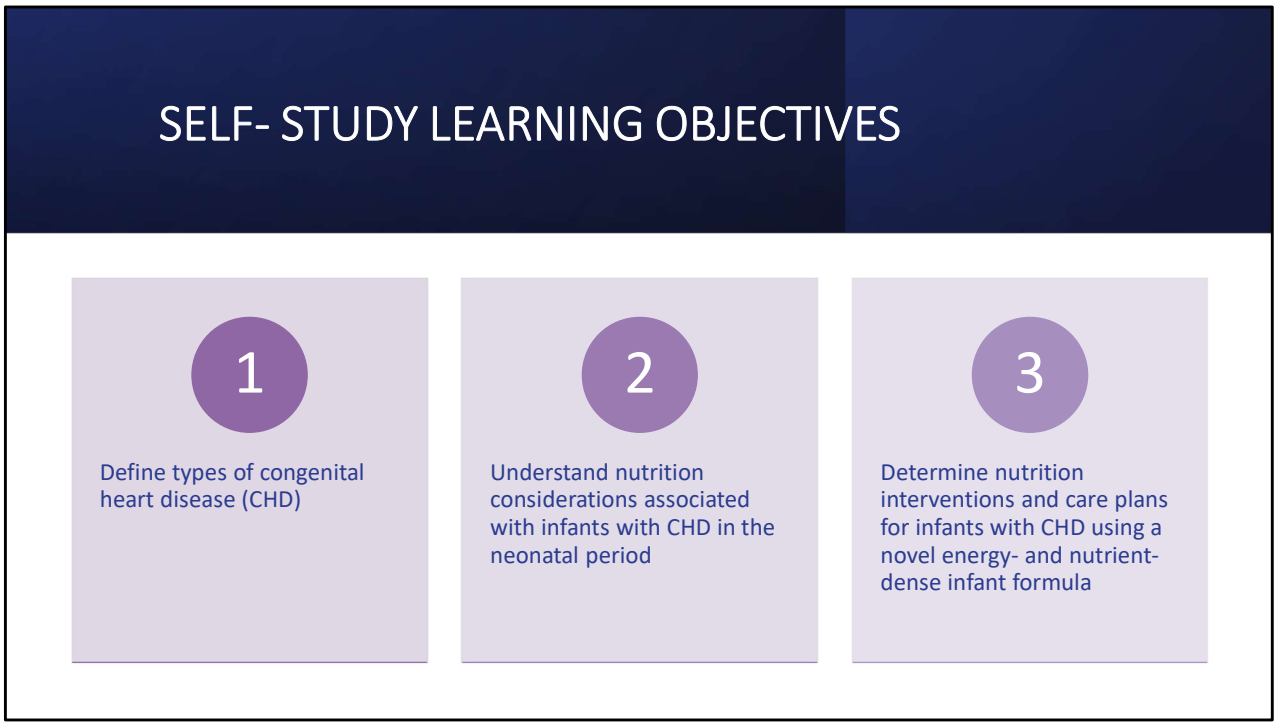
Amy R. Mahar created the content of this learning module and she is an employee of Nutricia North America.

There are no additional disclosures or conflicts of interest to report.

This slide lists the disclosures of the authors. Amy Mahar created the content of this self-study learning module and she is an employee of Nutricia North America. She has no additional disclosures or conflicts of interest to report.

Nutricia North America supports the use of human milk wherever possible

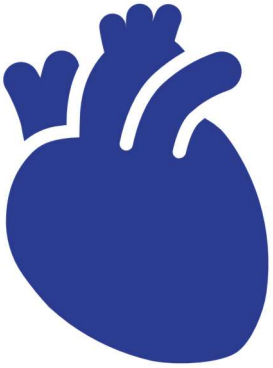
Nutricia North America supports the use of human milk whenever possible. Human milk is the best choice for infants. The following self-study module is for infants who do require formula feedings, whether as supplementation or sole source. This self-study module is not meant to be a comprehensive course on infant feeding options.



The objectives for this course are to:

1. define types of congenital heart disease, or CHD, in the neonate
2. understand nutrition considerations associated with CHD in the neonatal period, and finally,
3. to determine nutrition interventions and care plans for infants with CHD using a novel energy- and nutrient-dense infant formula.

References on slides are truncated and full references are provided at the end of the presentation



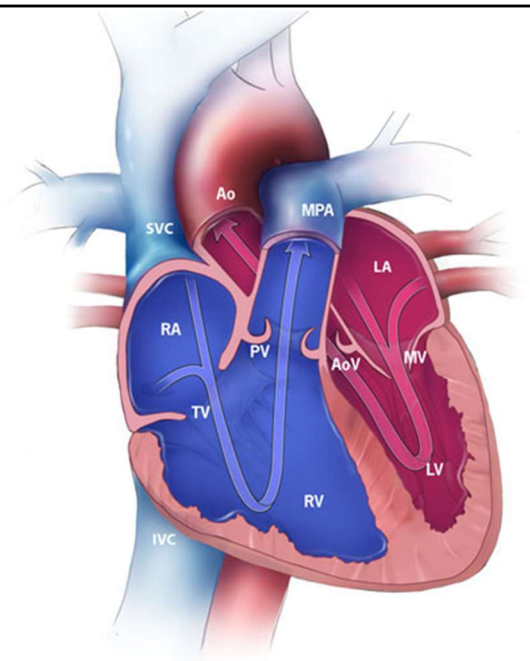
NORMAL ANATOMY OF THE HEART

Before we begin to explore congenital heart defects, let's first review the normal anatomy and function of the heart

NORMAL HEART

Function

- Oxygen depleted blood sent to heart→ lungs → heart →
- Oxygen rich blood sent to the body



RA. Right Atrium
RV. Right Ventricle
LA. Left Atrium
LV. Left Ventricle

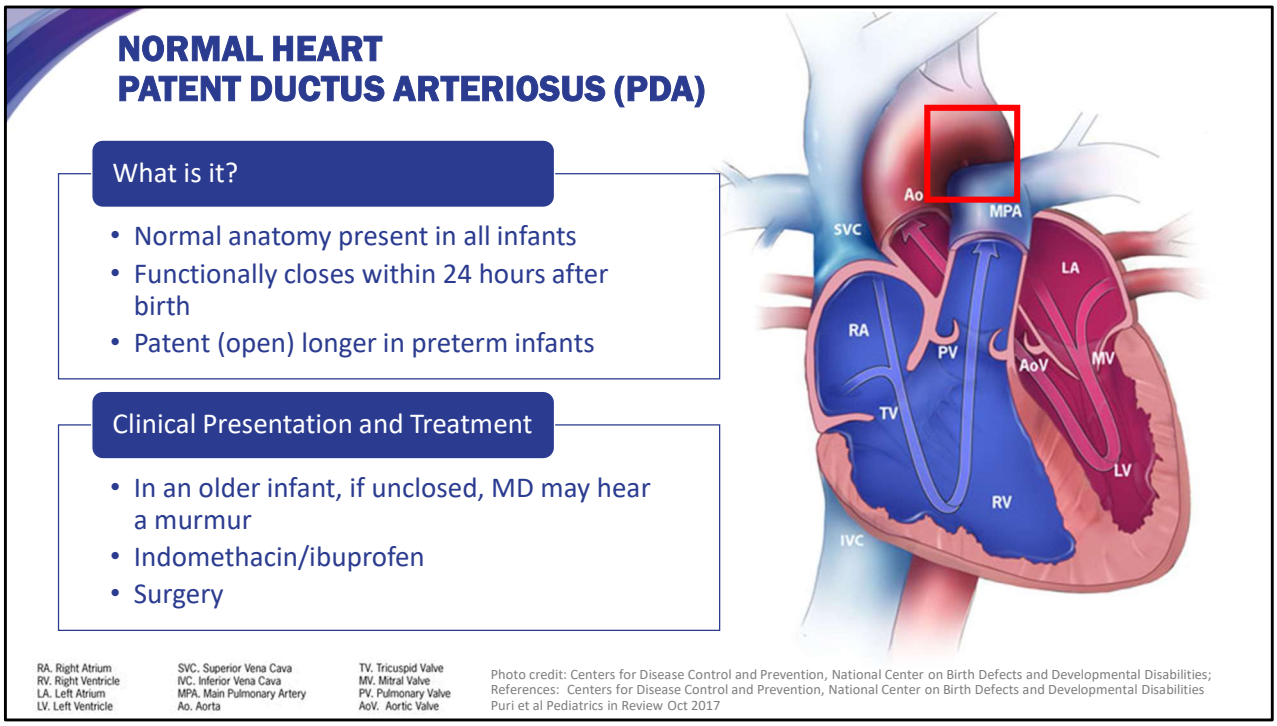
SVC. Superior Vena Cava
IVC. Inferior Vena Cava
MPA. Main Pulmonary Artery
Ao. Aorta

TV. Tricuspid Valve
MV. Mitral Valve
PV. Pulmonary Valve
AoV. Aortic Valve

Photo credit: Centers for Disease

References: Centers for Disease Control and Prevention, National Center on Birth Defects and Developmental Disabilities
Puri et al Pediatrics in Review Oct 2017

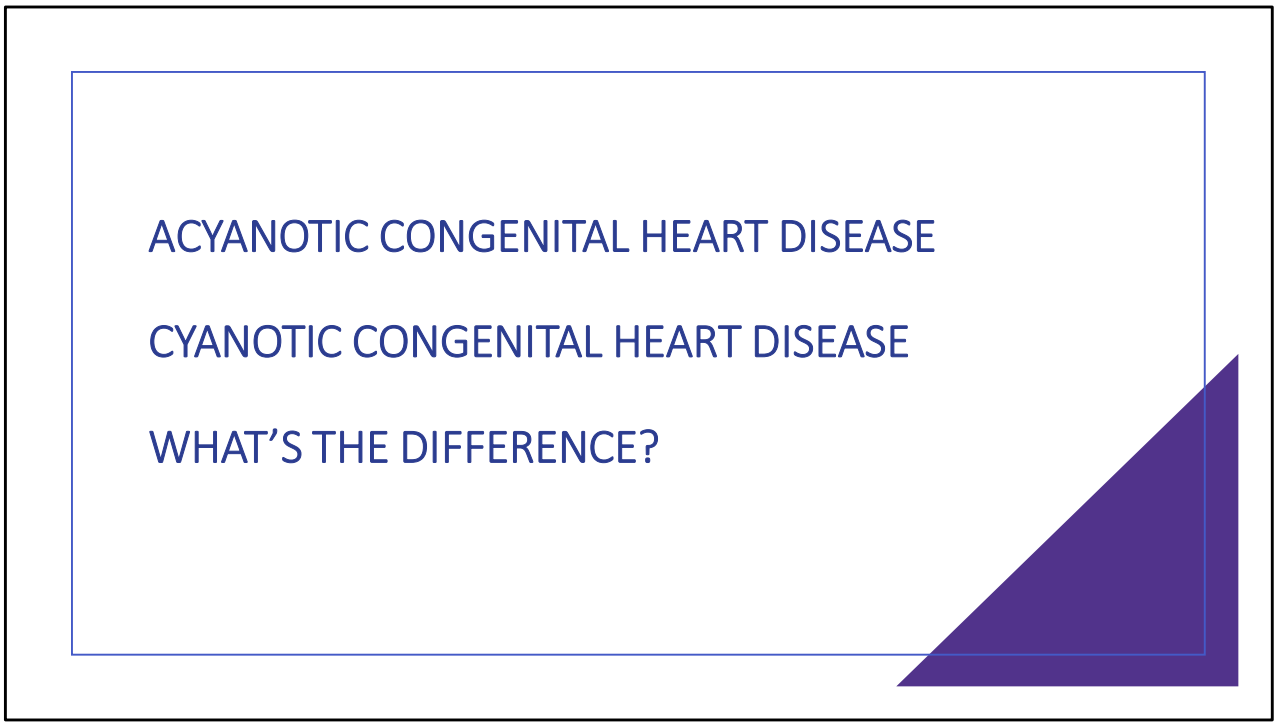
This is an image of an anatomically normal heart. In the absence of congenital heart disease, oxygen depleted blood is sent through the inferior and superior vena cava to the heart and enters the right atrium. It is then pumped through the tricuspid valve, and into the right ventricle. From here it travels via the pulmonary valve into the main pulmonary artery to the lungs where it is oxygenated. From the lungs, oxygenated blood travels through pulmonary veins and into the left atrium; then through the mitral valve into the left ventricle; when the ventricle is full, the mitral valve closes, and blood is sent through the aorta to oxygenate the rest of the body.



Fetal and neonatal heart anatomy are slightly different from adult anatomy. Before a baby is born, the fetus's blood does not need to be oxygenated by their lungs, as this is done through the mother's circulation. The ductus arteriosus is a vessel between the fetal pulmonary artery and the aorta that allows the blood to skip circulation to the fetal lungs.

In this image, a box is drawn where the vessel would be. This is present and normal in all newborns. In most babies, the ductus arteriosus closes functionally within 24 hours of life and is anatomically closed by 3-4 weeks of life. I've included this slide under normal anatomy because usually it closes as it is supposed to. However, it is important to note that in some infants and more often in preterm infants, this opening doesn't close as it should and is called a patent ductus arteriosus, or PDA.

If the PDA remains open for a prolonged period, it can be problematic for the neonate and lead to serious medical concerns as it can lead to congestive heart failure. Therefore, it is sometimes necessary to have medical or surgical intervention to close significant PDAs. This can be done via cardiac catheterization, or sometimes a surgical ligation. It is also important to note, that in some severe congenital heart defects, doctors will use medical treatment to keep the PDA open until a patient can undergo heart surgery. This is something to keep in mind as we go through the rest of the congenital heart defects.

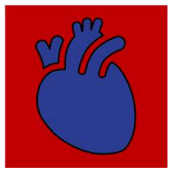


This module groups congenital heart defects by acyanotic and cyanotic. Cyanotic heart defects allow oxygen rich and oxygen poor blood to mix, and oxygen poor blood makes its way systemically, into the tissues of the body. This results in a blue color to the skin, lips, and nail beds. Congenital heart defects that don't typically interfere with the amount of oxygen or blood that reaches the body's tissues are called acyanotic.

TYPES OF CONGENITAL HEART DISEASE: EXAMPLES OF ACYANOTIC VS CYANOTIC DEFECTS

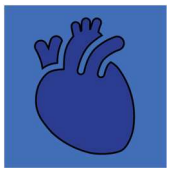
Acyanotic Heart Disease

- Atrial septal defect
- Ventricular septal defect
- Atrioventricular septal defect (AVSD)
- Coarctation of the aorta



Cyanotic Heart Disease

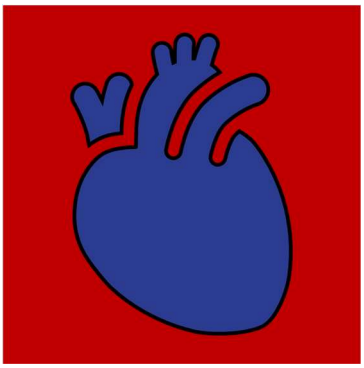
- Tetralogy of Fallot
- Transposition of the great arteries
- Hypoplastic left heart syndrome



References: Centers for Disease Control and Prevention, National Center on Birth Defects and Developmental Disabilities
Puri et al Pediatrics in Review Oct 2017

This slide lists some of the acyanotic and cyanotic heart diseases you may see in your practice, however this is not a comprehensive list. Acyanotic heart disease includes Atrial Septal Defect, Ventricular Septal Defect, Atrioventricular septal defect, and coarctation of the aorta. Cyanotic Heart diseases include Tetralogy of Fallot, Transposition of the great arteries, and hypoplastic left heart syndrome. In this section we will focus on two acyanotic diseases- Atrial septal Defect and Ventricular septal defects, and two cyanotic diseases- Tetralogy of Fallot, and Hypoplastic left heart syndrome. Have you cared for infants with any of these heart defects? If so, try to think about them as we continue along in this module.

ACYANOTIC CONGENITAL HEART DISEASE



Let's review the two acyanotic heart defects, Atrial Septal Defect and Ventricular septal defect.

ACYANOTIC HEART DISEASE: ATRIAL SEPTAL DEFECT

What is it?

- A hole that divides the atria of the heart (upper chambers)

Prevalence

- 1 in 1,859 infants annually (CDC)
- 7-10% of CHD (Puri 2017)

Clinical Presentation

- Many infants do not have signs/symptoms at birth
- MD may hear murmur ~4-6 mos of age
- May tire with feeds due to extra work on the heart
- Sometimes not diagnosed until adulthood

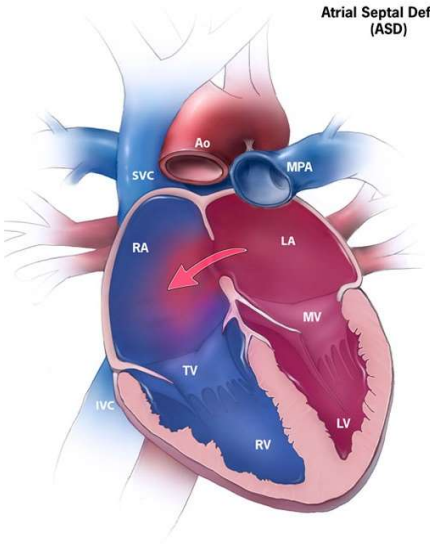
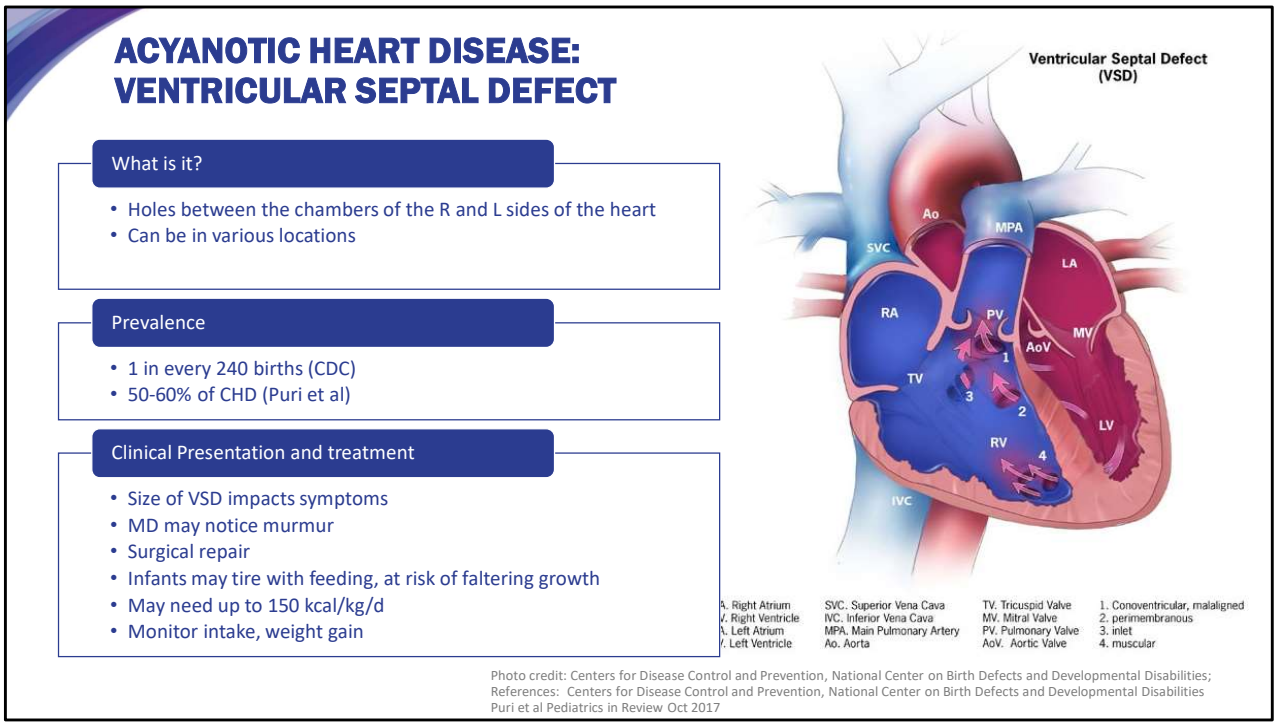


Photo credit: Centers for Disease Control and Prevention, National Center on Birth Defects and Developmental Disabilities;
References: Centers for Disease Control and Prevention, National Center on Birth Defects and Developmental Disabilities
Puri et al Pediatrics in Review Oct 2017
MD: medical doctor; physician
CDC: Centers for Disease Control

This is an atrial septal defect, referred to ASD. An ASD is a hole that divides the atria of the heart, which are the upper chambers. You can see from this image on the right, that this hole allows oxygen rich blood to mix with the oxygen depleted blood in the right atrium. ASDs make up approximately 7-10% of all congenital heart disease, and occurs in 1 out of 1859 infants annually

Clinical presentation: Many babies with ASDs don't exhibit many clinical symptoms and they are typically diagnosed around 4-6 months of age after a doctor hears a murmur on physical exam. These infants may tire with feedings due to extra work on their heart. If the ASD is hemodynamically significant, surgical repair might be done around 3-4 years of age. ASDs are sometimes not diagnosed until adulthood.

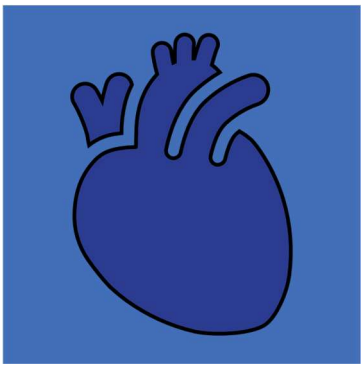


A ventricular septal defect is one or more holes in various locations of the septum- which is the dividing wall between the right and left sides of the heart. This image on the right shows what a VSD can look like. You can see there is a grouping of holes at the lower part of the right ventricle, and then another grouping of holes towards the middle of the heart by the pulmonary valve.

VSDs are the most common CHD lesion. They occur in approximately 1 out of every 240 births in the US and are present in 50-60% of all children with CHD (Puri). The size of the ventricular septal defect will influence what symptoms the infant has. Signs of a ventricular septal defect might be present at birth or might not appear until well after birth. The infant's doctor may hear a heart murmur during a physical examination.

If the hole is small, it may close on its own and the baby might not show any signs of the defect. However, if the hole is large or multiple holes are present, the baby might require surgery to correct it. If the VSD is severe, the infant may exhibit shortness of breath, fast or heavy breathing, tiredness while feeding, or poor weight gain. These infants may require up to 150 kcal/kg/d (Puri). Therefore, it is important to monitor nutrient intake and weight gain and adjust the nutrition regimen as needed based on clinical presentation.

CYANOTIC CONGENITAL HEART DISEASE



Let’s take a look at two cyanotic congenital heart diseases - Tetralogy of Fallot and hypoplastic left heart syndrome.

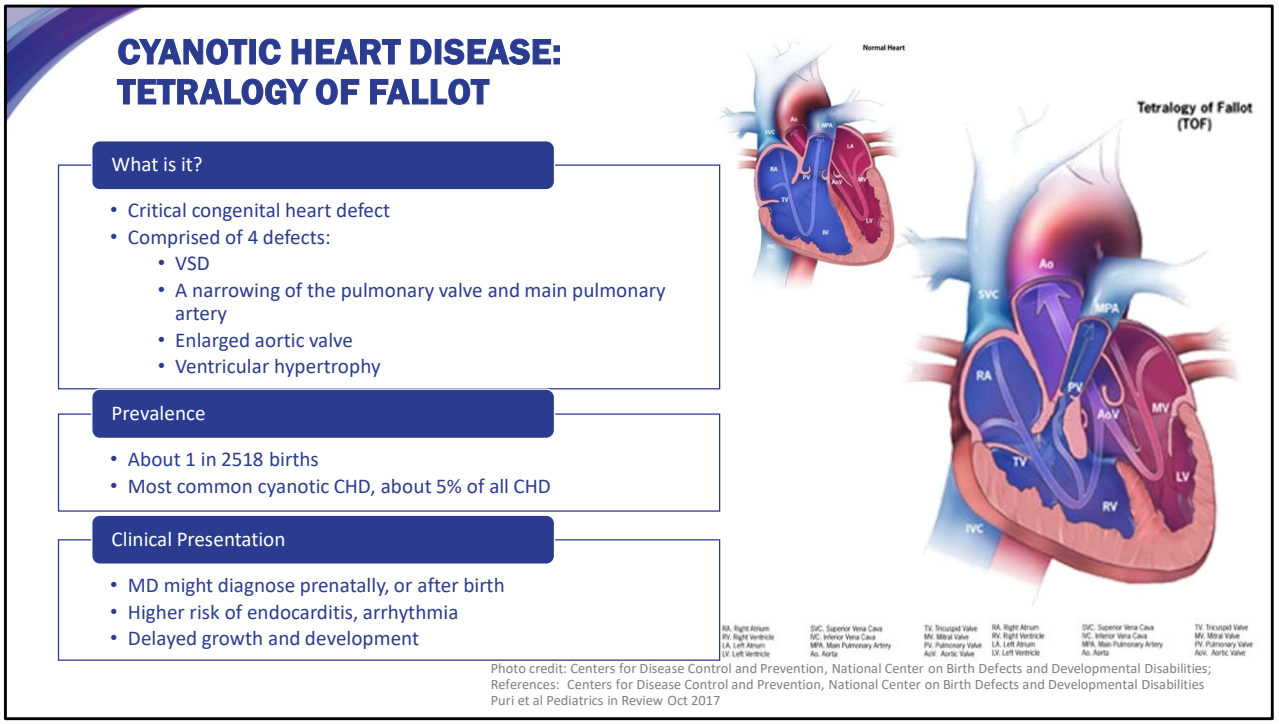


Photo credit: Centers for Disease Control and Prevention, National Center on Birth Defects and Developmental Disabilities;
References: Centers for Disease Control and Prevention, National Center on Birth Defects and Developmental Disabilities
Puri et al Pediatrics in Review Oct 2017

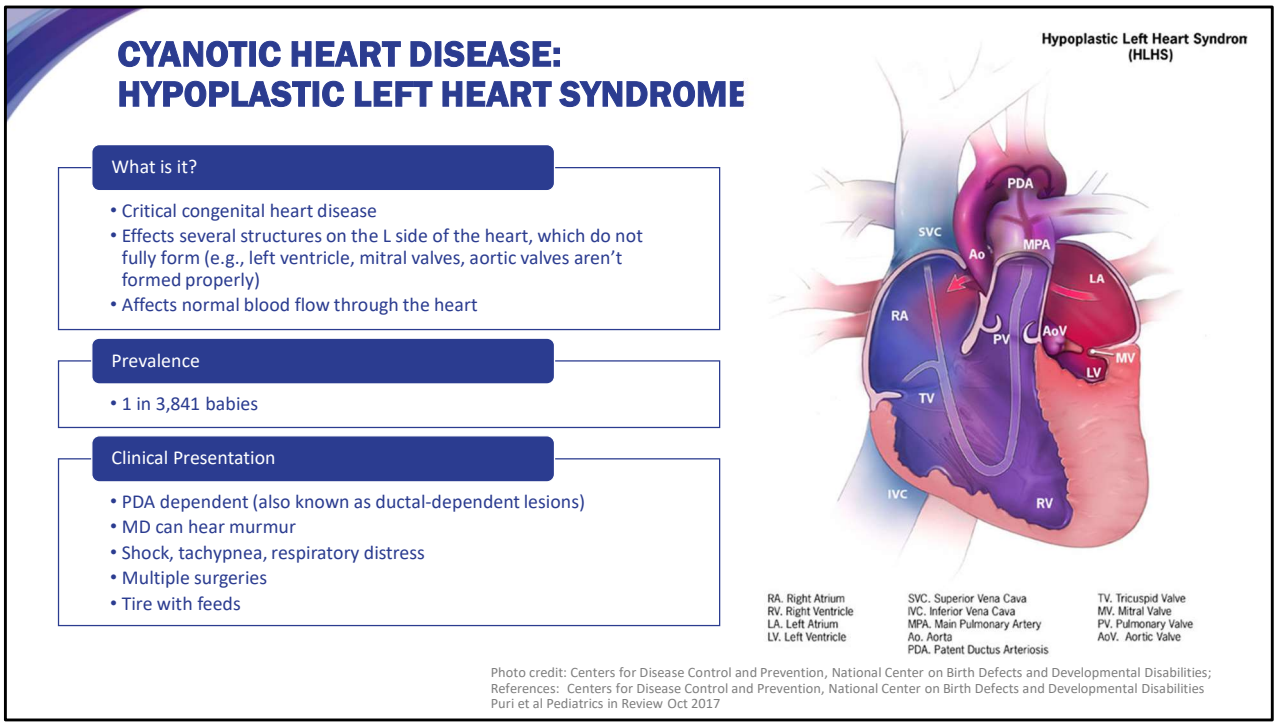
Tetralogy of Fallot is a critical congenital heart disease. Critical congenital heart diseases require surgery within the first few weeks, or year of life. Tetralogy of Fallot is made up of four defects of the heart and its blood vessels:

1. A VSD- which we reviewed earlier and is hole in the wall between the two lower chambers—or ventricles—of the heart.
2. Pulmonary stenosis, or a narrowing of the pulmonary valve and *main pulmonary artery*. There are varying degrees of this pulmonary valve defect, and sometimes these valves may not form at all, a condition known as pulmonary atresia.
3. An abnormality of the aortic valve. As you can see on the image to the right of the screen, the is enlarged and seems to open from both ventricles, rather than from the left ventricle only, as in a normal heart. In this defect, the aortic valve sits directly on top of the ventricular septal defect. And finally,
4. And ventricular hypertrophy. This is when the muscular wall of the lower right chamber of the heart (right ventricle) is thicker than normal,

Prevalence:

Tetralogy of Fallot occurs in every one out of 2518 births, and is the most common cyanotic CHD- it occurs in about 5% of all CHD

This heart defect reduces the amount of oxygen that is available to the rest of the body. Infants with this defect can have that blue cyanotic appearance—because their blood doesn't carry enough oxygen. At birth, infants might not have blue-looking skin, but later might develop sudden episodes of bluish skin during crying or feeding. These infants are also at a higher risk of endocarditis and arrythmia. They also may present with delayed growth and development. Even after surgical repair, these patients likely require lifelong cardiology follow up and monitoring.



And the final congenital heart defect that we will review today is hypoplastic left heart syndrome, or HLHS. HLHS is another critical congenital heart disease where structures on the left side of the heart do not fully form. You can see in this image that the Left ventricle is extremely small, almost missing entirely. This abnormality impacts normal blood flow through the heart.

HLHS is not as common and occurs in about one out of every 3,841 infants. While this is a critical congenital heart disease requiring surgery, these infants might not be symptomatic in the first few days of life while the patent ductus arteriosus are open. However, these infants quickly develop signs after their PDA closes and physicians may use medical management to keep their PDA open, and it is referred to as either a PDA-dependent heart defect, or a ductal-dependent lesion. Their clinical symptoms may include problems breathing, poor urine output, shock, tachypnea, respiratory distress, weak or feeble pulse, and/or cyanotic appearance.

Babies with hypoplastic left heart syndrome become tired while feeding and may not eat enough to gain weight. They may need a high calorie feeding or a supplemental feeding tube. Surgery for hypoplastic left heart syndrome usually is done in three separate surgeries, and beyond the scope of this module. Infants who have these surgeries may still have lifelong complications and will need regular follow-up visits with their cardiologists.

NUTRITION CONSIDERATIONS FOR INFANTS WITH CHD

Now that we have reviewed a few congenital heart defects, lets look at our second learning objective, and review some nutrition considerations for these infants.

WHY IS NUTRITION SO IMPORTANT IN INFANTS WITH CHD?

Growth failure in CHD

- 15-41% develop malnutrition in the first few months of life[1]
- More common among neonates with cyanotic CHD
  - worsened by presence of pulmonary hypertension[1,2]
- Better growth among infants with CHD with standardized feeding protocols[3,4]

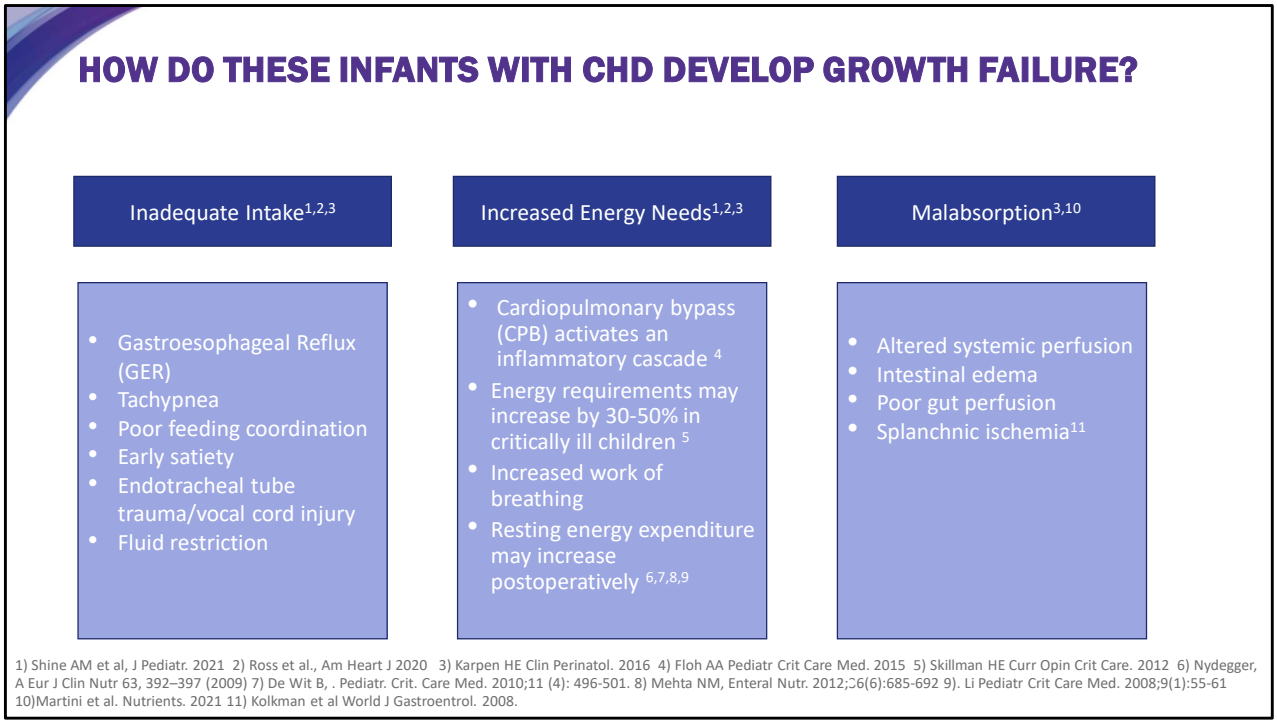
Lower HAZ and WAZ in neonates with CHD are associated with[5]:

- Increased mortality
- Increased infection
- Longer hospitalizations
- Adverse surgical outcomes (increased mortality, infection and length of stay)

HAZ = height-for-age z-score; WAZ = weight-for-age z-score.
1. Martini et al. Nutrients. 2021. 2. Blasquez et al. Eur J Clin Nutr. 2016. 3. Anderson et al. J Pediatr. 2021. 4. Lisanti et al. J Pediatr. 2021. 5. Ross et al. Am Heart J. 2020.

Growth failure can occur in up to 41% of infants with CHD within the first few months of life. Growth failure is also more common among neonates who have a cyanotic heart defect and is worsened by the presence of pulmonary hypertension. While feeding guidelines do not exist specifically for this population, research shows that infants that follow a standardized feeding approach demonstrate better growth than those who do not follow a standardized feeding approach.

A study by Ross and colleagues evaluated the associations between anthropometric indices and outcomes of congenital heart operations in infants and young children. Their study was retrospective, and data came from the Society of Thoracic Surgeons database. They looked at patients who ranged in age from 1 month to 10 years of age who were undergoing cardiac surgery, although 49% of their population were less than 12 months old. Their primary objective was to see if anthropometrics impacted surgical outcomes. They found lower length for age and weight for age z-scores were associated with increased mortality, infection, longer hospitalizations, and adverse surgical outcomes assessed by the authors which included mortality, infection, and length of stay.



Nutrition is of high importance for all infants and children, and especially so in the first 1000 days of life when there is that critical period of brain development (Georgieff MK *Acta Paediatr*. 2018). There are three main aspects that contribute to growth failure- inadequate nutrition intake, increased energy needs, and malabsorption. There are unique factors that infants with CHD have which contribute to these aspects.

Contributing factors for inadequate intake among infants with CHD include gastroesophageal reflux, tachypnea, or fast breathing. They may also have poor feeding coordination of their suck and swallow, early satiety, endotracheal tube trauma and vocal cord injury due to multiple procedures, and fluid restrictions. Infants with CHD also have increased energy needs which could be due to several factors. If these infants require cardiopulmonary bypass, they may have an increased energy requirement stemming from an activation of an inflammatory cascade. Research shows that infants and children with critical illness may have energy requirements that are increased by 30-50%. They also have increased energy needs due to their increased work of breathing. These infants maya also have an increased resting energy expenditure postoperatively, although there is some conflicting data in the literature and there is still controversy surrounding these findings. I suggest reviewing the linked references for a more detailed look on these data.

These infants also experience malabsorption due to altered systemic perfusion and there may be a decrease in blood flow to the superior mesenteric artery, and the intestinal vasculature which could lead to intestinal edema and overall poor gut perfusion. They may also experience splanchnic ischemia. Splanchnic ischemia is stenosis, or a narrowing of the main arteries that provide blood to the intestines- the celiac artery, the superior mesenteric artery and the arteries that supply blood to the colon and rectum. As a quick side note, there is controversy in the literature regarding the extent to which increased energy expenditure causes poor weight gain and growth failure. While all three of these etiologies can contribute to poor weight gain, inadequate nutrition intake is usually the primary cause, versus increased energy intake that leads to poor weight gain in children.

CALORIE AND PROTEIN NEEDS: NEONATES WITH CHD

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

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
Mehta et al., 2017 Pediatr Crit Care 18(7)675-715

Let's switch gears a little bit and talk about nutrient needs for this population. While feeding guidelines do not exist specifically for infants with CHD, we do have The ASPEN Guidelines for the provision and Assessment of Nutrition Support Therapy in the Pediatric Critically Ill patient which was published in 2017. These guidelines apply to infants over 1 month of age and less than 18 years of age who are expected to require a length of stay in a PICU for greater than 2-3 days. ASPEN recommends that energy requirements for this population are obtained using indirect calorimetry. ASPEN also recommends that critically ill children receive at least 1.5 g/kg/d of protein. As stated here, protein intakes above 1.5 g/kg/d has been shown to prevent cumulative negative protein balance in randomized controlled trials.

CALORIE AND PROTEIN NEEDS: NEONATES WITH CHD

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

In the absence of indirect calorimetry ASPEN recommends the following equations without the addition of stress factors:

- The Schofield equation or
- The World Health Organization Food and Agriculture Organization's equation

IC = indirect calorimetry; RCT = randomized controlled trials
Mehta et al., 2017 Pediatr Crit Care 18(7)675-715
WHO/FAO equation: https://www.fao.org/3/y5686e/y5686e00.htm

Because not every PICU can use indirect calorimetry to determine REE, ASPEN does have recommendations for equations to use when indirect calorimetry is not available. ASPEN recommends using either the Schofield equation or the Food agriculture organization/WH/United Nations equations without the addition of a stress factor during periods of critical illness. The addition of stress factors should be added with clinical judgment based on the patient's current clinical status, and factors such as sedation or mechanical ventilation support.

CALORIE AND PROTEIN NEEDS: NEONATES WITH CHD

For step-down/acute care of infants with CHD

While nutrient recommendations vary depending on the infant's age, clinical status, other medical diagnoses, and care plan goals, Non-critically ill infants may require:

- **Calories:** 120-150 kcal/kg/d, sometimes up to 200 kcal/kg/d for catch up growth
- **Protein:** 3-3.5 g/kg/d
- **Fluid**: May be restricted per medical management, up to maintenance calculated by Holiday-Segar Methods

Roman. Nourishing Little Hearts: Nutritional Implications for Congenital Heart Disease 2011
Luca et al., Optimal Nutrition Parameters for Neonates and Infants with Congenital Heart Disease 2022

As mentioned earlier, specific guidelines do not exist for this population, however, there are some recommended ranges for calories and protein that have been put forth by a few authors. Infants with congenital heart disease who are in step-down, or in acute care settings and not in the intensive care unit, may require calorie goals of 120-150, and sometimes, though rarely, up to 200 kcal/kg/d. Protein requirements may be up to 3-3.5 g/kg/d. Fluid needs vary greatly among this population. Typical fluid requirements for infants are estimated by the Holiday-Segar method, but fluid is often restricted by the medical team for medical management of cardiac disease.

WHY IS NECROTIZING ENTEROCOLITIS (NEC) A FEEDING CONCERN?

CHD is a Risk Factor for NEC

- 10-100 times more common among infants with CHD
- Different pathophysiology among CHD vs preterm neonates
- Reduced intestinal perfusion and oxygen delivery
- Higher risk in ductal-dependent anomalies

McElhinney et al., Pediatrics 2000 Nov;106(5):1080-7
Scahill et.al., World J Pediatr Congenit Heart Surg. 2017 Jan;8(1):62-68
Giannone et al., Life Sciences 2008; 82(7-8):341-7
NEC: Necrotizing enterocolitis

Another consideration for this population is the elevated risk of necrotizing enterocolitis, referred to as NEC. NEC is a devastating disease, in which parts of an infant's intestine become inflamed and may necrose- potentially leading to sepsis and death. NEC occurs primarily in preterm infants and does also occur in infants with CHD. NEC is 10-100 times more common among infants with CHD, and it has a different pathophysiology from the NEC seen among preterm neonates.

NEC that occurs among infants with CHD is due to altered systemic blood flow, specifically reduced oxygen delivery to the mesenteric artery. The risk of NEC is also higher among those infants with congenital heart disease that are ductal-dependent, also called PDA-dependent. These are the heart defects that require their PDA to remain open. Due to the increased risk of NEC in this population, feedings are often held, or there are delays in advancing.

EVIDENCE OF NEC AND FEEDING: NO INCREASED RISK

Scahill, et al., 2017 *World J Pediatr Congenit Heart* Surg 8(1):62-68			Kataria-Hale et al., 2019 Hosp Pediatr 9(12):998-1006
n=130			Systematic review and meta-analysis evaluating pre-op feedings and ductal dependent heart disease
Infants ≤31 days of life requiring neonatal cardiac surgery			
61% with single ventricle physiology	55% PDA-dependent	61% (n=79) received pre-op feeds	five retrospective cohort studies were included (high risk of bias)
No associations with preoperative feeding and NEC prevalence (n=130) Prematurity was only variable associated with NEC (P=0.03)			No significant difference in NEC when comparing infants who were fed vs not fed Authors concluded "insufficient evidence to suggest pre-op feeding adversely influence rate of NEC, LOS or feeding intolerance"

Breast milk is associated with reduced NEC rates for infants with CHD- for further reading:
Cognata A, et al. "Human Milk Use in the Preoperative Period Is Associated with a Lower Risk for Necrotizing Enterocolitis in Neonates with Complex Congenital Heart Disease". J Pediatr. 2019;215:11-16.e2

Let's review some recent studies that looked at the evidence for feeding and risk of NEC among this population. Many studies investigating NEC are observational, due to the ethical considerations to randomizing a population to a feeding intervention that has a high risk of NEC.

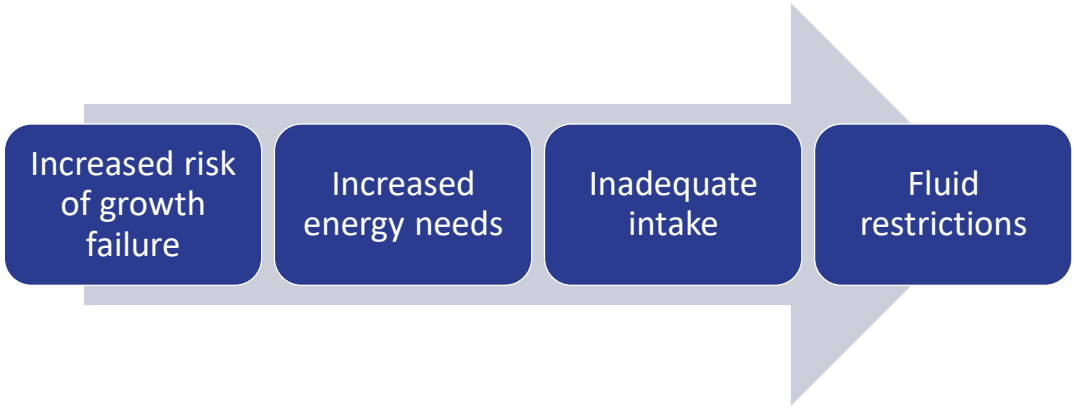
Scahill and colleagues conducted a retrospective chart review of neonates who underwent cardiac surgery between 2011 and 2013 at a single site. The primary objective of their study was to evaluate if preoperative feeding was associated with a higher risk of NEC. They were able to review 130 charts that met their inclusion criteria. The primary exposure was defined as any feedings during the preoperative period. When looking at their population characteristics, a total of 61% of infants had either hypoplastic left heart syndrome or other type of single ventricle physiology and 72% of their population had a PDA-dependent heart defect, which are the cardiac infants with a much higher risk of developing NEC, compared to other kinds of less severe heart defects. In this cohort, 61% pre-operative feedings and of those 61%, 33 infants received trophic feedings, which they defined as <20ml/kg/d and 32 infants received greater than trophic feeds. Schahill and colleagues found no association between pre-operative feedings and risk of NEC, and the only risk factor they identified was prematurity.

Kataria-Hale and colleagues performed a systematic review and meta-analysis evaluating pre-operative feedings and NEC. They were able to include five studies, which were all retrospective cohort studies. The authors evaluated the risk of bias for each article using the Newscastle-Ottowa Scale. Given the retrospective designs of the studies included, they were assessed as a high risk of bias. The authors did not find a significant difference in NEC when comparing infants who were fed vs. those who were not fed. However, given that only 5 studies were included in this meta-analysis, the authors also reported that there is insufficient evidence to suggest pre-op feeding adversely influences NEC.

Use of human milk is also associated with lower rates of NEC among infants with CHD- for further reading please review the paper at the bottom of the slide.

Ultimately, more research is needed in this population to evaluate NEC and feeding.

NUTRITION CONSIDERATIONS FOR CHD INFANTS IN CASES OF:



We have reviewed types of congenital heart diseases and some nutrition considerations for this specialized population. Let's take a look at some nutrition management strategies for when you see infants with CHD knowing they have an increased risk of growth failure, increased energy needs, inadequate intake and may also have some fluid restrictions. We are going to look specifically at using an energy- and nutrient-dense infant formula.

WHAT IS AN ENDF?

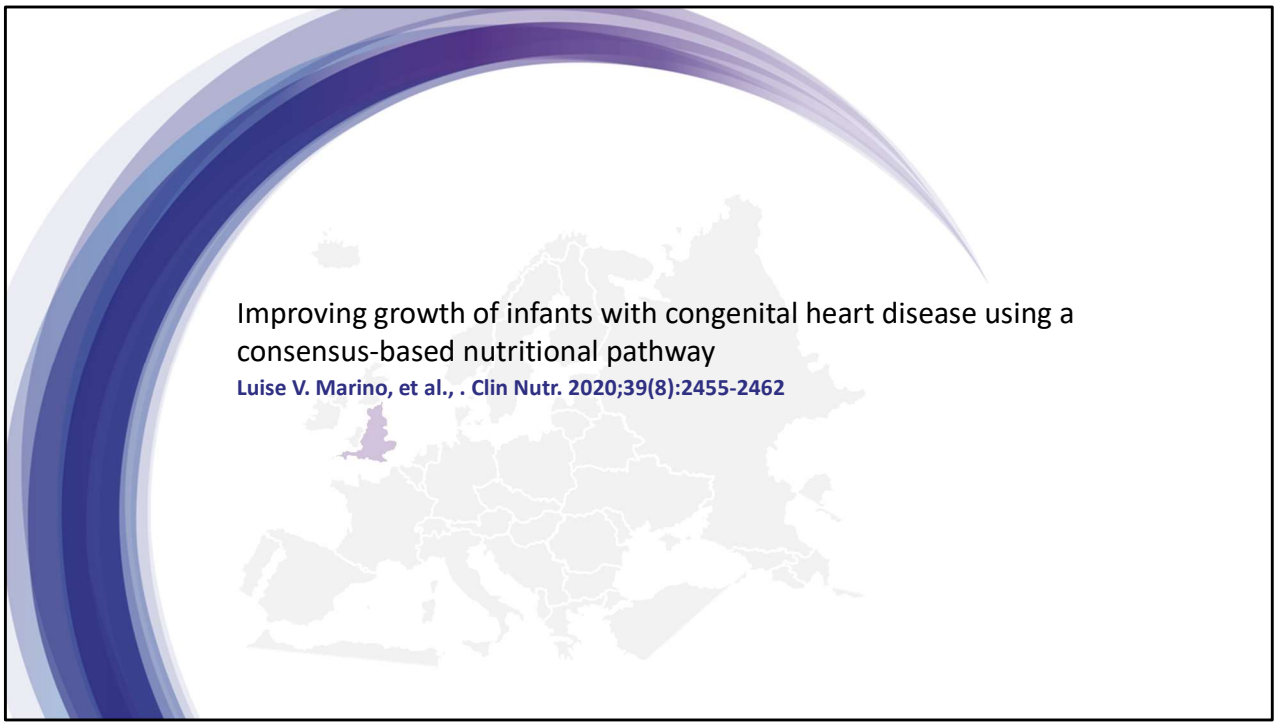
- ENDF = energy- and nutrient-dense formula
- 30 kcal/ounce term infant formula
- 2.6 g protein/100 kcals
- Lower osmolality (<400mOsm/L)
- Well tolerated and supports growth
- Ready to feed and sterile
- Nutritionally complete
- Can be used to supplement breastmilk

Nutrition Management of Term Infants With Growth Failure
ASPEN 2022

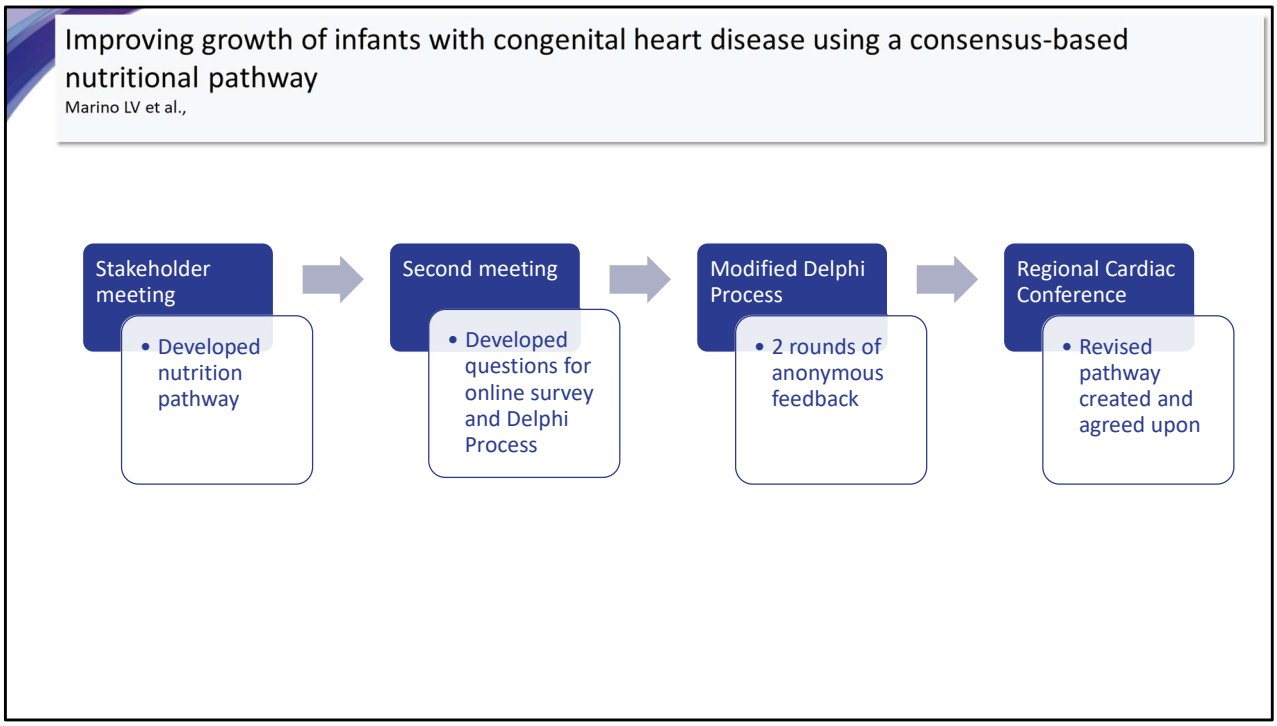
An energy- and nutrient-dense infant formula, also referred to as ENDF, provides 30 kcal/oz and has a higher protein and nutrient content than standard infant formulas. It is designed to provide 8.9-11.5% of energy from protein, as recommended by the World Health Organization. It has an osmolality of <400 mOsm/L. ENDFs in the United States are ready to feed and sterile. They are nutritionally complete and have a long history of use in Europe where they have been used for the last 20 years for infants with poor growth. The use of ENDFs are supported by clinical evidence and have been researched among infants with congenital heart disease. We will review three of these studies for the remaining time in this module.

CARE PLANS FOR THE INFANT WITH CHD USING ENERGY- AND NUTRIENT-DENSE INFANT FORMULA (ENDF)

Let’s move into our third learning objective and discuss nutrition interventions and care plans for infants with CHD using a novel energy- and nutrient-dense infant formula.



Earlier in this module, I mentioned that feeding protocols are associated with better anthropometric outcomes among infants with CHD. We will review an article by Dr. Luise Marino and colleagues using a consensus-based pathway using an energy- and nutrient-dense infant formula.



Dr. Marino and colleagues designed a study to evaluate growth among infants with CHD who required surgery who followed a consensus-based nutritional pathway. These pathways were developed over several steps. Initially, stakeholders met and developed the nutrition pathway using available published evidence. Then there was another meeting to finalize the guidelines and develop questions for the online survey used in the Delphi Process. A modified Delphi process based on 2 rounds of an anonymous online survey were conducted. The pathway was then revised at a regional cardiac conference, and then there was a final meeting to confirm the pathway.

The pathway includes the clinician assessing nutrition risk, classifying growth of the infant, evaluating how the infant is receiving food, and how much they are taking in, and then determining the nutrition risk and assigning them to a Nutrition Care Plan.

Improving growth of infants with congenital heart disease using a consensus-based nutritional pathway

Marino LV et al.,

Clinical Scenarios	Nutrition Care Plan	Energy Needs		Protein Needs		Fluids	Enteral nutrition sources
			kcal/kg/d	%EN	g/kg/d		
• Growing well • Can meet nutrient needs PO	A	Normal	90-100	No special considerations		Normal, e.g. 150 ml/kg/d	Breast milk or standard infant formula on demand
• Not growing well • CHD lesion + higher nutrition risk, feeding well • Finishes >75% of feeds PO • Fluid intake <120 mL/kg/d	B	+ ~10%	100-110	9-12	~2.5		Breast milk or standard infant formula + 30-80% of nutrition from ENDF
• Not growing • CHD lesion + higher nutrition risk • Needs NG/NJ tube • Fluid intake <100 mL/kg/d	C	+ ~10-20%	120-150	10-15	<4	May be restricted Check renal function	Breast milk or standard infant formula + 50-100% of nutrition from ENDF or as ON or NG feeds

CHD = congenital heart disease; %EN = Percent total energy; ENDF = energy- and nutrient-dense formula; NG = nasogastric; NJ = nasojejunal; ON = overnight; PO = by mouth

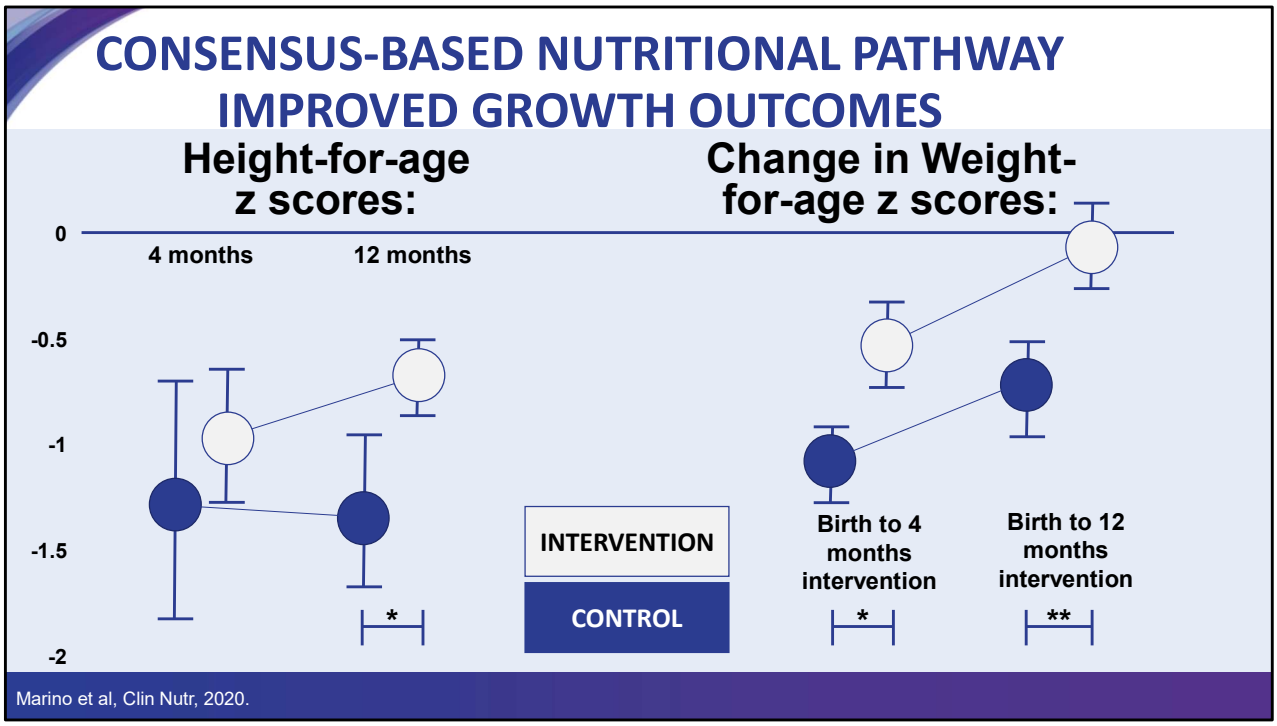
There were three Nutrition Care Plans an infant could be assigned to:

A. If infants were growing well and meeting their needs orally, they were assigned nutrition care plan A, where standard nutrition recommendations were followed.

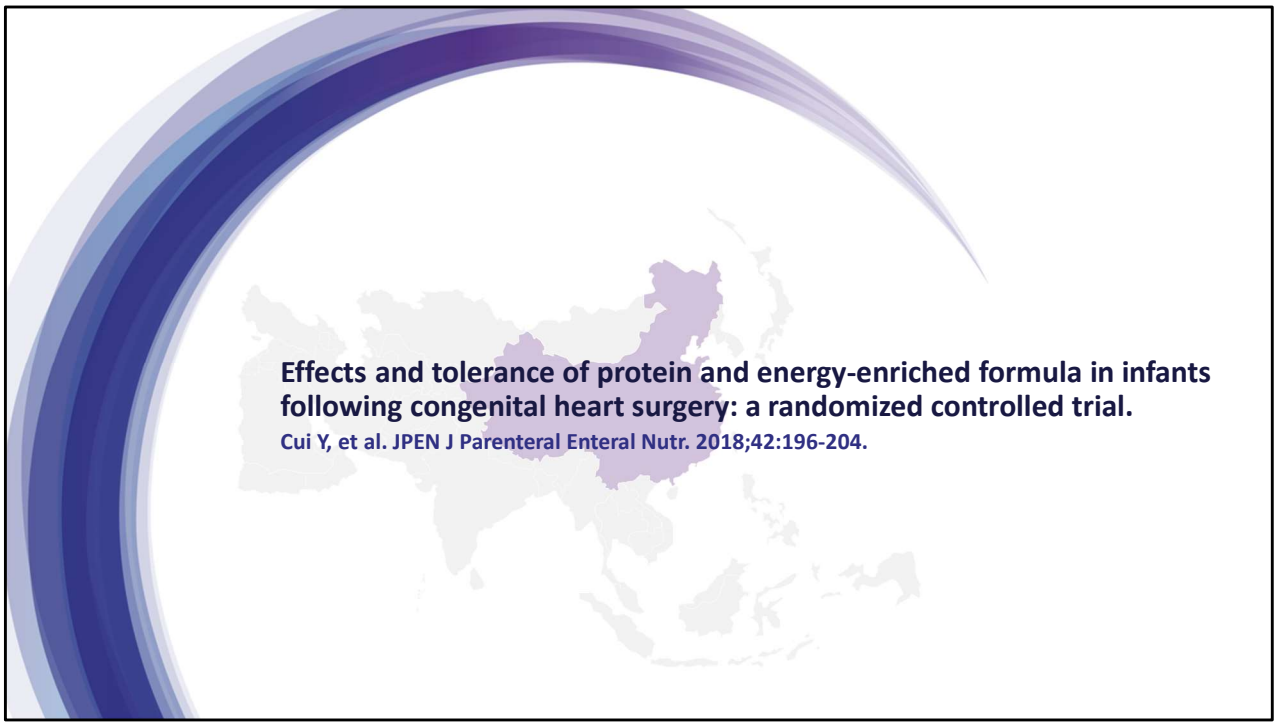
B. If the infant was not growing well, had a CHD lesion and higher nutrition needs, they were assigned to care pan B, where they were prescribed 10% more nutrition, and were given breast milk, or standard formula, with 30-80% from ENDF.

C. If the infant was not growing, or required feedings via enteral feeding tube, they were assigned to Nutrition Care plan C. This care plan provided 10-20% more calories, and provided 50-100% of enteral nutrition as ENDF, with breast milk or standard infant formula.

Infants were prospectively enrolled if they were less than 12 months old and were awaiting CHD surgery. The infants followed these care plans until surgery and then received standard nutrition care via an outpatient dietitian until they were 12 months old. A total of 54 patients were enrolled and compared to a total of 38 historical matched controls. Of the infants in the experimental group, 64% were in nutrition care plan C, and the remaining were in nutrition care plan B.



These are some of the anthropometric results. The intervention group is in white, and the control group is in blue. The left side of the slide indicates height for age Z-scores for both the intervention and control at 4 and 12 months. The intervention had a significantly higher Z-score compared to the controls at 12 months of age, meaning these infants had better linear growth at 12 months of age. On the right you can see change in weight-for-age z-scores from birth to 4 and 12 months into the intervention. These data show that the infants in the intervention group had significantly better weight gain compared to the historically matched controls.



The next study we are going to review is by Cui and colleagues and reviews the effects and tolerance of protein and energy-enriched formula in infants following congenital heart surgery using a randomized controlled trial.

Cui et al., ENDF Use Among Infants Post-Op for CHD Surgical Repair

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Design

- Randomized, double-blind controlled trial
- 5-day intervention
- Fed continuously via NG tube
  - Start 12-24 hours post-op at 1 mL/kg/h (24 mL/kg/d), advance 1 mL/kg/h Q6H as tolerated
- Study formulas

Intervention (n = 26)	Control (n = 24)
ENDF • 1 kcal/mL • 2.6 g protein/ 100 kcal (10.4% PE)	SIF • 0.67 kcal/mL • 2.0 g protein/100 kcal (8% PE)

Study Population

- Term infants, 4 weeks -12 months old, post-op for CHD repair (biventricular repairs only)

Outcomes

1 – Nutrition status
- Macronutrient intake
- Daily 24-hr urinary urea nitrogen
- Biochemical

2 – Tolerance
- Emesis + stools
- GRV Q4H
- GI bleeding
- Gastric motor drugs (anti-emetic or anti-diarrheal agents)

3 – Outcomes
- Infections
- Length of stay

NG = naso-gastric; SIF = standard infant formula; ENDF = energy- and nutrient-dense formula; CHD = congenital heart defect. PE= protein energy 1. Cui Y et al. JPEN J Parenteral and Enteral Nutrition. 2018.

Cui and colleagues conducted a randomized double blind controlled trial to investigate the effects of an energy- and nutrient-dense formula for infants who were post op for congenital heart disease repair at a single center. Infants were included in this trial if they were aged 4 weeks – 12 months, born at term, expected to require an ICU stay >5 days and had complex CHD undergoing biventricular repairs. Infants were excluded if they had GI malformations; GI intolerance prior to enrollment, PN support or breastfeeding, Single ventricle correction; coarctation of the aorta, inherited metabolic diseases; chromosomal disease Liver and kidney dysfunction.

These infants were randomized to either the control group, which provided a standard infant formula, or the intervention group which was an energy- and nutrient-dense infant formula that provided 1 kcal/mL, and 2.6 g protein per 100 kcals. They began feeds within 12 hours post op and were increased by 1 mL/kg/hr as tolerated, towards a goal of 130 mL/kg/d. The infants continued this intervention for 5 days. The authors primary outcomes of interest were daily intakes of protein, lipid, carbohydrate, energy, and urea nitrogen concentration in 24- hours urine output.

ENDF supported meeting nutrition goals sooner than standard infant formula with comparable tolerance

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Results

1 – Nutritional Status

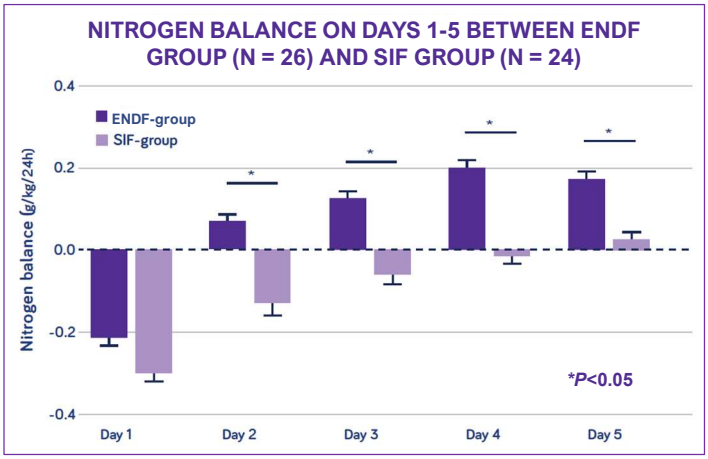
- ENDF group met adequate intake for energy and macronutrients before day 2
- SIF group only achieved adequate intake for CHO on days 2- 5

2 – Tolerance

- Increased stool frequency in the ENDF group on days 3 and 4 in the ENDF group
- Stool frequency and volume did not differ between groups overall

3 – Clinical outcomes

- No significant differences in infection, poor wound healing, prolonged ICU stay or prolonged ventilation time



CHO = carbohydrate; SIF = standard infant formula; ENDF = energy- and nutrient-dense formula. 1. Cui Y et al. JPEN J Parenteral and Enteral Nutrition. 2018.

When evaluating nutritional results, authors defined adequate intake as 87 kcal/kg/24 hours, protein of 2.67 g/kg/24 hours, carbohydrate of 7.95 g/kg/24 hrs and fat as 4.8 g/kg/24 hours. The ENDF group met these adequate intakes for energy and all macronutrients on day 2, but the SIF group achieved adequate intake for carbohydrates only on days 2-5, and did not meet adequate intakes for the remaining macronutrients by day 5 of the study.

When looking at tolerance for the combined study period there were no differences in stool frequency. When looking at individual days, authors found an increase in stool frequency in the ENDF group compared to the SIF group on days 3 and 4. When looking at clinical outcomes, there were no difference between groups for infection, poor wound healing, prolonged ICU days, or prolonged ventilation days.

And lastly, looking at the figure on the right we can see the nitrogen balance for each group on each of the 5 days. The ENDF group is in dark purple, and the SIF is in light purple. Both groups were in a negative nitrogen balance on POD 1, however by POD 2, the ENDF group is in a positive nitrogen balance which is significantly higher than the SIF group, and it takes the SIF until POD 5 to switch into a positive nitrogen balance.

Cui, et al. 2018.- Author conclusions

Nutritional Status

1) Achieve positive nitrogen balance in as little as 2 days
2) Promote anabolism compared to SIF

Tolerance

1) Equivalent tolerance to SIF
2) Well-tolerated in critically ill infants, including infants post-op for CHD repair

Safety

Safe in infants with growth failure due to CHD & other causes of growth failure

Cui and colleagues concluded that an ENDF improved nutrition status and supported anabolism post operatively, that it was well tolerated and safe.

IN SUMMARY

- CHD severity varies based on defect
- Growth failure is common among infants with CHD
- Providing adequate nutrition is challenging due to:
  - Infants tire easily
  - Feeding interruptions
  - Potential malabsorption
  - Increased energy needs
- Infants with CHD have better growth if a feeding protocol is in place
- Incorporating ENDF into care plans may improve growth among infants
- ENDF is safe, well tolerated and supports catch up growth among infants with CHD

We have covered a lot in this module. In summary, CHD severity varies based on defect. Growth failure is common among infants with CHD. Providing adequate nutrition is challenging due to the fact that infants tire easily, they have feeding interruptions and may have malabsorption. Infants with CHD have better growth if a feeding protocol is in place. Incorporating ENDF into care plans may improve growth among infants. And finally, an ENDF is safe, well tolerated and supports catch up growth among infants with CHD.

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