Cardiac NEC

This webinar is dedicated to Leyden.

#preventNEC
@NECsociety
FALL 2020 WEBINAR SERIES

ALL WEBINARS 3 PM EASTERN

SEPTEMBER 30  CARDiac NEC
OCTOBER 14  LONG TERM NEC OUTCOMES
NOVEMBER 18  NESt TRIAL
What are the long-term outcomes of NEC?

Learn more about our research project:
NECsociety.org

#preventNEC
Run for the NEC Society in your own community!
All proceeds support the NEC Society in building a world without NEC

REGISTER: address to come
Disclosure

• The NEC Society and featured faculty are not providing medical advice.

• All faculty views are independent from the NEC Society.
Preterm vs Term (Cardiac) NEC

Steven McElroy, MD
Associate Professor
Stead Family Dept of Pediatrics
Microbiology and Immunology
Graduate Program in Immunology
steven-mcelroy@uiowa.edu
Disclosures

• Evolve Biosystems collaboration

• Defensin Therapeutics collaboration

• Consultant for Abbott Nutrition

• Drawings created with BioRender.com
An acute inflammatory disease process of the bowel

Primarily a disease of premature infants
  - 7% incidence worldwide in ELBW infants

Mortality rate of 30% and can account for 10% of deaths in the NICU
NEC incidence is gestation-dependent...

**FIGURE 2**
Distribution of cases of NEC according to GA and postmenstrual age (PMA) in the study cohort.

Yee, *Pediatrics* 2012
How do we think NEC happens?
An as of yet unknown factor allows for a weakening of the protective barrier of the intestine

- Hypoxia
- Inflammation
- biome changes
- genetic predisposition
- Formula feeding factors
- ???
• This leads to:
  – Activation of Pattern Recognition Receptors (TLRs)
  – Disruption of Paneth cells
  – Loss of barrier integrity
  – Bacterial invasion
• This leads to:
  
  – Influx of inflammatory leukocytes
  
  – Which create free radicals and induce further inflammation
Development of pneumatosis intestinalis

Histology from Cornell University Medical College

Photo by SJ McElroy

Pneumatosis

Radiograph and bowel picture with permission by SJ McElroy
But so far we have only talked about...
But NEC does happen at term...

- 10-20% of neonates with NEC are term
- 0.4% of all term infants admitted to a NICU develop NEC
- Important to note: Term infants have essentially a fully mature intestine
Where does our information come from?

- Three large cohort studies
  - Christensen and Lambert (2013)
    - 11,596 infants from Intermountain Health from 2001-2011
  - Li (2017)
    - 70,326 from Children’s Hospital of Chongquing from 1996-2015
  - Overman (2019)
    - 170 infants from CS Mott Children’s Hospital from 2003-2012
Facts about term NEC

• These infants have associated co-morbidities
  • Intrauterine growth restriction
  • Sepsis
  • Asphyxia
  • Formula feeding
  • Neonatal abstinence syndrome
  • Congenital Heart Disease
Facts about term NEC

• Typically present at 6-22 days of life
  • Later onset seems to be more consistent with cardiac disease

• Bloody stools and radiologic changes are most often the first signs

• Most commonly have colon as site of NEC
  • Small intestine is the site of preemie NEC

Photo by SJ McElroy
NEC and Congenital Heart Disease

- **Risk factors:**
  - Prematurity
  - Impaired Systemic Perfusion
  - Overfeeding (esp with formula)
  - Hypoplastic Left Heart Syndrome (may be as high as 8% develop NEC)
  - Truncus arteriosus

- **Associated mortality**
  - Preemies: ~30%
  - Non-cyanotic CHD: 39%
  - Cyanotic CHD: 57%
  - Preterm with CHD: 43%
Asphyxia can induce NEC-like injury

• Severe decreases in piglet intestinal blood flow in both SMA and abdominal aorta cause NEC-like injury

Gellen B Pediatr Surg Int 2003
Term infants with CHD and NEC have abnormal blood flow patterns

- Persistent diastolic reversal in the abdominal aorta is associated with NEC in infants with CHD

*Carlo Pediatrics* 2007

- Study looked at 18 infants with CHD and NEC compared to 20 infants with CHD alone (matched diagnosis and age)

Image Source: Gray’s Anatomy
Term infants with CHD and NEC have abnormal blood flow patterns

- Fifty-one infants with HLHS who received an MRI.
  - Those with feeding intolerance or NEC had lower aortic flow
  
  Papneja *Int J Cardiovasc Imaging* 2020

- Retrospective cohort study looking at clinical characteristics in 36 surgical NEC infants
  - Infants with cardiac diagnoses (PDA or CHD) had higher levels of macroscopic necrosis and of intraoperative bacteria compared to preterm NEC infants
  - suggesting increased intestinal necrosis and ability of bacteria to invade tissue

  Diez *Frontiers Pediatr* 2020

---

**Fig. 1** Volume rendered reconstruction of a magnetic resonance angiogram, shown from the posterolateral aspect. The aortic arch is hypoplastic and joins a large caliber patent ductus arteriosus. *AAO* ascending aorta, *DAO* descending aorta, *PDA* patent ductus arteriosus

---

**Fig. 3** Descending aorta flow in patients who experienced feeding intolerance or NEC vs. those who did not.
This reduced blood flow may predispose to secondary injury

Thanks for listening! I will take questions at the end.
A Review of the Types of Critical Congenital Heart Disease Associated with Greater Risk of NEC

Kaitlin L’Italien, MD MS
Pediatric Cardiologist, Nationwide Children’s Hospital
Assistant Professor of Pediatrics, The Ohio State University College of Medicine
Objectives

• Understand the meaning of Critical Congenital Heart Disease (CCHD) and types commonly associated with poor systemic blood flow

• Describe Left Sided Obstructive heart lesions and the mechanism by which systemic blood delivery is impaired

• Understand the concept of Pulmonary Overcirculation and Systemic Steal and which types of CHD may be at risk

• Review the features of Hypoplastic Left Heart Syndrome that places those patients at unique risk for NEC
Disclosures

• None
The Normal Heart
The Normal Heart

Deoxygenated blood returns from the body via the superior and inferior vena cavae.
The Normal Heart

And returns to the Right Atrium
The Normal Heart

Exits the right atrium through the Tricuspid valve
The Normal Heart

And enters the Right Ventricle
The Normal Heart

Right ventricle pumps the blood through pulmonary valve
The Normal Heart

And into the main and branch pulmonary arteries
The branch pulmonary arteries bring the blood to the lungs.
The Normal Heart

The blood flow through the right sided heart chambers will provide the “Pulmonary Blood Flow” AKA “Qp”
The Normal Heart

Oxygenated blood returns from the lungs via the pulmonary veins
The Normal Heart

The blood enters into the left atrium
The Normal Heart

Exits the left atrium through the Mitral valve
The Normal Heart

Enters the Left ventricle which pumps the blood to the body
The blood passes through the Aortic valve.
The Normal Heart

The blood moves into the Aorta
The Normal Heart

And out to the body
The Normal Heart

The blood flow through the left sided heart chambers will provide the “Systemic Blood Flow” AKA “Qs”
The Normal Heart

\[ Q_p = Q_s \]

in a Normal Heart
Definitions:

**Congenital Heart Disease (CHD)**
Any heart malformation that is present from birth

**Critical Congenital Heart Disease (CCHD)**
CHD that requires surgery or intervention in the first year of life
One category of severe CCHD is a “Ductal Dependent” Heart Lesion

- CCHD that requires a Patent Ductus Arteriosus to help supply blood to the Pulmonary or Systemic Circulation
- Babies require a medication, Prostaglandin, to keep the PDA open after birth
- Patient will require CHD surgery as a neonate
CHD with Higher Risk of NEC

McElhinney et al. in Pediatrics, 2000:

- Hypoplastic Left Heart Syndrome (HLHS)
- Left Ventricular Outflow Tract Obstruction/Coarctation
- Any Single Ventricle Heart Disease (with or without arch obstruction)
- Palliation with a Shunt (BTT or Central)
- Truncus Arteriosus/AP Window
- Low Systemic Cardiac Output State/Shock
CHD with Higher Risk of NEC

Lau et al. in J Ped Surg, 2018:

<table>
<thead>
<tr>
<th>Cardiac lesion</th>
<th>No. of patients (n = 61)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLHS</td>
<td>16</td>
</tr>
<tr>
<td>Atrial Septal Defect</td>
<td>7</td>
</tr>
<tr>
<td>Ventricular Septal Defect</td>
<td>6</td>
</tr>
<tr>
<td>TGA</td>
<td>5</td>
</tr>
<tr>
<td>DORV</td>
<td>5</td>
</tr>
<tr>
<td>Coarctation of the aorta</td>
<td>3</td>
</tr>
<tr>
<td>Atrioventricular canal</td>
<td>3</td>
</tr>
<tr>
<td>Hypoplastic right ventricle</td>
<td>3</td>
</tr>
<tr>
<td>Truncus Arterious</td>
<td>2</td>
</tr>
<tr>
<td>ASD + VSD</td>
<td>2</td>
</tr>
<tr>
<td>Pulmonary atresia</td>
<td>2</td>
</tr>
<tr>
<td>Interrupted aortic arch</td>
<td>1</td>
</tr>
<tr>
<td>TAPVR</td>
<td>1</td>
</tr>
<tr>
<td>Coronary fistula</td>
<td>1</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>1</td>
</tr>
<tr>
<td>Pulmonary stenosis</td>
<td>1</td>
</tr>
<tr>
<td>Shone Complex</td>
<td>1</td>
</tr>
<tr>
<td>Tetralogy of Fallot</td>
<td>1</td>
</tr>
</tbody>
</table>

Distribution of patients with various cardiac anomalies.

HLHS: Hypoplastic left heart syndrome, TGA: Transposition of the great arteries, DORV: Double outlet right ventricle, ASD: Atrial septal defect, VSD: Ventricular septal defect, TAPVR: Total anomalous pulmonary venous return.
What Problems May Reduce Systemic Circulation in Patients with CHD?
What Problems May Reduce Systemic Circulation in Patients with CHD?

Mechanical Obstruction
What Problems May Reduce Systemic Circulation in Patients with CHD?

Mechanical Obstruction

Too much pulmonary blood flow and not enough systemic (Qp>>Qs)
What Problems May Reduce Systemic Circulation in Patients with CHD?

Mechanical Obstruction

Left Sided Obstructive Congenital Heart Disease

Coarctation of the Aorta

Narrowed Aorta

AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
RA = Right Atrium
LV = Left Ventricle
RV = Right Ventricle

Oxygen-rich Blood
Oxygen-poor Blood
Left Sided Obstructive Lesions

- Stenotic Aortic Valve
- Mitral valve stenosis
- Coarctation of the Aorta
- Interrupted Aortic Arch

Key:
- AD = Aorta
- PA = Pulmonary Artery
- LA = Left Atrium
- LV = Left Ventricle
- RV = Right Ventricle
- IA = Interrupted Aorta
- PDA = Patent Ductus Arteriosus
- VSD = Ventricular Septal Defect
Left Sided Obstructive Lesions

Stenotic Aortic Valve

Mitrval valve stenosis

Narrowed mitral valve

Mitral valve normal

Coarctation of the Aorta

Interrupted Aortic Arch

AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
LV = Left Ventricle
RV = Right Ventricle
VSD = Ventricular Septal Defect
PDA = Patent Ductus Arteriosus
Left Sided Obstructive Lesions

Stenotic Aortic Valve

Aortic valve

Coarctation of the Aorta

Narrowed Aorta

Mitral valve stenosis

Normal mitral valve

Narrowed mitral valve

Oxygen-rich Blood

Oxygen-poor Blood

Interrupted Aortic Arch

IAA

PDA

VSD

LV

RV
Left Sided Obstructive Lesions

Stenotic Aortic Valve

Mitral valve stenosis

Normal mitral valve

Narrowed mitral valve

Coarctation of the Aorta

Interrupted Aortic Arch

AO = Aorta
PA = Pulmonary Artery
LA = Left Atrium
RV = Right Ventricle
LV = Left Ventricle
PDA = Patent Ductus Arteriosus
VSD = Ventricular Septal Defect
Left Sided Obstructive Lesions

- Stenotic Aortic Valve
- Mitral valve stenosis
- Coarctation of the Aorta
- Interrupted Aortic Arch
Left Sided Obstructive Lesions

• Obstructed flow of oxygenated blood out to body = SHOCK → tachycardia, tachypnea, poor perfusion

• Depending upon severity of obstruction may be ductal dependent and/or require neonatal surgery for correction

• Severe obstruction decreases gut perfusion and raises risk for NEC
What Problems May Reduce Systemic Circulation in Patients with CHD?

Too much pulmonary blood flow and not enough systemic (Qp>>Qs)
Too much pulmonary blood flow and not enough systemic (Qp>>Qs)

What Problems May Reduce Systemic Circulation in Patients with CHD?
What Problems May Reduce Systemic Circulation in Patients with CHD?

Too much pulmonary blood flow and not enough systemic (Qp>>Qs)

Left to Right Shunts

Mixing Lesions (with Qp>Qs)
Left to Right Shunts

- Ventricular Septal Defect
- Atrial Septal Defect
- Atrioventricular Canal Defect
- Patent Ductus Arteriosus
- Aortopulmonary (AP) Window
Left to Right Shunts

- Ventricular Septal Defect
- Atrial Septal Defect
- Atrioventricular Canal Defect
- Patent Ductus Arteriosus
- Aortopulmonary (AP) Window
Left to Right Shunts

- Ventricular Septal Defect
- Atrial Septal Defect
- Atrioventricular Canal Defect
- Patent Ductus Arteriosus
- Aortopulmonary (Ap) Window
Left to Right Shunts

Ventricular Septal Defect

Atrial Septal Defect

Atrioventricular Canal Defect

Patent Ductus Arteriosus

Aortopulmonary (AP) Window
Left to Right Shunts

- Ventricular Septal Defect
- Atrial Septal Defect
- Atrioventricular Canal Defect
- Patent Ductus Arteriosus
- Aortopulmonary (AP) Window
Left to Right Shunts

- Key Concept: Blood will always move from higher pressure chamber to lower pressure chamber

- Unless there is some other problem that increases the pressure, blood will ALWAYS move from Left to Right

- LV to RV
- LA to RA
- Aorta to MPA
Left to Right Shunts

• Key Concept: Blood will always move from higher pressure chamber to lower pressure chamber

• Unless there is some other problem that increases the pressure, blood will ALWAYS move from Left to Right

LV to RV  Aorta to MPA  LA to RA
Left to Right Shunts

- Key Concept: Blood will always move from higher pressure chamber to lower pressure chamber

- Unless there is some other problem that increases the pressure, blood will ALWAYS move from Left to Right

- LV to RV
- LA to RA
- Aorta to MPA
Left to Right Shunts

- Key Concept: Blood will always move from higher pressure chamber to lower pressure chamber
- Unless there is some other problem that increases the pressure, blood will ALWAYS move from Left to Right

LV to RV
LA to RA
Aorta to MPA
Left to Right Shunts

CHD with L to R shunts $\rightarrow$ extra blood flow to the lungs (increased Qp) and decreased blood flow to the body (decreased Qs)

- LV to RV
- LA to RA
- Aorta to MPA
Left to Right Shunts

- Pulmonary “overcirculation” (high Qp) and relative decreased systemic output (low Qs) --> Sx of tachypnea, poor feeding, FTT

- In severe cases where Qp>>>Qs can lead to gut hypoperfusion and risk of NEC

- Can lead to irreversible pulmonary vascular changes → pulmonary hypertension

- May require CHD surgery based on symptoms/overall size of shunt and likelihood of spontaneous closure
What Problems May Reduce Systemic Circulation in Patients with CHD?

Too much pulmonary blood flow and not enough systemic (Qp >> Qs)

Left to Right Shunts
What Problems May Reduce Systemic Circulation in Patients with CHD?

Too much pulmonary blood flow and not enough systemic (Qp>>Qs)

Left to Right Shunts

Mixing Lesions (with Qp>Qs)
Mixing Lesions

RED (Primary)
BLUE (Primary)

VIOLET (Secondary)
Mixing Lesions

All the pulmonary venous return (oxygenated blood)
Mixing Lesions

All the pulmonary venous return (oxygenated blood)

All the systemic venous return (deoxygenated blood)
Mixing Lesions

All the pulmonary venous return (oxygenated blood)

All the systemic venous return (deoxygenated blood)

Completely Mixed!
Mixing Lesions

- Hypoplastic Left Heart Syndrome
- Tricuspid Atresia
- Total Anomalous Pulmonary Venous Return (TAPVR)

Images of heart diagrams illustrating the anatomical features of each condition.
Mixing Lesions

Versions of “Single Ventricle CHD”
Mixing Lesions

Hypoplastic Left Heart Syndrome

Very Small Aorta
Vessel Connecting Aorta and Pulmonary Artery
Opening Between Atria
Underdeveloped Left Ventricle

Tricuspid Atresia

Oxygen-rich Blood
Oxygen-poor Blood
Mixed Blood
AO = Aorta
PA = Pulmonary Artery
LA = left atrium
LV = Left Ventricle
RV = right Ventricle

Truncus Arteriosus

AO = aorta
PA = pulmonary artery
LA = left atrium
RV = right Ventricle

Continued aorta and pulmonary artery

Opening between ventricles

Total Anomalous Pulmonary Venous Return (TAPVR)

Right pulmonary vein
Left pulmonary vein
Common pulmonary vein
Vertical vein
Diaphragm

Versions of “Single Ventricle CHD”
Mixing Lesions

Versions of “Single Ventricle CHD”
Mixing Lesions

Hypoplastic Left Heart Syndrome

Tricuspid Atresia

Total Anomalous Pulmonary Venous Return (TAPVR)

Versions of “Single Ventricle CHD”
Mixing Lesions

versions of “single ventricle CHD”
Mixing Lesions

• Presentation is variable and depends whether “too much” or “too little” pulmonary blood flow, rarely well balanced

• If “too much” of the mixed blood is going to the lungs → pulmonary overcirculation → tachypnea, high sats, difficulty feeding, poor systemic perfusion

• If $Q_p >> Q_s$ risk for gut hypoperfusion and NEC

• If “too little” of the mixed blood is going to the lung → signs of significant cyanosis

• May be ductal dependent for pulmonary or systemic blood flow
Why do patients with HLHS seem to have increased risk of NEC?
Why do patients with HLHS seem to have increased risk of NEC?
They have potential for both problems!!

Hypoplastic Left Heart Syndrome

- Very Small Aorta
- Vessel Connecting Aorta and Pulmonary Artery
- Opening Between Atria
- Underdeveloped Left Ventricle
- RV = Right Ventricle
- PA = Pulmonary Artery
- LA = Left Atrium
- AO = Aorta
- LV = Left Ventricle

Oxygen-rich Blood
Oxygen-poor Blood
Mixed Blood
Why do patients with HLHS seem to have increased risk of NEC? They have potential for both problems!!
Why do patients with HLHS seem to have increased risk of NEC?

They have potential for both problems!!

Mixing Lesion with potential for $Q_p >> Q_s$
Why do patients with HLHS seem to have increased risk of NEC?

They have potential for both problems!!
Thank You!
Feeding Practices in Infants with Congenital Heart Disease

Amy B. Hair, M.D.
Assistant Professor of Pediatrics
Program Director of Neonatal Nutrition
Program Director of Intestinal Rehabilitation Team
Section of Neonatology
Department of Pediatrics
Baylor College of Medicine
Texas Children’s Hospital
Neonatal Nutrition Program
Disclosures

- I receive research grants from:
  - Prolacta Bioscience® for the Human Milk Cream Length of Stay Multicenter Study (Study PI) and Cardiac Study; Fresenius Kabi for SMOF Randomized Trial
Objectives:

• Discuss current feeding practices

• Summarize the literature regarding feeding practices and identify knowledge gaps

• Review the benefits of human milk for infants

• Review recent studies of human milk use for Congenital Heart Disease infants
Feeding Practices in Infants with Congenital Heart Disease

Feeding Practices in Infants with Congenital Heart Disease

- Data from premature neonates extrapolated to other populations

- Paucity of data for optimal feeding practices specifically for infants with ductal-dependent lesions
  - Lack of consensus and wide variation in feeding practice
  - No prospective studies
  - Very few human milk studies

Slicker et al. 2016
Feeding Protocols

• Standardization of care can lead to improvement in outcomes

• Use is often at discretion of provider (comfort level, experience)

• Impedes well-designed, multi-center studies from being conducted

Feeding Protocols

“Wide variations in practices exist in the nutritional care between European PICUs, which reflects the absence of local protocols and scientific society-endorsed guidelines.”

Enteral Feeding Practices in Infants With Congenital Heart Disease Across European PICUs: A European Society of Pediatric and Neonatal Intensive Care Survey*

Lyvonne N. Tume, RN, PhD; Reinis Balmaks, MD, Dr. Med; Eduardo da Cruz, MD; Lynne Latten, RD, BSc (Hons); Sascha Verbruggen, MD, PhD; Frédéric V. Valla, MD, MSc; on behalf of the members of the European Society of Pediatric and Neonatal Intensive Care Pediatric and Congenital Cardiac Intensive Care & Mechanical Circulatory Support Section, the Metabolism-Endocrinology-Nutrition Section, and the Nurse Science Section

Tume et al. 2018
Literature Review

Pubmed search: enteral feeding congenital heart disease
Literature Review

**Enteral feeding of neonates with congenital heart disease.**
Natarajan G, Reddy Anne S, Aggarwal S.  

**Preoperative trophic feeds in neonates with hypoplastic left heart syndrome.**
Toms R, Jackson KW, Dabal RJ, Reebals CH, Alten JA.  

**Enteral feeding in prostaglandin-dependent neonates: is it a safe practice?**
Willis L, Thureen P, Kaufman J, Wymore E, Skillman H, da Cruz E.  

**Necrotizing enterocolitis in infants with ductal-dependent congenital heart disease.**
Becker KC, Hornik CP, Cotten CM, Clark RH, Hill KD, Smith PB, Lenfestey RW.  

**Preoperative Feeding Neonates With Cardiac Disease.**
Scahill CJ, Graham EM, Atz AM, Bradley SM, Kavara NA, Zyblewski SC.
• Systematic review and Meta-analysis to summarize the evidence for pre-operative feeds in infants with ductal-dependent congenital heart disease

  • Majority of studies focus on post-operative feeding and hospital outcomes
  • Insufficient evidence that pre-operative enteral feeds adversely affect post-operative outcomes
  • Illustrates need for well-designed, prospective study
Risk of Feeding

- Necrotizing enterocolitis
- Mesenteric hypoperfusion
  - Particularly ductal-dependent due to risk of ductal steal
- Vulnerable vascular system undergoing cardiac surgery → ischemia
Risk of NOT Feeding

- Atrophy of intestinal mucosa
- Loss of important intestinal cell wall barriers
- Abnormal increase in gut permeability
- Delayed postnatal intestinal development and maturation
- Motility problems
Early Feedings with Human Milk for Premature Infants

- Breast milk: best source of nutrition when safe & available
  - ↓ Infection
  - ↓ Necrotizing enterocolitis (NEC)
  - ↓ Chronic lung disease
  - ↑ Neurodevelopmental outcomes

- Promote postnatal intestinal development & maturation → healthy intestinal microbiota

Non-Nutritional Components of Human Milk

**Antimicrobial**
- secretory IgA, IgM, IgG
- lactoferrin
- lysozyme
- complement C3
- leukocytes
- bifidus factor
- lipids and fatty acids
- antiviral mucins, GAGs
- oligosaccharides

**Digestive enzymes**
- amylase
- bile acid-stimulating esterase
- bile acid-stimulating lipases
- lipoprotein lipase
- Proteases

**Growth factors**
- epidermal (EGF)
- nerve (NGF)
- insulin
- insulin-like (IGF)
- transforming (TGF)
- taurine
- polyamines
- gastrin
- gastric inhibitory peptide (GIP)
- Gastric regulatory peptide (GRP)
- neurotensin
- peptide histidine methionine (PHM)
- Peptide YY (PYY)

**Hormones**
- feedback inhibitor of lactation (FIL)
- insulin
- prolactin
- thyroid hormones (T2, T3, Reverse T3)
- corticosteroids, ACTH
- oxytocin
- calcitonin
- parathyroid hormone
- erythropoietin
- progesterone
- estrogen

**Anti-inflammatory**
- tumor necrosis factor
- interleukins
- interferon-g
- prostaglandins
- a1-antichymotrypsin
- a1-antitrypsin
- platelet-activating factor: acetyl hydrolase

**Transporters**
- lactoferrin (Fe)
- xanthine oxidase
- glutathione peroxidase
- alkaline phosphatase
- folate binder
- cobalamin binder
- IgF binder
- thyroxine binder
- corticosteroid binder
Knowledge Gap

- Is it safe to feed neonates with ductal-dependent CHD preoperatively?
- Do the benefits outweigh the risks?
- Does the type of cardiac lesion matter?
- What about the use of human milk?
  - Does feeding CHD infants human milk confer the same benefits as it does for premature infants?
  - Does human milk lead to an improvement in outcomes for this population as it does in premature infants?
TCH Experience

- Retrospective study of 546 infants with complex CHD at Texas Children’s Hospital from 2010-2016
- Evaluate risk of pre-operative NEC with human milk feeding
- Overall incidence of pre-operative NEC 3.3%
- An exclusive unfortified human milk diet was associated with a significantly lower risk of pre-operative NEC (OR 0.17, 95% CI 0.04 - 0.84, P = .03)

*Human Milk Use in the Preoperative Period Is Associated with a Lower Risk for Necrotizing Enterocolitis in Neonates with Complex Congenital Heart Disease.*

Cognata A1, Kataria-Hale J1, Griffiths P2, Maskatia S3, Rios D1, O’Donnell A1, Roddy DJ4, Mehollin-Ray A5, Hagan J1, Placencia J1, Hair AB6.
Challenges over the past 10 years at TCH:

• Examples of barriers we have encountered:
  • No dedicated refrigerators for mother’s own milk
  • Limited lactation support
  • Limited lactation education for all providers and caregivers
  • Extreme fear of NEC
  • Lack of evidence-based protocols
  • Lack of literature to guide practice
  • Nutrition “doesn’t matter”
FEEDING PROTOCOL FOR NEONATES WITH DUCTAL-DEPENDENT CONGENITAL HEART DISEASE BEFORE SURGERY

General Principle: Our data suggest that an unfortified, exclusive human milk diet is protective in infants with ductal-dependent congenital heart disease.

Infant should receive oral care with mother’s colostrum within 6 hours of birth. Apply 0.2 mL to each buccal mucosa via syringe or swab every 3 hours regardless of clinical status or respiratory support.

Continue oral care with mother’s breast milk until first surgery

Factors to consider prior to starting feeds:
- Low and stable lactate trend
- Normal urine output
- HR, MAP and DBP appropriate for age
- NIRS trend stable
- Minimal or no inotropic support

Total fluid restriction 120-140 mL/kg/day

Start bolus enteral feeds of EBM at 20 mL/kg/day divided q3h. Feeds should be PO. Do not advance for 24 hours and monitor for intolerance
- TPN/I/IL to meet total fluid restriction of 120-140 mL/kg/day

Advance enteral feeds by 20 mL/kg/day to maximum feeding volume of 40-60 mL/kg/day as tolerated
- TPN/I/IL should be weaned proportionately to meet total fluid restriction, provided there is still adequate nutrient intake

If surgery date postponed, please discuss advancement of feeds versus continuation of TPN/I/IL with Neo Nutrition Team.

* Decision to start enteral feeds to be made in discussion with Neo team, Cardiology, and Neo Dietitian
* Mother’s own milk preferred over donor EBM. The use of formula should be avoided
* Feeds should NOT be fortified in pre-intervention period unless discussed with Neo Nutrition Team
* Please reassess need for EBM after 4 weeks based on cardiac physiology and clinical status
Oral Care with Colostrum

©Katariia-Hale
Proportion of Infants Receiving Formula Before Surgery

![Bar chart showing the proportion of infants receiving formula before and after a protocol. Pre-Protocol: 41.6% (P<0.0001, Fisher's Exact Test) vs. Post-Protocol: 100%.](chart.png)

Kataria-Hale and Hair, et al. Under review
What’s next?

• If there is one intervention you can do in your unit, it would be to increase the use of mother’s own milk!

• Guidelines are coming
  • Neonatal Heart Society in conjunction with other societies is working on the Neonatal Cardiac Care Collaborative

• Research Studies are pending
  • Donor milk use
  • Ongoing nutrition study in single ventricle babies- using a donor human milk-derived term fortifier
Acknowledgements

• Neonatal Cardiac Nutrition
  • Jeramy Roddy, MD
  • Scott Osborne, MD
  • Jasmeet Kataria-Hale, MD

• Acacia Cognata, MD
• Paul Checchia, MD
• Joseph Hagan, ScD
• Mohan Pammi, MD
• Murali Premkumar, MD
• Sharda Gowda, MD

• Neonatal Dietitians

• Neonatal Nutrition Research Group
  - Heeju Yang
  - Jana Unger, RD, MS
  - Laura Gollins, RD, MBA
  - Pam Gordon, RNC-NIC

TCH Milk Banks and Lactation
• Nancy Hurst, PhD
• Kristina Tucker, RN, MS
Thank you!

Discussion & Questions

#preventNEC
@NECsociety