CARDIOLOGY 2024

Ductal Dependent Feeds

Does it matter which way the duct flows?

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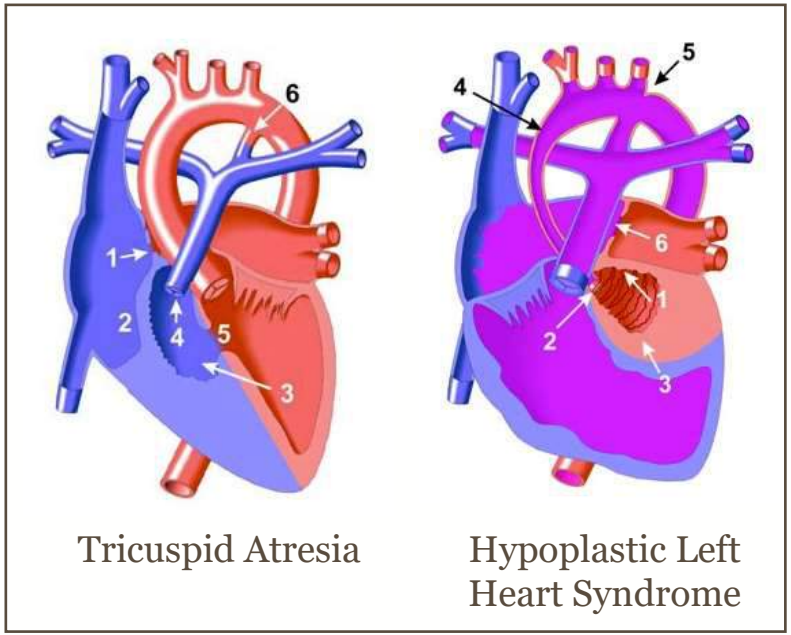
Phoenix Children's

OBJECTIVES

- Review function of fetal circulation & ductus arteriosus
- Risk of enteral feeding
- Protective factor of enteral feeds
- Practice recommendations



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REVIEW OF FETAL CIRCULATION

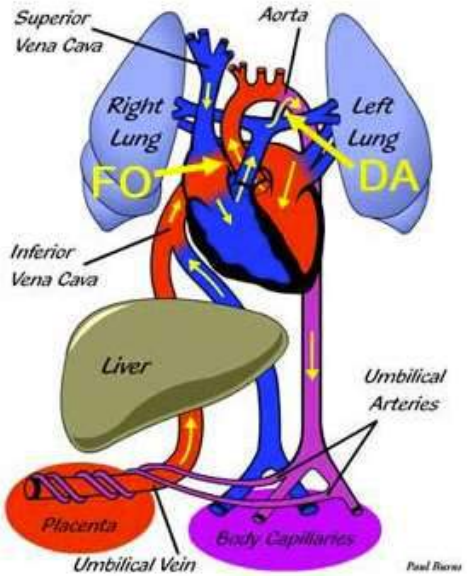
3 features of fetal circulation

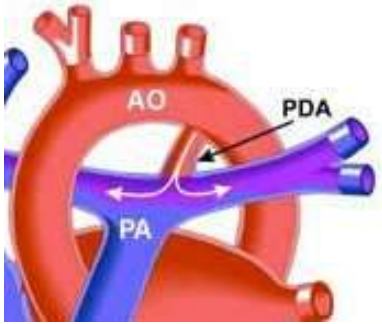
1. Foramen ovale (FO)
2. Ductus arteriosus (DA)
3. Placenta

The FO and DA allow for 80% of circulating volume to bypass the lungs during fetal life.

- Important for somatic growth & maturation
- Both “should” close around birth

The placenta is the filter





http://pted.org/?id=fetal1

WHAT'S THE RISK?

- Necrotizing enterocolitis (NEC)
- CHD major risk factor for developing NEC (3-33% of infants)
  - Assumed higher risk in ductal dependent lesions, d-transposition of the arteries (d-TGA), truncus arteriosus, aortopulmonary window
- Delay surgical repair or palliation
- Increased length of stay
- Increased morbidity & mortality

Modified Bell's Staging for NEC

Stage	Systemic Signs	Gastrointestinal Findings	Radiologic Findings
I a	Temperature instability, A&Bs, Lethargy	Elevated residuals, mild abdominal distention, emesis, guaiac-positive stool	Normal, mild ileus, mild dilation
I b	Same as I a	Above + Bright red blood from rectum	Same as I a
II a	Same as I a	Above + absent bowel sounds with or without abdominal tenderness	Intestinal dilation, ileus, pneumatosis intestinalis
II b	Above + Mild metabolic acidosis, mild thrombocytopenia	Above + definite abdominal tenderness with or without abdominal cellulitis or right lower quadrant mass	Above + portal venous gas with or without ascites
III a	Above + hypotension, bradycardia, severe apnea, combined respiratory and metabolic acidosis, DIC, neutropenia	Above + signs of generalize peritonitis, marked tenderness, abdominal distention	Above + definite ascites
III b	Same as III a	Same as III a	Above + pneumoperitoneum

Cognata, A., et. al. (2019)

WHAT'S THE SIZE OF THE RISK?

- Pre-op NEC rate between 3-11%
- Larger feed volumes pre-op increased risk of NEC (P=0.04)
  - NEC group: Median 100 mL/kg/day (IQR 40–140)
  - Non-NEC group: Median 20 mL/kg/day (IQR 0–100)
- Increased caloric density—fortification

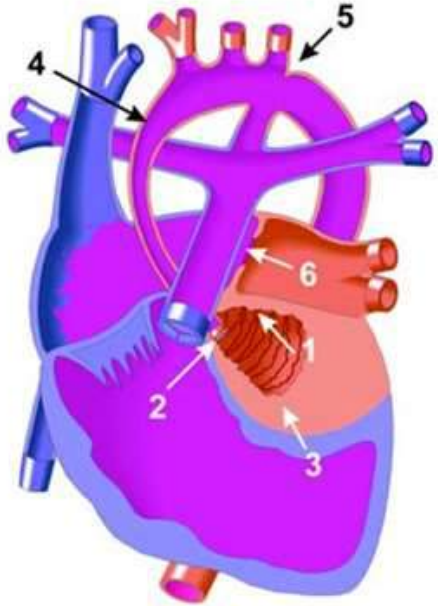
UNDERSTANDING THE PATHOPHYSIOLOGY

Hemodynamic Factors	Gut Factors
• Impaired mesenteric blood flow • Low cardiac output state & shock (mod-sev ventricular dysfunction) • Abnormal vasculature related to CHD	• Low diversity of gut microbiome • Introduction of formula • Altered mucosal barrier • Intestinal cellular atrophy

Unknown Factors

WHO'S AT RISK?

- Preterm infants
- LBW infants
- Trisomy 21
- Abdominal wall abnormalities
- Heterotaxy syndrome
- Specific CHD lesions
  - HLHS (6.1-9% risk of NEC)
- Single ventricle physiology
- Higher RACHS-1 score (higher complexity lesions)
- Previous h/o NEC



Hypoplastic Left Heart Syndrome

http://pted.org/?id=hypoplasticleft1

LONG HELD BELIEF DUCTAL DEPENDENT FEEDS

"dd-PBF safer than dd-SBF"

- Pre-op risk as defined by the science to date is conflicting
  - Some studies show no difference
  - Others show increased risk in dd-PBF
- Retrospective review of infants in NPC-QIC dataset did not have increased odds of NEC
  - 75% of study population HLHS

Characteristics	All infants with CHD and proven necrotizing enterocolitis (n = 82)	Composite primary outcome of in-hospital mortality and morbidity after diagnosis of necrotizing enterocolitis* (n = 30)	No primary outcome (n = 52)	p value
Primary cardiac diagnosis				0.49
Cyanotic mixing conditions	6 (6%)	1 (3%)	5 (10%)	
Single ventricle	44 (54%)	17 (57%)	27 (52%)	
Increased pulmonary blood flow	12 (15%)	5 (17%)	7 (13%)	
Left ventricle outflow tract obstruction	4 (5%)	3 (10%)	1 (2%)	
Right ventricle outflow tract obstruction	16 (20%)	4 (13%)	12 (23%)	
Ductal-dependent category				0.98
Biventricular pulmonary blood flow	13 (16%)	4 (13%)	9 (17%)	
Biventricular systemic blood flow	4 (5%)	2 (7%)	2 (4%)	
Biventricular other	1 (1%)	0 (0%)	1 (2%)	
Non ductal dependent	20 (24%)	7 (23%)	13 (25%)	
Single ventricle pulmonary blood flow	9 (11%)	3 (10%)	6 (12%)	
Single ventricle systemic blood flow	32 (39%)	13 (43%)	19 (37%)	
Single ventricle	3 (4%)	1 (3%)	2 (4%)	
	3 (0, 6)	2 (0, 5)	3 (0, 6)	0.37

Deitch, A., et. al. (2023)

WHAT'S THE BENEFIT?

- Unfortified human milk independently protective
  - Immunoglobulins, lactoferrin, growth factors, human milk oligosaccharides, prebiotics, cytokines
- Use of probiotics
  - Bifdobacterium Breve
  - Bifdobacterium Lactis

Bivariate Associations with NEC in the Pre-Operative Period

Risk Factor	Odds Ratio	95% CI	P-Value
Patient Gender Female	0.56	0.22–1.43	0.22
Caucasian	**0.36**	**0.13–0.99**	**0.049**
<37 weeks gestation	**2.79**	**1.06–7.39**	**0.04**
PGE dose > 0.0125	0.82	0.31–2.20	0.68
Patient was Growth Restricted	1.79	0.57–5.60	0.32
Nasal CPAP	1.48	0.32–6.95	0.62
Mechanical Ventilation	0.93	0.28–3.10	0.91
Patient Received Inotropes	1.14	0.37–3.52	0.83
Patient Received Antibiotics	2.40	0.87–6.4	0.09
Patient had culture + bacteremia	1.74	0.21–14.6	0.61
Patient received any feeds	2.59	0.74–9.05	0.14
Feeds > 100 ml/kg/day	**3.05**	**1.19–7.90**	**0.02**
Received Feeds while on PGE	1.46	0.57–3.73	0.43
Received any Feeds via Ng	1.89	0.67–5.34	0.23
Exclusively unfortified Human Milk Diet	**0.12**	**0.03–0.54**	**0.006**
Formula Fed	2.94	0.98–8.77	0.054
Fortified Feeds	2.49	0.82–7.56	0.11
Feeds started while UAC in place	0.64	0.22–1.84	0.41
Cardiac Lesion			
Patient with SV w/o ductal dep lung or sys perfusion	0.98	0.13–7.59	0.98
Patient with SV w/ductal dep pulmonary perfusion	0.99	0.22–4.43	0.99
Patient with SV w/ductal dep systemic perfusion	0.41	0.09–1.80	0.24
Patient with BV w/ductal dep pulmonary perfusion	**5.95**	**2.29–15.46**	**0.0003**
Patient with BV w/ductal dep systemic perfusion	0.2	0.03–1.55	0.13
Patient with dTGA	0.29	0.04–2.24	0.24
Truncus Arteriosus	1.09	0.14–8.51	0.93
Tetralogy of Fallot with absent pulmonary valve	5.12	0.58–44.89	0.14

Cognata, A., et. al. (2019)

BEST PRACTICE?

1. Clinical readiness for enteral feeds?
   a) Stable somatic NIRS
   b) Freedom from lactic acidosis
   c) No/Minimal inotropic support
   d) No signs & symptoms of feeding intolerance
2. Use human milk whenever possible (mom's first, then donor)
   - Mom's milk > Donor milk > Formula > NPO
3. Limit feeds to somewhere between 20 mL/kg/day and 100 mL/kg/day
4. Use human milk for oral care if not taking PO
5. Avoid delays to the OR for palliation or repair
6. Standardize feeding practices (use feeding algorithm)
7. Continual reassessment

8. Developmental plug
   a) Encourage parent to give first feed
   b) Baby to feed by mouth, if safe

REFERENCES

- Cognata A, Kataria-Hale J, Griffiths P, Maskatia S, Rios D, O'Donnell A, Roddy DJ, Mehollin-Ray A, Hagan J, Placencia J, Hair AB. 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 Dec;215:11-16.e2. doi: 10.1016/j.jpeds.2019.08.009. Epub 2019 Sep 24. PMID: 31561958; PMCID: PMC7294855.
- Deitch AM, Moynihan K, Przybylski R, Gauvreau K, Braudis NJ, Farr B, Modi B, Mills KI, Nathan M, Levy PT. Risk Factors for Adverse Outcomes in Term Infants with CHD and Definitive Necrotising Enterocolitis. Cardiol Young. 2024 Jan;34(1):92-100. doi: 10.1017/S104795112300121X. Epub 2023 May 25. PMID: 37226515.
- Kataria-Hale J, Cognata A, Hagan J, Zender J, Sheaks P, Osborne S, Roddy J, Hair A. The Relationship Between Preoperative Feeding Exposures and Postoperative Outcomes in Infants With Congenital Heart Disease. Pediatr Crit Care Med. 2021 Jan 1;22(1):e91-e98. doi: 10.1097/PCC.0000000000002540. PMID: 33009358.
- Kelleher ST, McMahon CJ, James A. Necrotizing Enterocolitis in Children with Congenital Heart Disease: A Literature Review. Pediatr Cardiol. 2021 Dec;42(8):1688-1699. doi: 10.1007/s00246-021-02691-1. Epub 2021 Sep 12. PMID: 34510235; PMCID: PMC8557173.
- Penk J, Cagle W, Holloway A, Connolly J, Miles A, Bhakta R, Jain P, Davis SP, Riley C, Roddy DJ. Multicenter Evaluation of Pre-operative Feeding in Infants with Ductal Dependent Circulation. Pediatr Cardiol. 2023 May 20. doi: 10.1007/s00246-023-03182-1. Epub ahead of print. PMID: 37209186.
- Sagiv, E., Tjoeng, Y.L., Davis, M. *et al.* Assessing the Association Between Pre-operative Feeding and the Development of Oral Feeding Skills in Infants with Single Ventricle Heart Disease: An Analysis of the NPC-QIC Dataset. *Pediatr Cardiol* **43**, 1141–1155 (2022). https://doi.org/10.1007/s00246-022-02837-9