Linking Feeding Behaviors to Developmental Outcomes

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Conflicts of Interest

- Dr. Medoff Cooper has served as a consultant to Nutricia

- *The opinions reflected in this presentation are those of the speaker and independent of Nutricia*

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- National Institute of Nursing Research
- Cardiac Center of The Children's Hospital of Philadelphia
- The University of Pennsylvania

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Objectives

- Explore feeding protocols from infancy to toddlerhood
- Describe factors which contribute to feeding dysfunction and growth failure
- Describe growth and developmental outcomes during the first two years of life

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To feed or not to feed pre-surgical intervention

- The decision to offer oral feeding prior to surgery varies from institution to institution
  - Do you feed an infant on prostaglandin?
  - Is TPN in play?
  - What are the parameters for safely feeding a newborn with CHD?
  - How long before surgery?
  - Inborn or transferred in
  - Interventions to increase oral motor skills?

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The Complexity of Complex CHD

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Plethora of Protocols

- To increase weight gain
- To prevent NEC
- To decrease time to full oral feeding
- Infant driven feeding method

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Pre-Surgical Feeding Protocol

- All infants are started on TPN
- Stable infants are offered oral feeding either at breast or bottle
  - Milk bank breast milk is available

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Post-Surgical Feeding Protocol

- TPN started on day 1
  Increase total fluid intake to 130ml/Kg/day
  IV lipids until enteral caloric intake > 100ml/Kg/day
- All infants have NG in place
  - Kept in place until infants are able to PO 100% caloric intake goals for two consecutive days.

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Who is at Risk for Feeding Dysfunction

- Single ventricle infants
- Infants dependent on TF
- Increase time NPO
- Longer intubation
- GERD

- Indramohan, et al. Journal of Pediatric Nursing, 2017

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Feeding Dysfunction

- Lack of organization in feeding pattern
- Unable to sustain feeding to ingest proscribed calories (fatigue)
- Unable to maintain HR, RR during feeding
- Cough, sputtering, gagging

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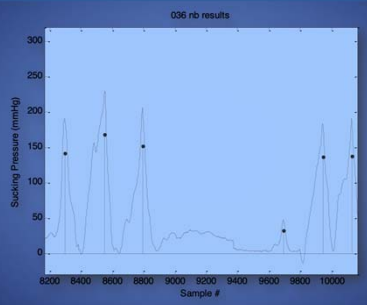
Disorganized Feeder



Medoff Cooper, Irving, (2009)
Cardiology in the Young

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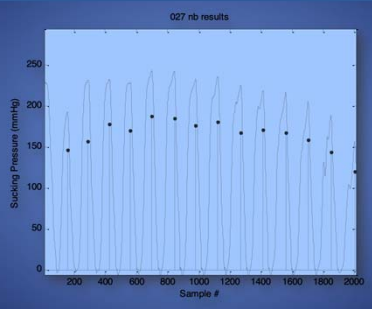
Organized Feeder



Medoff Cooper, Irving (2009) Cardiology in the Young

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The Impact of Tube Feeding

Long term TF is associated with :

longer LOS

decrease in overall length at 2 years

delay in full oral feeding

Butto, et al 2019. Congenital Heart Disease

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What is Growth Failure

- Many terms
  - Growth Failure
  - Growth Faltering
  - Failure to Thrive
- When rate of growth is below expectation based on age and gender
- Weight for age decreasing across two major percentiles
- WAZ <-2

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Growth Faltering

- Infants with complex CHD are usually born full term and within normal weight ranges
- Nutritional issues often emerge shortly after surgery and persist throughout the first years of life
- Growth faltering is associated with an array of health problems which appears to be related to feeding challenges.

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Growth Faltering

- All infants who experience neonatal cardiac surgery are at risk for experiencing growth faltering during first year of life
- Most at risk are infants who have undergone Stage I palliation
- A decrease in weight for age weight z-score of more than 0.67 is strongly associated with mortality during the first year of life.(Eskedal, et al, Arch Dis Child, 2008)

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Early Growth Faltering

- Malnutrition early in life is associated with later neurobehavioral deficits
- Later growth and cognitive deficiencies in children with early growth faltering including:
  - Short stature
  - Poor arithmetic performance
  - Attention problems and behavioral problems
  - Poor overall emotional, social and cognitive development

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Factors Contributing to Growth Faltering

- Poor Feeding
- Chronic Hypoxia
- Persistent Tachypnea
- Venous Congestion
- Overload of Fluid
- Gastro-Esophageal Reflux
- Genetic Syndromes
- Other Non-cardiac Anomalies

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Growth Faltering

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Causes of Dysfunctional Feeding

Stress
Fluid restriction
Dysphagia
Feeding Behaviors
NPO Hours
GERD
NEC
Neurologic insults
Immature brains

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Feeding Difficulties – Dysphasia

- 20-50% of infants are at risk for dysphasia
- Potential etiology:
  - type of surgical repair
    - intraoperative manipulation of the recurrent laryngeal nerve increasing the potential for neural damage
  - Length of post-operative intubation
  - Use of trans esophageal echocardic probe
    - Ajemian et al Arch Surg 2001;36:434-437

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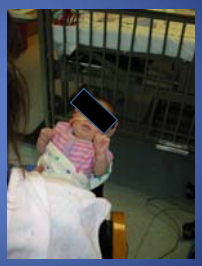
Feeding Difficulties – Poor Intake

- Poor nutritional intake
- Difficult to establish the necessary intake
- 120 kcal/kg per day
- Weight gain: 20-30 grams per day



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Enteral Feeding Practices European Survey

- Wide variations of enteral feeding practices
- 59 PICU's from 18 European countries
  - < than 60% had dedicated dieticians
  - routinely fed preoperatively in 63%
  - 78% feed during first 24 hours postoperatively
  - Intermittent bolus feeds via NG
  - 69% did not have written guidelines for feeding

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Post-Operative Feeding Practices

- Responses from CNOC Feeding Committee
  - All infants start enteral feeds via NG tubes
  - Oral feeding assessment within 24 hours via bottle
  - Weaning practices vary from unit to unit
  - Physiologic guidelines vary – may be dependent on attending staff
  - Decision to move from NG to G tube varies
  - May be different decisions based on physiology

CNOC: Cardiac Neurodevelopmental Outcomes Collaborative

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Impact of Device Assisted Feedings

- Many infants and children struggle to progress to full oral feeding
- Tube dependency is a complication of tube feeding
- Lack of oral feeding leads to deficits in cortical development as motor and sensory pathways between the pharynx and the cortex are not established.

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Impact of Device Assisted Feedings

- Association between device assisted feedings and risk of neurodevelopmental delay
- Ability to achieve full oral feedings is most significant factor associated with developmental process
- Weaning from tube feeding at earlier ages is more efficient
- Link between prolonged DA F and speech?

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Prevalence of Later Feeding Disorders in Infants and Children with CHD

- Feeding disorder in infancy and childhood is complex
- With more very sick children surviving and increase in feeding disorders
- Defined as:
  - Child still partially or completely dependent on tube assisted feedings at 2 years of age
  - Child only drinks or take pureed food
  - Failure to thrive (< 3rd percentile)

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Prevalence of Feeding Disorders

- Of 82 study subjects, 18 (22%) were diagnosed as having a feeding disorder
- Significant relationships:
  - Perioperative tube assisted feeding duration
  - LOS
  - Ventilation duration
  - Duration in CICU

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Feeding Dysfunction

- Pre-surgery: Positive Outcome
  - Infants with alert behavioral state before surgery, using the NNNS,
  - shorter time to oral feeding
  - Overall infant physiologic stability
- Post-surgery: Negative Outcome
  - Younger age at surgery,
  - ↑ ventilator days,
  - ↑ length of stay,
  - single or 2-ventricle anatomy with aortic arch obstruction
  - were associated with lower percentage of oral feeds at discharge and/or delay in full oral feeds

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CHD and Feeding Dysfunction

- What is not associated with secondary feeding disorders
  - Birth weight
  - Gestational age
  - Pre-operative hemodynamics
  - Environmental factors

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Feeding Difficulties-Gastrointestinal

- Gastroesophageal Reflux Disease
  - Children with congenital heart disease are at increased risk for complications of gastroesophageal reflux even after repair of their cardiac abnormalities.
  - The optimal management of reflux in these patients is not known.
    - Thompson et al. Journal of Pediatric Surgery. 34(9):1359-63, 1999 Se
- Fundoplication – not without risks
  - Post-operative mortality (< or =30 days) was 4.5% (5/112); 5-year survival was 74%.
  - Post-operative median weight percentiles increased to 4% at 3 months (p < .001) and to 20% at 5 years post-operatively (p = .004).
    - Cribbs et al. Journal of Pediatric Surgery. 43(2):283-9, 2008 Feb.

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Other Nutritional Factors

- Body Composition
- Resting Energy Expenditure
- Total Energy Expenditure

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Resting Energy Expenditure

- Controversy still exists about the role of increased energy expenditure in poor weight gain
- No difference in REE, as measured with a metabolic cart, compared to healthy 3 month olds
- No difference in TEE as measured by isotope dilute process

Irving, et al (2013) Congenital Heart Disease

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Total Energy Expenditure

	Healthy Infants	Infants with CHD
3 months	Mean (SD)	Mean (SD)
Weight for age z-score	-0.2 (1.0)	-0.62 (1.26)
Fat-free mass, kg	4.5 (0.5)	4.54 (0.65)
Total energy expenditure, kcal/d	403 (60)	439 (138)
6 months		
Weight for Age, z-score	0.21 (0.79) §	-0.72 (1.40)§
Length for Age, z-score	-0.07 (0.83) §	-1.10 (1.67) §
Fat-free mass, kg	6.78 (0.33)	6.92 (0.79)
Total energy expenditure, kcal/d	706 (91)	767 (124)
§ p<0.05		

Trabulsi, et al. (2015) American Journal of Clinical Nutrition

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Feeding Difficulties- Necrotizing Enterocolitis

- NEC and CHD seem to be interrelated
- Highest among infants with single ventricle physiology
- Prevalence in HLHS between 7-13%
- Earlier gestational age is a significant risk factor
  - Luce et al. Pediatric Critical Care Medicine, 2011, 12(1).

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Feeding Difficulties- Neurologic Compromise

- Immature/compromised brain associated with poor feeding
  - Periventricular leukomalacia
  - Strokes before and after surgery
  - CPB and DHCA may contribute to brain injury
    - Licht, D.J., et al. J Thorac Cardiovasc Surg, 2009. **137**(3): p. 529-36
    - Donofrio, Massaro International Journal of Pediatrics, 2010, p1-13.

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Other Risk Factors

Feeding disorders observed during the first hospital stay

Multiple operations

Presence of neurologic abnormalities

SV physiology

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Human Milk and Breastfeeding Outcomes

- 89% of mothers initiated lactation via pumping
- Mothers pumped 5-6 times per day
- Achieved milk supply over 500 mL/day
- Over 70% of infants received breast milk
- 13% of infants were put to breast

- Torowicz, et al. Breastfeeding Medicine, 10(1), 2015

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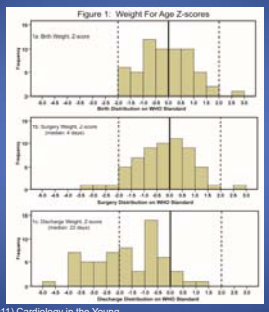
WHO Weight for Age Z scores – Single Ventricle



Medoff Cooper et al (2011) Cardiology in the Young

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Discharge Practices

- Infants going home with NG tubes
  - Parents reinsert tubes
  - Parents come back to ER for reinsertion of tubes
- Infants going home with G tubes
  - Risks involved with another surgical procedure
  - Infants with swallowing issues
- Infants kept in unit if full oral feeding is not accomplished

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Feeding Challenges after Discharge

- Difficulties with fortification
- Managing vomiting
- Achieving daily calorie goals
- Reflux management

- Strategies
  - Frequent contact with families
  - Listening to parental concerns
  - Individualizing feeding approach
  - Team approach with cardiologist and nurse

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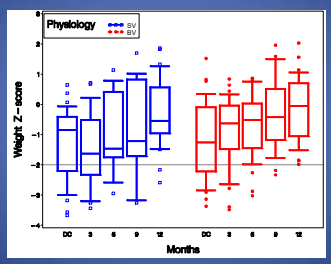
Weight Z-scores Over the 1st Year



Medoff Cooper et al. (2015) J Peds

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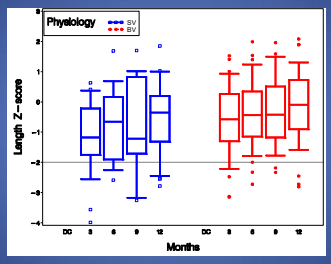
Length Z-scores Over the 1st Year



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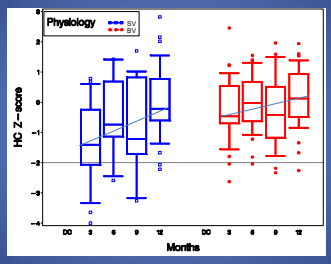
Head Circumference Z-scores Over the 1st Year



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Proportion of Infants with Weight Z-scores ≤-2

Month	Overall	SV	BV	p-values[a]
Discharge	30%	28%	31%	0.99
Month 3	27%	33%	22%	0.40
Month 6	16%	28%	9%	0.11
Month 9	9%	11%	7%	0.99
Month 12	3%	6%	0%	0.22

Medoff Cooper et al. (2015) J Peds

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Comparison of Neurodevelopment Outcomes by Physiology & Feeding Mode

	MDI at 6 mo Mean (SD)	MDI at 12 mo Mean (SD)	PDI at 6 mo Mean (SD)	PDI at 12 mo Mean (SD)
Physiology				
Single ventricle	90.53 (8.78)	91.18 (10.33)	76.58 (14.77)	73.94 (15.78)
Bi-ventricle	92.81 (10.56)	97.05 (12.60)	83.97 (13.47)	84.58 (15.33)
Sub-sample P value	0.435	0.035	0.074	0.005
Feeding mode at discharge				
Orally fed	94.62 (10.25)	96.16 (12.68)	85.70 (11.58)	80.47 (15.36)
Tube assisted	89.04 (8.79)	92.18 (10.70)	76.17 (15.54)	78.53 (17.54)
Sub-sample P value	0.045	0.157	0.016	0.618
Feeding mode at 3 months				
Orally fed	93.18 (9.14)	94.98 (12.15)	83.43 (12.85)	81.84 (15.36)
Tube assisted	80.8 (10.33)	89.9 (9.35)	60.8 (10.71)	65.4 (15.75)
Sub-sample P value	0.007	0.211	<0.001	0.003

Medoff Cooper et al (2015) JPeds

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Feeding Mode and Development

- Infants were studied at 6, 12, and 24 months
- Comparison between infants orally fed and TF
  - TF infants were significantly shorter and < WAZ
  - TF infants had significantly lower motor and cognitive scores

Holst et al. (2019) Congenital Heart Disease

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Consequences of Growth Faltering

Long Term Growth Problems
- Stunting
- Obesity

Cognition

Psychomotor

Behavioral problems

Autism

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Cognition

- Consistently see mean scores 80's-90's
- 24-Month MDI assessment (Toronto Study, 2012)
  - Maternal education
  - Household income
  - Post-operative length of stay
- Classification
  - 9% accelerated
  - 61% normal
  - 21% mildly delayed
  - 9% severely delayed

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Motor

- Fine and gross motor delays
- Mean ranges from 60-80's
- 30% rated as abnormal
- Contributing factors
  - Growth
  - Physiology

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Behavioral

- Increased incidence of ADHD
- Increase incidence of autism
- Impaired problem solving skills
- Impaired social skills

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Nutrition and Development

- Lower z-scores at 3 months are the most significant predictors of lower BSID assessments at 6 and 12 months of age
- Growth/Nutrition matters!

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Long Term Challenges

- Maintaining weight trajectory
  - Infants discharged home on oral feeding have better average daily weight than infants with tube-assisted feeding.
  - Weight gain increased over time seen in infants on oral feedings and oral/tube assisted feedings compared to infants on only tube assisted feedings.
  - Finding the right combination of breast milk/formulas/caloric intake that an infant can tolerate.

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Neurodevelopmental Phenotypes

- Surgery during first year
- Developmental delays during infancy
- Multiple cardiac interventions
- Exposure to ECMO
- History of exposure to CPR
- Seizures
- Long LOS
- Genetic polymorphism

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Modifiable Factors

- Pre-op
  - Physiologic stability
- Post-op
  - Physiologic stability
  - Adequate nutrition
- During the first years of life
  - Most important- PREVENT GROWTH FAILURE

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Toddler Phenotypes

- Apraxia of speech
- Gross and fine motor delays
- Internalizing and externalizing behaviors
- Increased incidence of autism
- Hearing loss
- Cognitive delays

Ryan et. al. (2019) Proceedings of Cardiac intensive Care Society

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Percentage of Normal Development TF Infants and Toddlers

- Motor Skills
  - 6 months 7%, 12 months 20%, 24 months 40%
- Cognitive Skills
  - 6 months 76%, 12 months 62%, 24 months 36%
- Language Skills
  - 6 Months 69%, 12 months 44%, 24 months 33%

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In Summary

- Feeding matters!
- Feeding skills are linked to both weight gain and development from infancy to toddlerhood

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