Feeding problems in the Preterm neonate: Technologies to assess and treat

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Practice Gaps

- Premature infants with feeding difficulties may not receive optimal evaluation and treatment because of coexisting morbidities
- Dysphagic mechanisms are unclear in the ICU neonates; therefore management approaches remain unclear
- Application of new technologies aid in diagnosis
Learning Objectives

- Definition and Burden of Feeding Difficulties in the Premature Infant
- Clarify Potential Mechanisms of Feeding Difficulties
- Novel Technologies to assess Feeding Difficulties
- Precision Medicine approach to develop Individualized Management Strategy
Definition of Feeding Difficulties

Troublesome symptoms resulting from the disruption to the ability to move food or liquid from the mouth through the pharynx and esophagus into the stomach safely and efficiently

- Arching
- Crying
- Regurgitation
- Congestion
- Coughing
- Intolerance
- Early Satiety
- Fatigue
- Pneumonia
- Gagging
- Oral Aversion
- Autonomic Disturbances
- Poor Growth

Tracheostomy / Fundoplication / Gastrostomy / Death
Prevalence and Burden Feeding Difficulties

~37-40% infants and children that received feeding difficulty assessment in clinics were born prematurely


3.5% of all newborns had feeding problems, 3-fold more if born < 37 wks, and 7-fold more if born VLBW

Motion et al. Ambulatory Child Health 2001

Infants < 28 wks GA have significant oral feeding delays as well as prolonged LOS vs. infants > 28 wks GA; Majority of healthy premies achieved oral feeding skills by 36-38 wks PMA

Jadcherla et al. J Perinatol 2009
Economic Burden of Feeding Failure

Tracheostomy
- >100,000 tracheostomies are performed annually in the USA overall
- Estimated hospital charges for children receiving tracheostomy exceeded $952 million (for 4681 Tracheostomies/mean$200K)

Gastrostomy
- Incidence: 25% of children with chronic feeding difficulties
- $180,000 per infant over 5 yrs, and ~$50,000 for the first year
- Need to be replaced every 8 to 12 months
  - Piazza et al 2004
- Prevention of gastrostomy placement in a multidisciplinary feeding program saved $2.1 million in 1 year and $9.1 million over 5 yrs
Learning Objectives

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Cross-systems Integration of Aerodigestive Apparatus is complex

Cardiac
Heart, Arteries, Veins

CNS

Airway
Larynx, Trachea, Lungs, Diaphragm, Intercostal muscles

Foregut
Oral Cavity, Pharynx, Upper Esophageal Sphincter, Esophageal Body, Lower Esophageal Sphincter, Stomach

C1, C2, C3, C4, CN VII, CN IX, CN X, CN XI, CN XII
RLN, SLN
Feeding & Swallowing involves integrated function of multiple sub-systems

1. CONTRACTION & RELAXATION
2. COORDINATION & REGULATION OF MOTILITY BY CNS AND ENS
3. MATURATION & EXPERIENCE
4. AERODIGESTIVE PROTECTIVE REFLEXES

Modified after: Wood J et al
Methods to test Hierarchical regulation of Aerodigestive Reflexes

**Multimodal and concurrent methodology personalized to the needs**

**Foregut**
- Suck-Swallow-Peristalsis-Breathing
- Adaptive Pharyngo-Esophageal Manometry
- Upper and Lower Esophageal Sphincters  
  *Jadcherla et al (2001-2014)*

**Airway**
- Nasal Airflow Thermistor
- Respiratory Inductance Plethysmography
- Glottal Ultrasonography  

**Cardiac**
- ECG rhythms and Pulse-Oximetry

**CNS**
- Functional near infrared spectroscopy
- EEG and polysomnography  
Feeding without Symptoms
Feeding with Symptoms
Simulated Gastroesophageal Reflux

With Symptoms

Without Symptoms

Movement, Arching, Throat Clearing, Flushing, Gasping
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Swallowing Assessments

- Standardized Observation (OFS/NOMAS)
- Structural evaluation: Radiologic studies such as Upper GI, Video swallow study
- Endoscopic methods as FEES, FEESST
- GERD evaluation: pH-Impedance testing
- Pharyngo-Esophageal Motility evaluation using manometry studies
- Sucking/swallowing evaluation
- Surface EMG
- Cervical auscultation
- Respiratory evaluation: Nasal flow, respiratory inductance plethysmography
- Bottle feeding video recording
Radiological tests

Video swallow study
- R/O Aspiration
- To evaluate oromotor or neuromuscular abnormality

Upper GI
- Useful to rule out structural malformations R/O Tracheo-esophageal fistula, esophageal obstruction either intrinsic or extrinsic, rings and slings, mediastinal masses, strictures, hiatal hernia, malrotation
- Radiation exposure
Upper Gastrointestinal Series (UGI)
Assists in evaluating aerodigestive tract anomalies
- Growths
- Hiatal Hernia
- Inflammation
- Scars/strictures
- GERD (not definitive)
- Malrotation

GERD
Hiatal Hernia
Malrotation
Structural Evaluation

ENT Evaluation
- Regression of oral feeding
- Stridor

Nasopharyngoscopy

Vallecular cyst  Vocal cord palsy  Ganuloma/Polyps  Laryngeal cleft


www.gbmc.com  www.sickkids.ca
Flexible Endoscopic Evaluation of Swallowing (FEES) and Sensory Testing (FEESST)

Evaluates anatomic pathology within Pharynx, Esophagus, Larynx
- Laryngeal adductor responses
- Pharyngeal swallowing
- Pooling, penetration, and aspiration

Disadvantages:
- Sedation or anesthesia
- Complications can occur even in skilled hands
- Subject restraint and cooperation vital
- Not widely available and not feasible in small infants

**Esophageal Assessment Methods**

**pH/Impedance**
- Detects absence/presence of GERD in 24 hours
  - Physical- Gas/Liquid/Mixed
  - Chemical- Acid/Non-Acid
  - Height of refluxate

Pharyngo-esophageal manometry
- Evaluates muscle function during swallowing by utilizing pressure sensors

Water Perfusion
- 9 Pressure Channels
- Better for Sphincter Evaluation
- Dependent on gravity

Solid State
- 25 Pressure Channels
- Contour as and conventional plots
- Impedance (Clearance)

Clouse, Berseth, Shaker, Mittal, Kahrilas, Pandolfino, Rommel, Omari
Testing Aero-digestive Reflexes

Esophageal Stimulation
- Simulates reflux (Air-Gas, Water- Non Acid, Apple Juice- Acid)
  - Gupta ‘09; Hill ‘12; Pena ‘10; Jadcherla ‘03,’09

Pharyngeal Stimulation
- Simulates secretions or feeding (water)
  - Jadcherla ’07, ’14; Malkar ’14

Jadcherla AJG 2009
Oral Feeding Challenge Test

Px-Inf.

M-Eso-Inf.

Respiration

EMG

Pharynx

UES

P-Eso

M-Eso

D-Eso

LES

Stomach

Slow Flow, 142/26/100

Regular Respir

Medium Flow 150/44/100

Regular Respir

Fast Flow 107/95 103/77 149/88 148/96

Erratic Respir

Decreased Suck : Swallow Ratio

Propagated Swallow

10 S

10 S

10 S

Jadcherla et al. JPGN 2009
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Jadcherla et al (2001-2014)

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Impact of Personalized Feeding Program in 100 NICU Infants: A Novel Pathophysiology-based Approach for Better Outcomes

*Sudarshan R. Jadcherla, †Juan Peng, †Rebecca Moore, ‡Jason Saavedra, ¶Edward Shepherd, *Soledad Fernandez, #Steven H. Erdman, and **Carlo DiLorenzo
Motility Correlates with Feeding Success

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Success (N=15)</th>
<th>Failure (N=5)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely Propagated Swallow, #</td>
<td>2.4±0.3</td>
<td>0.4±0.2</td>
<td>0.001</td>
</tr>
<tr>
<td>Completely propagated swallow, %</td>
<td>69.4±6.9</td>
<td>32.5±21.4</td>
<td>0.04</td>
</tr>
<tr>
<td>Peristaltic response wet swallow, %</td>
<td>86.7±5.7</td>
<td>28.7±16.5</td>
<td>0.001</td>
</tr>
<tr>
<td>Propagation OFCT, %</td>
<td>100</td>
<td>33</td>
<td>0.002</td>
</tr>
<tr>
<td>Suck-Sw-Rhythm, %</td>
<td>100</td>
<td>0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Data presented as Mean ± SEM, or %
Operational approach → → → Tactics

- Good Clinical Exam with Feeding Challenge
- Anatomical evaluation
- Comprehensive medical evaluation
- Occupational Therapy evaluation
- Dietetic evaluation
- Psychologist advice
- Extended pharyngo-esophageal manometry evaluation during a feeding cycle

Personalized Feeding Strategy and Education

- Hunger regulation
- Position
- Flow
- Pacing
- Airway protection
- Nutrition
- Growth

Jadcherla et al. JPGN, 2009
Personalized Multidisciplinary NICU Swallowing Therapy

- Cough or Choking spells
- Frequent Spit ups

Dysphagia

Arching

- ALTE
- Irritability

Failure of medical therapy

N=100

Feeding success
N=51

Feeding failure
N=49

Outcomes at discharge

Referral to Neonatal Feeding Disorders Program

Individualized Strategy

• Compliance
• Follow up
• Review

Individualized Innovative Management Care Plan

Jadcherla et al. JPGN 2009
Jadcherla et al. JPGN 2012
Individualized Management Care Plan

**Feeding and Nutrient Modifications**

- **Vol/Frequency**
  - Vol: Ad Lib/Restricted
  - Frequency: # /day

- **Calories**
  - Type: EBM/Formula
  - Restricted/Unrestricted

- **Nipple**
  - Flow: Slow/Med/Fast
  - Shape/Size/Material: Numerous brands

- **Viscosity**
  - Thickness: Thin/Nectar/Thick
  - Type: Rice/Oatmeal

**Occupational Therapy**

- **Pacing**
  - Rate: 3 or 5 sucks/sw

- **Posture**
  - Position: Supine, Sidelying (R/L), Semi-reclined, Upright

- **Operant Conditioning**
  - Hunger manipulation
  - Pacifier dips

- **Stabilization**
  - Swaddling
  - Chin/Cheek Support

**Pharmacological Treatment**

- **Gastroesophageal Reflux**
  - PPI, H2RA, Prokinetics, Formula

- **Primary Disease Treatment**
  - **BPD**: Systemic and Inhaled Corticosteroids, Bronchodilators, Diuretics, Oxygen
  - **Apnea of Prematurity**: Caffeine
  - **Neurological**: Opioids, Alpha-2-antagonists
  - **Cardiac**: PDE-5 inhibitor, Inhaled NO
# Feeding Program vs. Historical Controls

## Referrals for Gastrostomy

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Innovative Feeding Program (N=100)</th>
<th>Historical control group (N=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Gestation Age (weeks)</td>
<td>31</td>
<td>33</td>
</tr>
<tr>
<td>Mean Birth Weight (kg)</td>
<td>1.8</td>
<td>2.3</td>
</tr>
<tr>
<td>Neuropathology (%)</td>
<td>44</td>
<td>54</td>
</tr>
<tr>
<td>BPD (%)</td>
<td>74</td>
<td>48</td>
</tr>
<tr>
<td>GER symptoms (%)</td>
<td>66</td>
<td>54</td>
</tr>
<tr>
<td>Feeding success at discharge (%)</td>
<td>51</td>
<td>10</td>
</tr>
<tr>
<td>Feeding success at 1st birthday (%)</td>
<td>84.3 (75/89)</td>
<td>42.9 (21/49)</td>
</tr>
<tr>
<td>Mean Length of stay (wk)</td>
<td>19</td>
<td>18</td>
</tr>
</tbody>
</table>

*In the innovative feeding program, nine patients died after discharge and two patients were transferred to other hospitals; thus data from the remaining 89 patients is shown. In the historical control group, one patient died after discharge; thus data from 49 patients is shown.

*Jadcherla et al. JPGN 2012*
At Discharge

- Innovative Feeding Program
  - Primary Oral Feeding: 51%
  - Tube + Oral Feeding: 34%
  - No Oral Feeding: 15%

At 1 yr Birthday

- Innovative Feeding Program
  - Primary Oral Feeding: 71%
  - Tube + Oral Feeding: 16%
  - No Oral Feeding: 14%

- Historical Controls
  - Primary Oral Feeding: 37%
  - Tube + Oral Feeding: 37%
  - No Oral Feeding: 25%

P < 0.01 for both comparisons.
Safe Oral Feeding Saves Health Care Resources

Health care **costs for children with feeding tubes** at discharge

- $ 46,875 for the first year, and
- $180,000 per infant over 5 years

*Piazza et al 2004*

Saving with Oral Feeding by **avoiding Gastrostomy** in 51% of chronic NICU feeding problem referrals for G-tube, we saved:

- $ 2.1 million over the 1st year
- $ 9.1 Million over 5 years

*Jadcherla et al. JPGN 2011*
Feeding Method at Discharge Predicts Neurodevelopmental Outcomes

Feeding/Respiratory Milestones

- Weeks at First Oral Feed
  - G-tube Fed vs. Full-PO-Fed
  - p = .03

- Days of Ventilation
  - G-tube Fed vs. Full-PO-Fed
  - p = .01

Neurodevelopmental Delays in G-tube

- Cognitive Delay (%)
  - G-tube Fed vs. Full-PO-Fed
  - p = .01

- Communication Delay (%)
  - G-tube Fed vs. Full-PO-Fed
  - p = .03

- Respiratory Support (%)
  - G-tube Fed vs. Full-PO-Fed
  - Trach, NC, RA
  - p = .02

- Motor Delay (%)
  - G-tube Fed vs. Full-PO-Fed
  - p = .01

EXCLUDED (Total = 126)
- Lost to follow up: n = 69
- Followed by another clinic: n = 22
- No BSID-III administered within 18-24 months: n = 27
- Patient died: n = 6
- Untested due to severe delays: n = 2

Summary-1

Hypoxia
- Hypoxic Ischemic Encephalopathy
- Ischemia and Reperfusion Injury

Prematurity
- Perinatal interventions
- Physiological Immaturity
- Ontogeny variations
- Variations in GI organ functions
- Birth defects

Neural & Endocrine
- Hunger & Satiety
- Smell & Taste
- Thirst
- Congenital Birth Defects
- Perinatal trauma
- Maternal Diabetes
- Perinatal Addictive Drugs & Withdrawal

Inflammation
- Infection
- Interventions, Injury & Surgery
- Nociceptive events
- Side effects of drugs
- NEC
- BPD
- GERD
- Aspiration Syndrome

Central Nervous System, Enteric Nervous System & Neuro-Muscular Effects on Maturational delays, Maldevelopment, Maladaptation, Malfunction involving:

Neurons and Glial Networks
- Multiple Cranial Nerves
- Afferent & Efferent Neurons
- Excitatory & Inhibitory Neurons
- Neural Networks & CPG
- Synaptogenesis and Pruning

Muscles
- Striated Muscles
- Smooth Muscles
- Mixed muscles
- Interstitial cells of Cajal
- Sphincters

Regional Mechanisms
- Autonomic Reflexes, Secretory Reflexes, Enteric Reflexes & Aerodigestive protective Reflexes
- Contraction & Relaxation of GI muscles and sphincters
- Coordination, Regulation & Pattern Generation of Gut Motility by CNS & ENS interactions
- Maturation & Experience of favorable sensory stimuli vs. nociceptive stimuli

Multiple newer assessment and management approaches are available for dysphagia.

Dysphagia is multifactorial, personalized and individualized approaches should be considered.
Symptoms are heterogeneous and cross-systems involvement is often noted

Inter-disciplinary communications are important in effecting better clinical outcomes

Safe feeding involves airway protection and swallowing as important factors for feeding success
Definition and Burden of Feeding Difficulties in the Premature Infant

Clarify Potential Mechanisms of Feeding Difficulties

Novel Technologies to assess Feeding Difficulties

Precision Medicine approach to develop Individualized Management Strategy
Thank-you!!

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