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Rush System for Health

Effects of Infant-Driven Feeding in the Neonatal Intensive Care Unit (NICU) for Premature Infants with Additional Morbidities

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Disclosure

There are no relevant financial or non financial relationships to disclose.

1 Statement of the Problem

Swallowing is a complex process that can be disrupted by preterm birth

Physiologic stability, sensorimotor pathway functioning, and respiration

Premature birth is highly associated with comorbid conditions

High risk of neurologic, cardiac, respiratory, and/or gastrointestinal disorders

Comorbidities exacerbate dysphagia and burden

Infant-driven feeding has been emphasized in the literature to reduce these implications

Prolonged hospitalization/length of stay

Full oral feeding is a common final barrier preterm infants face in order to be discharged from the NICU

Delany and Arvedson (2008)
Lau (2016)
Viswanathan and Jadcherla (2022)

Limitations of Current Literature

Dodrill et al. (2008)
Volume-driven feeding only
Did not specify which morbidity had the greatest impact

Jackson et al. (2015)
Only included late preterm infants (i.e., 32-36 weeks)
Only 9% of the infants had a comorbidity

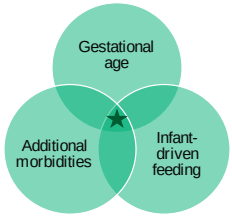
Park et al. (2015)
Only included extremely preterm infants (i.e., <28 weeks)
Volume-driven feeding only
Morbidities were analyzed in isolation, despite a majority of infants having more than one

Rogers (2016)
Volume-driven feeding only

Manilla (2018)
Interactions between GA at birth, comorbidities, and feeding method on time to full oral feeding was not analyzed

Osman et al. (2021), Lane et al. (2021)
Exclusion of premature infants with various morbidities (e.g., IVH grade III or IV, cardiac anomalies, GI anomalies)

Interactions between gestational age, additional morbidities, and infant-driven feeding practices



2 Normal Infant Swallowing

Phases of Swallowing

Infants complete this process at a rate of one suck per second

1 Oral Phase	2 Pharyngeal Phase	3 Esophageal Phase
• Expression • Suction • Containment • Propulsion to the pharynx	• Swallowing reflex • Pharyngeal constriction • Transportation to and through the upper esophageal sphincter (UES)	• Transportation through the esophagus and into the stomach

All phases are reflexive and mediated by a central pattern generator

Delany and Arvedson (2008)
Dodrill and Gosa (2015)
Lau (2016)
Viswanathan and Jadcherla (2012)

3 Swallowing Development in Utero

Oral-motor Movements

13-15 weeks
- Suckling
- Swallowing

21 weeks
- Tongue thrust

28 weeks
- Tongue cupping

Adaptive reflexes*
- Rooting
- Sucking

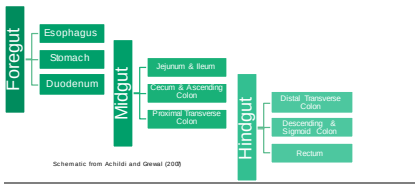
Protective reflexes*
- Tongue protrusion
- Tongue lateralization
- Phasic bite
- Gag reflex
- Coughing

*emerge during the third trimester of pregnancy

Delany and Arvedson (2008)
Dodrill and Gosa (2015)
Goldfield et al. (2006)

Gastrointestinal and Respiratory Systems

Emerge around 4 weeks gestation as a result of cellular division



Schematic from Achidi and Grewal (2008)

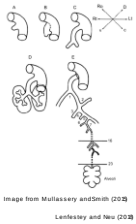


Image from Mullassery and Smith (2015)

Lemlesley and Neu (2013)
Warburton (2017)

4 Effects of Prematurity on Swallowing

Classifications of Prematurity According to the World Health Organization (WHO)

Extremely Preterm
<28;0 weeks' gestation

Very Preterm
28;0-31;6 weeks' gestation

Moderate to Late Preterm
32;0-36;6 weeks' gestation

WHO (2023)

Dysphagia in Healthy Premature Infants

Prevalence: ~10.5% to ~26%

1 Signs of Oral Dysphagia
- Absent or reduced oral reflexes
- Impaired suction/expression
- Irregular lingual movements
- Nasal regurgitation
- Delays in bolus formation
- Posterior loss

2 Signs of Pharyngeal Dysphagia
- Delayed pharyngeal response
- Decreased pharyngeal pressure
- Incoordination between the pharyngeal reflex and UES distention

3 Signs of Esophageal Dysphagia
- Impaired pressure gradients
- Esophageal immobility
- Abnormal peristalsis

Dodrill (2011) Jadcherla (2016)
Kamity et al. (2021) Rommel et al. (2011)
Viswanathan and Jadcherla (2021)

5 Effects of Additional Comorbidities on Swallowing

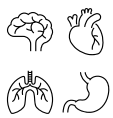
Morbidity Overview

- Neurologic disorders
- Cardiac disorders
- Respiratory disorders
- Gastrointestinal disorders

Morbidity risk significantly increases as gestational age decreases

Allen et al. (2011)
Dodrill (2011)
Engle (2011)

Morbidity Overview



Neurologic
- Dysfunctional sensorimotor integration
- Dysfunctional coordination

Cardiac
- Uncoordinated SSB patterns
- Desaturation fatigue
- Oral stasis
- Anterior spillage
- Intestinal deficits d/t lack of blood flow

Respiratory
- Oxygen desaturations
- Prolonged deglutition apnea
- Uncoordinated SSB patterns
- Arrhythmical sucking
- Weaker suction

Gastrointestinal
- Feeding aversion
- Frequent regurgitation
- Discomfort following feedings
- Apnea, desaturations, bradycardia

Carter (2007)
Eichenwald (2018)
Ramani and Ambalavanan (2013)
Schurr and Perkins (2008)

6 Feeding Factors that Impact Swallowing in Premature Infants

Volume-Driven Feeding

Premise

Superior feeders – consume larger volumes
Poor feeders – consume smaller volumes

Characteristics

Strategies to "empty the bottle"

- Increasing flow rate
- Prodding
- Putting the infant's head back
- Unswaddling

Strict feeding schedule
Continue feeding despite mild signs of stress, incoordination, and disengagement

Drawbacks

Unnecessary stress
Risk of developing oral aversion
Risk of long-term feeding problems

Signs of stress during feeding:

- Change in alertness
- Change in cardiorespiratory behaviors
- Change in postural control
- Fingers splayed
- Extension
- Loss of bolus
- Coughing/choking

Lane et al. (2021)
Shaker (2012)
Shaker (2013)

Infant-Driven Feeding

Premise

Dynamic process between caregiver and infant during feeding
Highly individualized process based on the infant's communication
Quality > quantity

Characteristics

Evaluating readiness to feed
Altering flow rate
Side-lying
Swaddling
Pacing techniques
Calming or re-alerting

Benefits

Supports neurodevelopmental maturation
Safer feeding
Achieve full oral feeding sooner
Fewer adverse events
Improved SSB patterns at discharge
Shorter hospitalization

Signs of stability during feeding:

- Regular respirations
- Hands to midline
- Good postural control
- Organized, calm
- Alert

Lane et al. (2021)
Lubbe (2018)
Newland et al. (2013)
Shaker (2012)
Shaker (2013)
Whetten (2016)

Research Question

1 What are the interactions between gestational age, comorbidities, and feeding practice (i.e., infant-driven versus volume-driven approaches) in the NICU on time to full oral feeding?

7 Methods of the Current Study

Methods

1. Retrospective chart review of 120 premature infants admitted to the Rush University Medical Center NICU born between Jan 1, 2018, and Jan 1, 2020, who received infant-driven feeding interventions
2. Eliminated infants from the data set based on predetermined inclusionary and exclusionary criteria
3. Analyzed the data according to each hypothesis (n = 88)
4. Combined the new data set with previous data from Manilla's (2018) study
5. Compared the results to Rogers' (2016) study to investigate feeding outcomes depending on feeding intervention (i.e., volume-driven versus infant-driven) (n = 268)

Data Collected from Chart Review

Sex	Volume of 1st oral feed	PMA at discharge
Race	Date of 1st oral feed	Weight at discharge
Date of birth	PMA at exclusive oral feeding	Length of hospitalization (days)
Gestational age at birth	Weight at exclusive oral feeding	Participation in a Videofluoroscopic Swallowing Study
Postmenstrual age (PMA) at time of 1st exposure to oral feeding	Volume at exclusive oral feeding	Diagnoses/morbidities
Weight at 1st oral feed		

Morbidity Assessment Index of Newborns (MAIN)

Item No.	Item name	Discrimination statistic*	χ^2 statistic*	Scale value†
1	Poor sucking within 24 h	1.14	16.3	81
	Apnea with spontaneous recovery‡§	0.39	28.6	
	Serum bilirubin 171-250 μmol/L§	0.33	31.8	
2	Poor sucking at 24 h to 7 days	1.46	5.3	98
3	Serum bilirubin 251-340 μmol/L, or need for phototherapy	0.41	21.3	103
	Assisted ventilation within 24 h‖	0.19	65.1	
4	Apnea and need for oxygen‖	1.49	6.7	115
5	Assisted ventilation beyond 24 h‖	0.76	26.2	117
6	Poor sucking beyond 7 days	1.15	12.9	119
7	Heart rate >160 beats/min‖	0.60	2.9	120
8	Apgar score <7 at 5 min	0.51	14.1	125
9	Resuscitation at birth with intubation	0.99	8.0	127
10	Hypotonia at 1-120 h‖	1.12	8.8	129
11	Mechanical ventilation within 24 h	1.27	2.8	130
12	Respiratory rate <30/min or >60/min at 3-24 h	0.67	16.8	131
13	Mechanical ventilation at 24 h to 7 days	1.45	4.5	135
	Respiratory rate <30/min or >60/min in first 3 h‖ ‖	0.19	37.5	
14	Low systolic blood pressure‖: <30 mm Hg for 28-32 wk; <40 mm Hg for 32-42 wk	1.00	7.9	136
15	Persistent vomiting	0.68	11.8	136
16	Level of consciousness: Drowsy or lethargic‖	1.08	0.6	137
17	Tremors or single seizure	0.92	2.2	137
18	Apnea corrected by resuscitation	1.19	3.4	140
19	Respiratory rate >100/min at 3-24 h‖	0.59	8.5	140
20	Low urine output (<2 mL/kg per hour)‖	1.47	1.5	141
21	Altered color: Central cyanosis or dusky	0.81	17.9	145
22	Thrombocytopenia or bleeding skin, lungs, or gastrointestinal tract	0.94	2.3	147
23	Cord blood pH <7.1	0.54	9.6	151

Verma et al. (1998)

MAIN score	95% Confidence band	Corresponding range of morbidity
<300	Score ± 36% (of score)	Very mild to mild
301-600	Score ± 20% (of score)	Mild
601-2000	Score ± 10% (of score)	Mild to moderate
>2000	Score ± 8% (of score)	Moderate to severe

Statistical Analysis by Hypothesis

Hypothesis 1
Effect of age on time to full oral feeding

1. Age as a continuous variable: Pearson correlation
2. Age as a categorical variable: point-biserial correlation and ANOVA

Hypothesis 2
Effect of additional morbidities on time to full oral feeding

1. One-way independent ANOVA with the binary presence or absence of morbidity as the independent variable

Hypothesis 3
Effect of specific morbidities on time to full oral feeding

1. ANOVA was used to compare results among the four morbidity groups
2. Pearson correlations were used to compare results among MAIN severity score

Statistical Analysis by Hypothesis

Hypothesis 4
Effect of morbidity on time to full oral feeding in extremely premature infants

1. One-way independent ANOVA with the binary presence or absence of morbidity as the independent variable

Hypothesis 5
Effect of feeding protocol on time to full oral feeding

1. Independent t-tests to compare the mean time to full oral feeding between the two feeding method groups

Hypothesis 6
Interaction between gestational age, morbidity, and feeding method

1. ANCOVA

8 Results

Hypothesis 1 (n = 88)

Effect of Gestational Age at Birth on Time to Full Oral Feeding

Pearson correlation coefficient

Strong negative correlation between gestational age at birth and time from birth to full oral feeding [r = -0.856, p < 0.0001]

Moderately negative correlation between gestational age at birth and time from first to full oral feeding [r = -0.567, p < 0.0001]

Univariate ANOVA

Statistically significant difference between gestation age group at birth and time from:

1. Birth to first oral feeding [F(2, 85) = 200.469, p < 0.0001]
2. First to full oral feeding [F(2, 85) = 20.123, p < 0.0001]
3. Birth to full oral feeding [F(2, 85) = 121.30, p < 0.0001]

Bonferroni's multiple comparisons post-hoc analysis

Mean value of time from birth to first oral feeding was significantly different (p < 0.0001) between the following age groups:

<28.0 weeks' gestation and 28.0-31.6 weeks' gestation	<28.0 weeks' gestation and 32.0-36.6 weeks' gestation	28.0-31.6 weeks' gestation and 32.0-36.6 weeks' gestation

Hypothesis 2 (n = 88)

Effect of Morbidities on Time to Full Oral Feeding

One-way independent ANOVA

Statistically significant between group difference among premature infants diagnosed with at least one additional morbidity (n = 76) compared to those without (n = 12) on time from:

1. Birth to full oral feeding [F(1, 74) = 13.877, p < 0.0001]
2. First to full oral feeding [F(1, 86) = 19.634, p < 0.0001]

Hypothesis 3 (n = 88)

Effect of Specific Diagnoses on Time to Full Oral Feeding

ANOVA

Statistically significant between group difference among specific diagnoses on time from:

1. Birth to full oral feeding [F(8, 79) = 16.693, p < 0.0001] and
2. First to full oral feeding [F(8, 79) = 8.120, p < 0.0001]

Diagnosis	n	M	SD
Time from Birth to Full Oral Feeding (days)			
Respiratory	45	26.67	22.758
Cardiac	2	20.0	5.657
GI[a]	1	32.0	—
Neurologic and Respiratory	3	36.67	20.744
Respiratory and Cardiac	3	53.33	12.662
Neurologic, Respiratory, and Cardiac	2	118.50	38.891
Neurologic, Respiratory, and GI	1	93.0	—
Neurologic, Respiratory, Cardiac, and GI	2	95.50	7.778

Diagnosis	n	M	SD
Time from First to Full Oral Feeding (days)			
Respiratory	45	15.0	11.685
Cardiac	2	19.0	5.657
GI[a]	1	1.0	—
Neurologic and Respiratory	3	21.67	9.815
Respiratory and Cardiac	3	22.67	24.947
Neurologic, Respiratory, and Cardiac	2	54.50	3.536
Neurologic, Respiratory, and GI	1	44.0	—
Neurologic, Respiratory, Cardiac, and GI	2	28.50	6.364

Note. Each diagnostic category represents the number of infants with a single morbidity (e.g., respiratory, cardiac, etc.) and infants with multiple morbidities (e.g., neurologic + respiratory + cardiac).
[a]GI = gastrointestinal.

Hypothesis 3 (n = 88)

Effect of Specific Diagnoses on Time to Full Oral Feeding

Pearson correlation

Moderately positive correlation between MAIN severity and time from:

1. Birth to full oral feeding [r = 0.546, p < 0.0001]
2. First to full oral feeding [r = 0.518, p < 0.0001]

Hypothesis 4 (n = 88)

Interaction Between Gestational Age and Morbidity in the Youngest Premature Infants (i.e., <28;0 weeks')

One-way independent ANOVA

Planned; however, analysis could not be performed because all infants born <28;0 weeks' gestation had at least one additional morbidity

ANOVA

No statistically significant difference between the morbidities of the youngest premature infants on time from

1. Birth to full oral feeding [F(4, 6) = 1.553, p = 0.300
2. First to full oral feeding [F(4, 6) = 1.743, p = 0.258]

Hypothesis 5 (n = 268)

Effect of Infant-Driven Feeding Protocol on Time to Full Oral Feeding

Independent t-test

No statistically significant difference between feeding methods on time from:

1. Birth to full oral feeding ($t(267) = -0.454, p = 0.650$)
2. First to full oral feeding ($t(267) = -1.382, p = 0.168$)

ANOVA

No statistically significant interactions between WHO (2023) GA group and feeding method on time from:

1. Birth to full oral feeding [$F(2, 262) = 1.187, p = 0.307$]
2. First to full oral feeding [$F(2, 262) = 0.560, p = 0.572$]

Main effect of age for time from:

1. Birth to full oral feeding [$F(2, 2) = 269.555, p = 0.004$]
2. First to full oral feeding [$F(2, 2) = 64.430, p = 0.015$]

Hypothesis 5 (n = 268)

Effect of Infant-Driven Feeding Protocol on Time to First Full Oral Feeding

Infants were reclassified into four groups based on gestational age at birth

Univariate ANOVA

No statistically significant difference between the redassified gestational age groups on time from:

1. Birth to full oral feeding [$F(3, 260) = 1.701, p = 0.167$]
2. First to full oral feeding [$F(3, 260) = 1.256, p = 0.290$]

Main effect of age for time from:

1. Birth to full oral feeding [$F(4, 4.139) = 109.815, p < 0.0001$]
2. First to full oral feeding [$F(4, 4.585) = 16.026, p = 0.006$]

Hypothesis 6 (n = 268)

Interaction Between Gestational Age at Birth, Comorbidities, and Feeding Method

ANOVA

No statistically significant interactions between WHO (2023) GA group, morbidity, and feeding method on time from:

1. Birth to full oral feeding [$F(1, 258) = 1.033, p = 0.310$]
2. First to full oral feeding [$F(1, 258) = 0.548, p = 0.460$]

Main effect of morbidity on time from first to full oral feeding [$F(1, 1) = 366.933, p = 0.033$]

ANOVA

No statistically significant interactions between reclassified GA group, morbidity, and feeding method on time from:

1. Birth to full oral feeding [$F(1, 256) = 1.133, p = 0.288$]
2. First to full oral feeding [$F(1, 256) = 0.553, p = 0.458$]

Infants 23;0-24;6 weeks' gestation with at least one additional morbidity in the volume-driven feeding group:

- **12.29** more days from birth to full oral feeding
- **18.43** more days from first to full oral feeding

Hypothesis 6 (n = 268)

Interaction Between Gestational Age at Birth, Comorbidity Severity, and Feeding Method

ANOVA

No statistically significant interactions between WHO (2023) GA group, morbidity severity, and feeding method on time from:

1. Birth to full oral feeding [F(4, 249) = 0.531, p = 0.713]
2. First to full oral feeding [F(4, 249) = 0.899, p = 0.465]

Main effect of age and MAIN severity for time from birth to full oral feeding

1. Age [F(2, 1.850) = 0.691, p = 0.005]
2. MAIN severity [F(3, 12.185) = 274.181, p = 0.007]

ANOVA

No statistically significant interactions between reclassified GA group, morbidity severity, and feeding method on time from:

1. Birth to full oral feeding [F(4, 245) = 0.531, p = 0.726]
2. First to full oral feeding [F(4, 245) = 0.386, p = 0.819]

Main effect of age for time from birth to full oral feeding [F(3.5.018) = 65.014, p < 0.0001]

8 Discussion

Gestational Age

Time to achieve oral feeding milestones

Gestational age at birth

Comorbid Medical Diagnoses

Presence of at least one morbidity

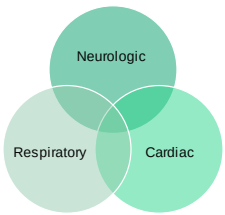
Time to achieve oral feeding milestones

Specific Morbidity Diagnoses

Morbidity severity

Time to achieve oral feeding milestones

Specific Morbidity Diagnoses



Time to achieve oral feeding milestones

Extreme Prematurity and Comorbidities

All infants <28;0 weeks' gestation had at least one concomitant morbidity

Highlights how prevalent comorbidities are among extremely preterm infants

No difference on time to full oral feeding between morbidities

Highlights the inevitability of delayed attainment of oral feeding milestones in this GA group regardless of morbidity diagnoses

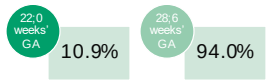
Feeding Protocol

Gestational Age Categorized According to the WHO (2023)

No statistically significant interaction may have been due to the wide range of ages lumped into the <28-week group and the extreme values → regression to the mean

WHO (2023) GA categories were created at a time when infants born <28 weeks did not survive

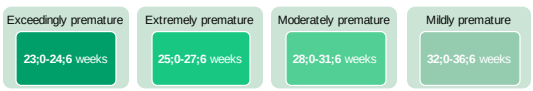
Survival Rates



Bell et al. (2022)

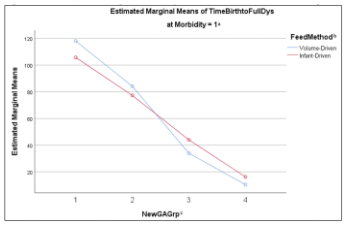
Feeding Protocol

Proposing a new premature infant GA classification schema:



Youngest infants reached full oral feeding almost 20 days sooner when infant-driven feeding was implemented

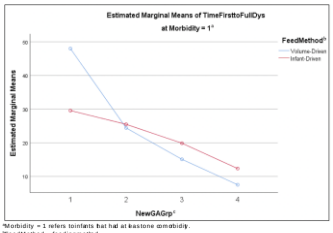
Feeding Protocol x Comorbidities



Birth to full oral feeding — 12.29 days earlier

aMorbidity = 1 refers to infants that had at least one comorbidity.
bFeedMethod = feedingmethod.
cNewGAGp = reclassified gestational age groups.1) 23;0-24;6 weeks' gestation, 2) 25;0-27;6weeks' gestation, 3) 28;0-31;6 weeks' gestation, 4) ≥32;0-36;6 weeks' gestation

Feeding Protocol x Comorbidities



First to full oral feeding — 18.43 days earlier

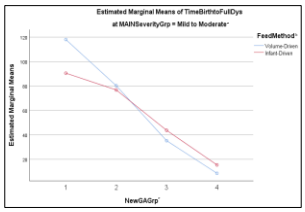
aMorbidity = 1 refers to infants that had at least one comorbidity.
bFeedMethod = feedingmethod.
cNewGAGp = reclassified gestational age groups.1) 23;0-24;6 weeks' gestation, 2) 25;0-27;6weeks' gestation, 3) 28;0-31;6 weeks' gestation, 4) ≥32;0-36;6 weeks' gestation

Gestational Age x Comorbidities x Feeding Protocol

After reclassification of the infants into the new GA groups:

Youngest infants (23;0-24;6 weeks) + Mild-moderate morbidity → Birth to full oral feeding 27.50 days earlier and first to full oral feeding 29.75 days earlier

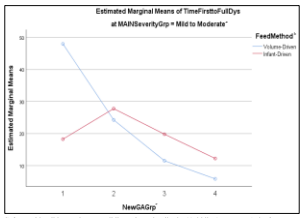
Gestational Age x Comorbidities x Feeding Protocol



Birth to full oral feeding: 27.50 days earlier

*Infants with mild to moderate morbidity as determined by the Morbidity Assessment Index for Newborns (MAIN) (Verma et al., 1999).
*FeedMethod = feedingmethod.
*NewGAGrp = reclassified gestational age groups: 1) 23;0-24;6 weeks' gestation, 2) 25;0-27;6 weeks' gestation, 3) 28;0-31;6 weeks' gestation, 4) 32;0-36;6 weeks' gestation.

Gestational Age x Comorbidities x Feeding Protocol



First to full oral feeding: 29.75 days earlier

*Infants with mild to moderate morbidity as determined by the Morbidity Assessment Index for Newborns (MAIN) (Verma et al., 1999).
*FeedMethod = feedingmethod.
*NewGAGrp = reclassified gestational age groups: 1) 23;0-24;6 weeks' gestation, 2) 25;0-27;6 weeks' gestation, 3) 28;0-31;6 weeks' gestation, 4) 32;0-36;6 weeks' gestation.

Conclusion

Exceedingly premature + Mild-moderate morbidity + Infant-driven feeding = Earlier attainment of oral feeding milestones

There is a need to reclassify preterm infants based on gestational age at birth

Exceedingly premature	Extremely premature	Moderately premature	Mildly premature
23;0-24;6 weeks	**25;0-27;6** weeks	**28;0-31;6** weeks	**32;0-36;6** weeks

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Thank you.

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Excellence is just the beginning.