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A Retrospective Examination of Prandial Aspiration in Preterm Infants

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Abstract

Purpose: *We conducted this retrospective study to identify potential signs of aspiration in preterm infants based on crib-side nursing documentation.*

Study Design and Methods: *A total of 2,590 bottle-feedings were examined for signs of distress across 41 preterm infants who were referred for a swallowing evaluation. All infants underwent either a videofluoroscopic swallow study (VSS) or upper gastrointestinal study (GIS). Physiologic and behavioral warning signs were coded across feedings 10 days prior to the imaging study. Presence or absence of documented aspiration during VSS/GIS was coded for each infant.*

Results: *Distress signs were documented in seven percent of oral feeding attempts. Aspiration was more common when the crib-side nurse documented coughing (LR+, 8.77; 95% CI, .99–77.09), compromised oxygen saturation levels (LR+, 2.15; CI, .86–5.47), and tachypnea (LR+, 2.15; CI, .28–3.01) during bottle-feeding.*

Clinical Implications: *Evidence-based distress signs that signal increased suspicion for prandial aspiration will facilitate correct clinical judgments at crib-side. Early identification and prevention of prandial aspiration improves health outcomes for preterm infants.*

Complications from preterm birth increase the incidence of respiratory distress and feeding problems (Hawdon, Beauregard, Slattery, & Kennedy, 2000). Prevalence of overt and silent aspiration has yet to be established in preterm infants (Weir, McMahon, Taylor, & Chang, 2011). However, these infants frequently experience distress as they learn to eat by mouth (Premji, McNeil, & Scotland, 2004). Undoubtely, occurrences of prandial (food) aspiration cause stress responses and compromise breathing, which may interfere with neurological development or brain growth (de Benedictis, Carnielli, & de Benedictis, 2009). Respiratory distress and feeding problems are associated with physiologic instability. Identifying the cause for physiologic instability in preterm infants is complex. During oral feeding, physiologic instability may be attributed to overwhelming extra-uterine environmental stimuli or to prandial aspiration. As we better understand the symptomatology associated with prandial aspiration in preterm infants, medical management for prevention will progress and health outcomes will improve.

Preterm infants may experience swallowing deficits because immature biologic systems make it difficult to integrate the complex physiologic requirements needed to bottle feed safely and competently. Competent feeding and safe swallowing require infants to sequentially coordinate and transport liquid boluses past the airway into the esophagus and stomach. The pharynx is a dual function chamber that rapidly oscillates between ventilation and deglutition during nipple feeding. Given underdeveloped physiology, even healthy premature infants may have difficulty sustaining oral feeding competently with only 0.3 seconds to ventilate between swallows (Lau, 2014). Therefore, compromised ventilation is likely with co-occurring comorbid illnesses in preterm infants. Infants who chronically aspirate are at increased risk for poor health, malnutrition, and delayed developmental outcomes.

If swallowing deficits are approached from the perspective of differential diagnosis, signs and symptoms of disorganization and hypoventilation during oral feeding must be identified. Infants use stress behaviors to communicate when they are struggling to manage the demands of oral feeding. While behaviors that signal disorganization and stress may not directly relate to aspiration, disorganized infants are more likely to mistime swallowing and breathing which increases their aspiration risk. Complications of aspiration may decrease energy and oxygenation levels, interfere with caloric intake, and cause physiologic distress. As aspiration signs are established for preterm infants, evidence-based management protocols may be developed to decrease the occurrence and iatrogenic pathology.

While limited research on the signs and symptoms of aspiration in preterm infants exists, evidence from other populations, knowledge of development, and theory may be used to guide our judgments of increased risk for aspiration. What do we know from the term infant and child literature? Several studies reported that coughing, desaturation, and color change were related to aspiration in term infants and children (DeMatteo, Matovich, & Hjartarson, 2005; Suiter & Leder, 2010). Harrison, Roane, and Weaver (2004) reported that decreased motor activity in preterm infants was positively correlated with low oxygen saturation levels. Anterior spillage during oral feeding indicates inadequate bolus control and poor tolerance of large bolus volumes flowing from a bottle/breast, which increases risk for aspiration (Dusick, 2003; Shaker, 1990). However, research evidence is unclear on coughing, decrease in oxygen saturation levels (desaturation), color change, changes in musle tone, and spillage as signs of prandial aspiration in preterm infants.

What are the developmental differences that contribute to aspiration in preterm infants? Evidence shows that children are more likely to have food penetrate into the larynx and aspirate silently than adults (Newman, Keckley, Petersen, & Hamner, 2001; Weir et al., 2011). Children's predisposition for silent aspiration may reflect the degree of neurological maturation of their cough and swallow reflexes at the time of aspiration (Thach, 2007). Differences in respiratory physiology during infancy and immaturity of the laryngeal chemoreflex (LCR) may also contribute to silent aspiration in infants (Chang, 2006; Kelly, Huckabee, Frampton, & Jones, 2008). While the LCR protects full-term infants from aspiration, an immature LCR results in life-threatening prolonged apnea, severely compromized oxygen saturation levels, and bradycardia in preterm infants (Praud & Reix, 2005; St-Hilaire, Samson, Duvareille, & Praud, 2008). Given the complexity of contributory factors compromising preterm infants' physiological stability, silent aspiration may be overlooked as a potential cause.

How can theory guide our discovery of signs for aspiraton in preterm infants? The Synactive Theory of Development states that five subsystems govern infants' interactions with the enviroment (Als, 1986). Disruption within and between five identified subsystems causes a change in infant behavior because the systems are interdependent and hierarchial. These five subsystems include: (a) autonomic/physiologic, which governs cardiorespiratory activity, gastrointestinal peristalisi, and peripheral skin blood flow; (b) motor, which regulates muscle tone, infant movement, and posture; (c) state organization, which regulates transition through the stages of arousal; (d) attentional/interactive, which governs infants' response to auditory and visual stimuli when awake; and (d) self regulatory capacity, which balances all the subystems (Als, 1986). Given that silent aspiration is under-identified and under-reported, this theory seems an appropriate model for examining behaviors that might suggest increased suspicion for aspiration in preterm infants. The purpose of this study was to gain an understanding of aspiration symptomatology in preterm infants by determining if nurses document feeding behavior differently for infants with and without aspiration.

Methods

A retrospective chart review was conducted on preterm infants born ≤ 37 weeks gestation. Records were selected from a population of preterm infants admitted to a 55 bed NICU of a tertiary care medical center in the southeastern United States. Once approved by the hospital's clinical institutional review board (CIRB), all records of preterm infants who participated in a video-fluoroscopic swallow study (VSS) or an upper gastrointestinal study (GIS) and those who attempted oral feeding daily were included in this study. See Table 1 for a description of infant characteristics.

Table 1. Infant Characteristics Across Groups.

	VSS-A	VSS-NA	GIS/C-NA
	N=13	**N=16**	**N=12**
Gender			
Male	63%	46%	67%
Female	38%	54%	33%
Race			
African American	19%	7%	33%
Caucasian	81%	85%	67%
Other	0%	8%	0%
	M(SD)	**M(SD)**	**M(SD)**
Birth Gestation (weeks)	29.2(4.2)	29.3(3.4)	29.2(2.4)
Birth Weight (grams)	1,236(579)	1,428(821)	1,855(472)
Apgar scores 1 minute	4(2.3)	5(2.8)	5(3)
Apgar scores 5 minutes	6(2.7)	7(2.3)	7(2)
Length of hospitalization (days)	124.4(77.9)	81.3(37.1)	106.1(67.5)
Range of hospital days	35 to 266 days	15 to 165 days	43 to 269 day
Number of days on oxygen	37.7 (48.2)	43.12(48.99)	16.25(19.0)
Range of days on oxygen	1 to 148 days	0 to 165 days	0 to 56 days

A = aspiration; GIS = [upper] gastrointestinal study; NA = no aspiration; VSS = videofluoroscopic swallow study.

Sets of possible behavioral and physiological signs/symptoms of aspiration in preterm infants were postulated based on research evidence from term-infant, child, and adult populations and components of the Synactive Theory of Development (Als, 1986). Behavioral indicators extrapolated from infants' charts signal poor tolerance of sensory stimuli and included shut down (abrupt change from an alert state to a sleep state), abrupt change in muscle tone from normal to flaccid, gulping (suspected audible large bolus swallows), and spillage.

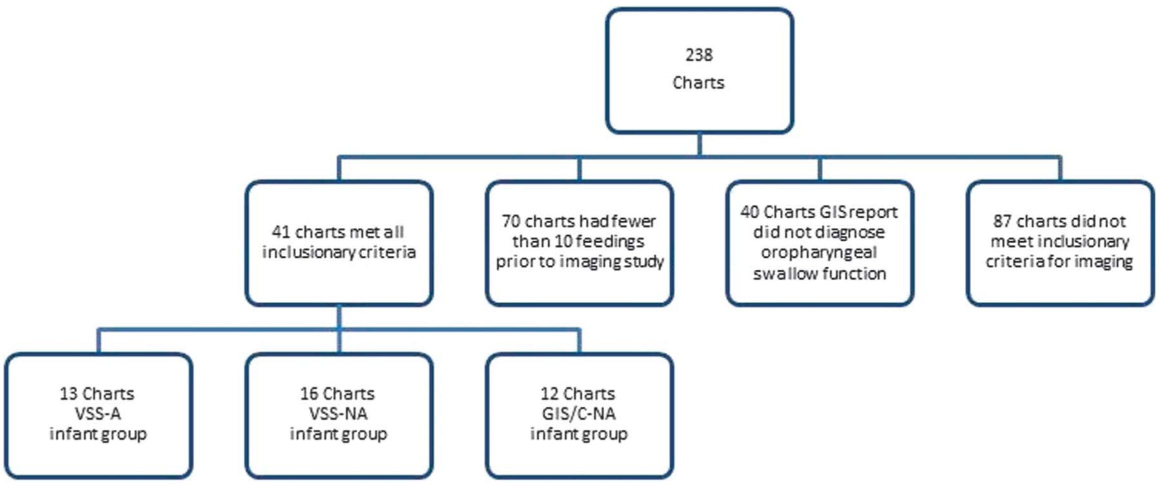
Behavioral indicators reflect disorganization or disruption within the five subsystems described in the Synactive Theory of Development, but do not necessarily suggest hypoventilation. Given that behavior has meaning, infants may display stress behaviors prior to or as a result of physiologic compromise while oral feeding. Or, perhaps internal disorganized compromises their ability to coordinate sucking-swallowing and breathing, thereby increasing aspiration risk. Regardless, intervention at the first sign of disorganization may prevent life-threatening physiological events that occur with aspiration.

Physiological signs relate directly to hypoventilation and physiological instability. The selection rationale for these signs was that episodes of interrupted breathing negatively affect physiologic stability, thereby increasing aspiration risk. The physiological indicators extrapolated from infants' charts were coughing, apnea, decreased oxygen saturation levels below 90%, bradycardia below 100 beats per minute, color changes, and tachypnea.

Data Collection

Initially, 238 charts were identified for potential inclusion in this investigation. Charts were included if documentation revealed: (a) a referral to speech pathology for a swallowing evaluation; or (b) or referral to radiology for an upper GIS; and (c) bottle feeding was attempted during a 14-day period prior to infants participating in a videofluoroscopic swallow study (VSS) or GIS. Infants who underwent a GIS with documented functional oropharyngeal skills and who did not present with aspiration were included as a control group. Charts that did not meet all criteria were excluded from analysis (see Figure 1 for details). Healthy preterm infants and those diagnosed with bronchopulmonry dysplasia, necrotizing enterocolitis, and intra-ventricular hemorrhage were all included. No infant in this sample had craniofacial abnormalities or syndromes.

Figure 1. Chart Selection for Retrospective Data Collection.



Note. A=aspiration; C=control group; NA=no aspiration; GIS=[upper] gastrointestional study; VSS=videofluoroscopic swallow study.

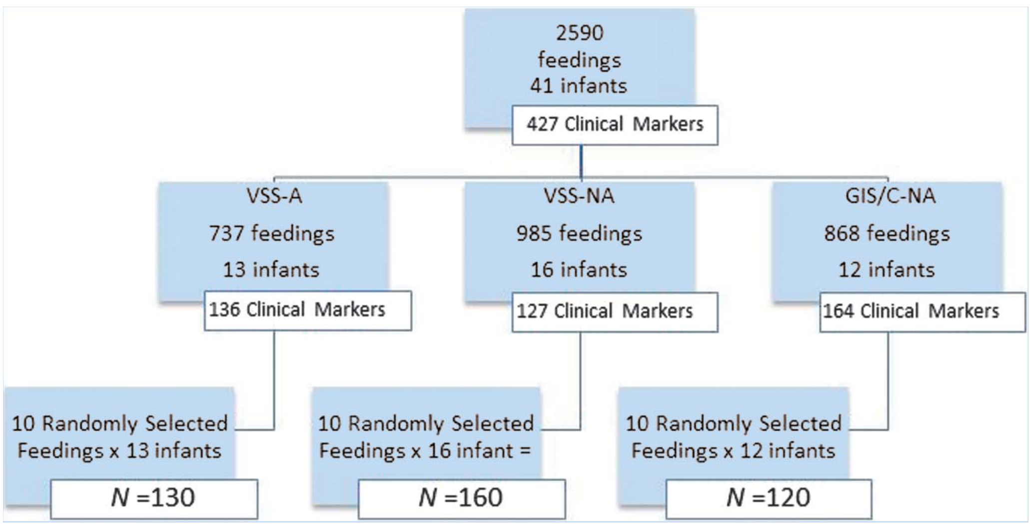
Frequency of occurrence for each distress sign documented in a chart was coded for this investigation. Records were coded for behavioral cues (shut down/loss of state, change in muscle tone from normal to flaccid, gulping, spillage, etc.), physiological distress signs (apnea, bradycardia, cyanosis, coughing, desaturation, and tachypnea), and nursing judgment of difficulty feeding. Variables were coded for each infant if nurses self-recorded them during bottle-feeding attempts fourteen days prior to radiographic imaging studies. Clinical judgments were available for coding in the electronic medical record (EMR). Standardized documentation was provided for nurses in the form of a check box format. Standardized description options in the EMR were “infant fed well”, “infant fed with difficulty”, “infant aspirated,” and/or “infant choked”. Nurses’ judgments of “difficulty” were coded if nurses indicated infant fed with difficulty, infant aspirated, or infant choked.

Multiple analyses were used to explore relationships between prandial aspiration and signs of infant distress (physiological, behavioral, and nursing judgment of difficulty). An alpha level of .05 was used to assign statistical significance.

Results

Charts were stratified into three mutually exclusive groups based on the results from radiographic imaging studies: (a) infants with observed prandial aspiration on VSS (n=13; VSS-A), (b) infants without observed prandial aspiration on VSS (n=16; VSS-NA), and (c) infants without prandial aspiration on upper GIS (n=12; GIS/C-NA). Aspiration on upper GIS was not included in this investigation because aspiration may have occurred due to testing procedures. Results were analyzed in three ways. First, frequency of documentation per variable was analyzed across all feedings regardless of infant. Second, 10 feedings per infant was randomly selected using a random number generator to analyze across infant groups (see Figure 2). Third, given an absence of group differences, the GIS/C-NA and VSS-NA groups were combined in order to compare documentation for infants with and without aspiration.

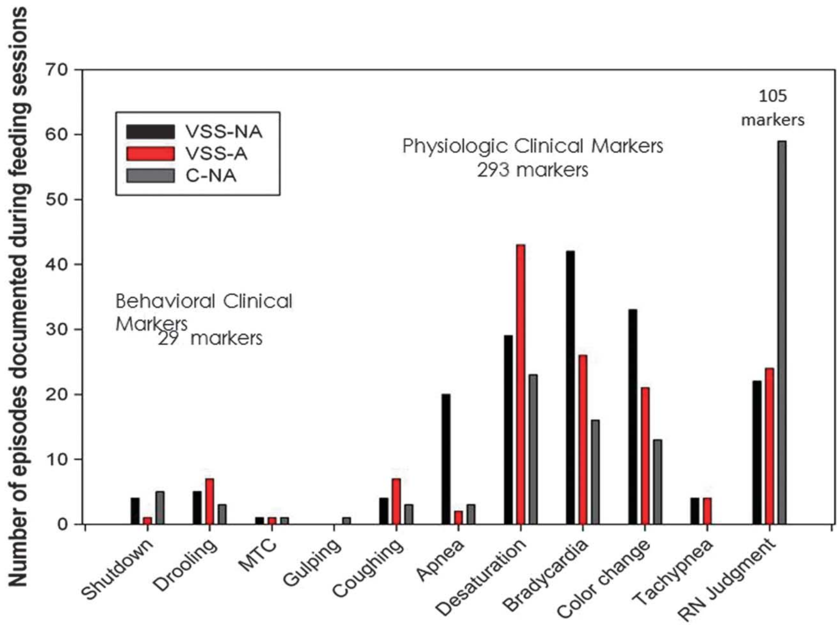
Figure 2. Frequency of Feedings and Clinical Markers; Process of Random Selection Across Infant Groups.



Frequency of Individually Documented Distress Signs Across Groups

In the first analysis, total number of bottle-feedings (2,590) were coded and tallied. Nurses documented physiological signs, behavioral symptoms, and difficulty feeding in only 182 (7%) of these feedings. Means were calculated for each individually documented behavioral or physiological sign (clinical marker) across groups. In this first analysis, a single infant feeding attempt could have multiple documented signs. The final calculation for individual reports of signs/clinical markers (behavioral/physiological) across these 182 feeding sessions was 427. Figure 2 includes the total number of clinical markers documented per infant group and Figure 3 shows the distribution of the 427 individually documented distress signs for each of the three mutually exclusive groups (VSS-A; VSS-NA; and GIS/C-NA).

Figure 3. The Total Number of Clinical Markers Documented in the 182 Feedings With Nursing Documentation Across Infant Groups.



Note. Drooling = Spillage.

Analysis for Randomly Selected Feedings Across Groups

In the second analysis, feedings were randomly selected from each infant group. Descriptive data for 410 randomly selected feedings (10 feedings per infant across groups) are presented in Table 2. The results of the 3(group) by 11(distress sign) mixed model, repeated measures ANOVA revealed a significant main effect of distress sign $F(2.304, 87.541) = 6.679$, $p = .001$, $\eta^2 = .149$, but no main effect of group $F(2, 38) = .002$, $p = .998$, $\eta^2 = .000$. No interaction was found. Post-hoc pairwise comparisons were conducted to determine mean differences among nursing reports of spillage/drooling, coughing, apnea, desaturation, bradycardia, color change, tachypnea, and nursing judgment independent of infant group. Shut down, muscle tone changes, and gulping were not included in post-hoc tests because there were no reports of these distress signs in the *randomly selected* feeding attempts. Results for the post-hoc tests are presented in Table 3. Of the 410 randomly selected infant feeding attempts, the total number of reported behavioral symptoms across bottle-feeding attempts, regardless of infant group, was 11. There were 55 reported physiological signs across feeding attempts. Desaturation accounted for 51% of these reports compared to 31% for color changes, 9% for coughing, 5% for apnea, and 4% for tachypnea.

Table 2. Means and Standard Deviations for the Number of Reported Distress Signs Tallied Across Categories in 410 Randomly Selected Feeding Attempts.

Distress Sign		**VSS-A**	**VSS-NA**	**GIS/NA-NA**
		M(SD)	***M(SD)***	***M(SD)***
		***N* = 13**	***N* = 16**	***N* = 12**
Behavioral				
	Shut-down	.00(.00)	.00(.00)	.00(.00)
	MTC	.00(.00)	.00(.00)	.00(.00)
	Gulping	.00(.00)	.00(.00)	.00(.00)
	Spillage	.06(.25)	.08(.28)	.08(.30)
Nursing Judgment		.25(.45)	.46(.78)	.08(.30)
Physiological				
	Coughing	.31(.63)	.06(.25)	.00(.00)
	Apnea	.00(.00)	.19(.54)	.00(.00)
	Desaturation	1.23(1.79)	.25(.58)	.67(1.30)
	Bradycardia	1.00(1.92)	.31(.60)	.33(1.16)
	Color change	.54(1.05)	.31(.60)	.42(.79)
	Tachypnea	.08(.28)	.06(.25)	.00(.00)

MTC = muscle tone changes

Table 3. Significant Differences Between Reported Clinical Markers.

Distress Sign	***M(SD)***	**Clinical marker**	***M(SD)***	***P < .05***
Nursing Judgment	2.713(.804)	Spillage	.367(.146)	0.004
		Coughing	.346(.121)	0.005
		Apnea	.551(.471)	0.023
		Tachypnea	.186(.088)	0.004
Bradycardia	1.986(.713)	Spillage	.367(.146)	0.038
		Coughing	.346(.121)	0.020
		Apnea	.551(.471)	0.001
		Tachypnea	.186(.088)	0.018
Desaturation	2.346(.538)	Spillage	.367(.146)	0.001
		Coughing	.346(.121)	0.000
		Apnea	.551(.471)	0.000
		Tachypnea	.186(.088)	0.000
Color change	1.587(.544)	Tachypnea	.186(.088)	0.017

Differences for Infants With and Without Aspiration on VSS

In the third analysis, data was reclassified. VSS-NA and GIS/C-NA did not differ across variables. Therefore, data was re-classified in order to compare variables when aspiration occurred and did not occur on radiographic imaging. Pearson chi-square analyses were performed to explore physiological signs and spillage for infants with and without observed aspiration on radiographic imaging. Variables chosen for chi-square analysis were discrete variables that contained adequate data. Results from chi-square analyses revealed if nurses documented coughing, X^2 (1, N = 41) = 3.837, p = .050, and desaturation, X^2 (1, N = 41) = 7.791, p = .005, during the 14 days prior to radiographic imaging, infants were significantly more likely to show aspiration on VSS. The difference between all other physiologic variables and spillage/drooling was not statistically significant, X^2 (1, N = 41) = 3.029, p = .082.

Sensitivity, specificity, and postive likelyhood ratio (LR+) analyses were performed and results are presented in Table 4. Coughing had a LR+ of 8.77 (specificity 97%), desaturation had a LR+ of 2.15 (specificity 79%), and tachypnea had a LR+ of 2.15 (specificity 96%). In summary, when nurses for these 41 preterm infants documented coughing, desaturation, and tachypnea during bottle-feeding, infants were more likely to have aspiration noted on radiographic imaging reports.

Table 4. Sensitivity (SENS), Specificity (SPEC), and Positive Likelihood Ratios (LR+) for Variables and Aspiration on Videofluoroscopic Swallow Study.

	SENS	95% Confidence Interval		SPEC	95% Confidence Interval		LR+	95% Confidence Interval	
		Lower	Upper		Lower	Upper		Lower	Upper
Physiologic Clinical Markers									
Coughing	23	8	50	97	87	99	8.77	0.99	77.09
Apnea	#	#	#	93	77	98	#	0.55	5.38
Desaturation	46	23	71	79	60	90	2.15	0.86	5.47
Bradycardia	31	13	58	82	64	92	1.72	0.15	31.80
Color change	23	8	50	75	57	87	0.92	0.283	3.00
Spillage	8	1	33	93	77	98	1.08	0.11	10.83
Tachypnea	8	1	33	96	82	99	2.15	0.28	3.01
Nursing Negative Judgment	30	13	58	82	64	92	1.73	0.55	5.39
Comorbidities									
BPD	62	36	82	57	39	73	1.44	0.78	2.63
NEC	38	18	64	86	68	94	2.69	0.86	8.41
Cardiac abnormalities	77	50	92	36	21	54	1.20	0.80	1.80
Neurologic abnormalities	46	23	71	75	57	87	1.85	0.77	4.41
Gl abnormalities	23	8	50	50	33	67	0.46	0.16	1.33
CP/Syndromes	8	1	33	89	73	96	0.72	0.08	6.26

Note. SENS, SPEC values = percentages; # = unable to calculate due to zeros in one or more cells.

Clinical Implications

Limited documentation across charts may underrepresent true occurrence of chosen theoretically based signs of aspiration. Regardless, nurses reported physiological signs more often than behavioral cues with a ratio of 10 to 1. Given preterm infants are predisposed to silent aspiration, training crib-side healthcare professionals to identify subtle changes in infant behavior is a critical component in preventing aspiration. As we move toward an infant-driven culture in NICUs, documentation of behavioral cues across healthcare providers is critical.

While behavioral cues are acknowledged signs of disorganization and stress in preterm infants, evidence does not directly relate behavioral cues to increased risk for aspiration. In this investigation, nurses reported very few behavioral cues. Spillage of milk from the mouth was most frequently reported. Expectorated milk from the lips is an overt clinical sign with characteristics that are frequently associated with reduced bolus control, which interferes with adequate volume intake. Shut down/rapid state changes, gulping, and changes in muscle tone are covert changes. Additional research, and perhaps training, is needed before healthcare professionals confidently associate selected behavioral cues in preterm infants to poor tolerance of oral feeding and to increased risk for aspiration.

While this study did not differentiate between overt and silent aspiration, if a nurse reported coughing during oral feeding, the likelihood of noted aspiration on VSS reports increased by 8.77 times. Our results are consistent with evidence from term-infants, children, and adults (DeMatteo et al., 2005; Weir, McMahon, Barry, Masters, & Chang, 2009). Current literature suggests that the laryngeal cough reflex emerges around 44 weeks gestation (Thach, 2007). However, coughing was reported in these younger preterm infants. To our knowledge, prandial aspiration and stimulation of lower pulmonary irritant receptors has not been directly studied in human premature infants. However, infants as young as 35 weeks gestation coughed in response to stimulation of sensory receptors in the bronchi (Fleming, Bryan, & Bryan, 1978). Further investigation is necessary to confirm the presence of a cough reflex in response to pulmonary irritant receptors in preterm infants and to document the developmental trajectory of the protective cough reflex.

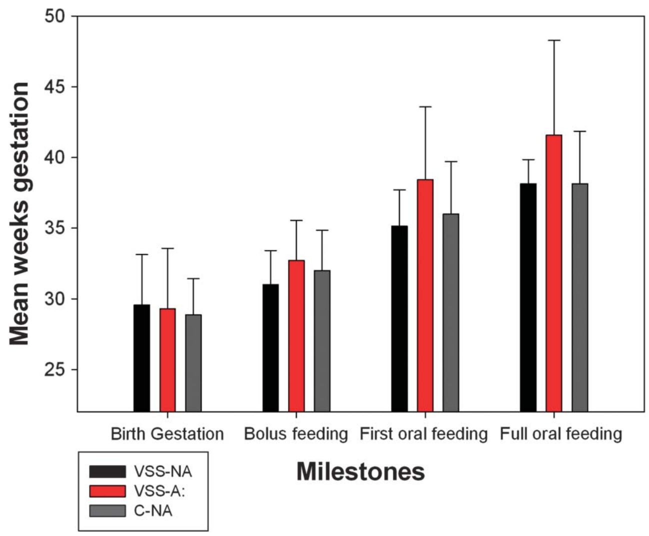
In this group of preterm infants, nurses documented apnea, bradycardia, and color changes most often in infants *without* observed prandial aspiration on VSS. This finding, while counter-intuitive, is consistent with Praud and Reix (2005) and St-Hilaire et al. (2008) who reported extreme life-threating repercussions in response to the LCR when studying animal models. Apnea, bradycardia, and color change may occur in response to the LCR or indeed as a result of aspiration (Kelly, Huckabee, Frampton, & Jones, 2008; Thach, 2007). Therefore, additional research is needed to reveal specific behaviors that occur when preterm infants trigger the LCR and when they aspirate.

In this small group of preterm infants, those who aspirated on VSS were discharged later than those who did not aspirate on VSS (see Table 1). An important caveat to discuss at this point is the purpose of a VSS, which is to assess the biomechanical functions of swallowing. That is, to determine the exact pathophysiological dysfunction preventing safe swallowing. As discussed by many authors, the VSS is *not* a pass/fail assessment. To view it in this manner is to reduce the VSS to a screening tool. At best, the VSS can rule in aspiration, in an unnatural environment. Lack of aspiration on VSS does *not* indicate infants are safe to feed orally. A holistic and comprehensive assessment of each infant is required to determine safety during feeding. First and foremost, the goal of a feeding and swallowing assessment is to maintain adequate nutrition and preserve pulmonary health. However, currently the VSS is the gold standard for assessing swallow function. As such, it was used to understand documentation patterns of crib-side nurses for infants who did and did not aspirate.

Longer hospitalization was associated with our sample of preterm infants who aspirated. Comparion of nursing documentation across distress signals/clinical markers suggested that bedside documentation of prolonged apnea and severe bradycardia was observed most often in infants with denied aspiration on VSS reports. In contrast, the same comparsion of nursing documentation for infants who coughed and desaturated revealed confirmed aspiration on VSS reports. Coughing and desaturation have been linked to increase risk for aspiration in term infants, children, and adults (Daniels et al., 1998; DeMatteo et al., 2005; Weir et al., 2009).

Infants in the current study with confirmed aspiration were hospitalized approximately 43 days longer than those with denied aspiration on VSS reports. Data also revealed a trend toward delayed achievement of feeding milestones (see Figure 4) The propensity for silent aspiration in preterm infants increases their risk for undetected aspiraiton, which may persist after discharge and contribute to higher rates of rehospitalization (Raju, Higgins, Stark, & Leveno, 2006). Without sufficient evidence for behaviorial responses that reliably indicate aspiration and a clear understanding of the cough reflex development in an extra-uterine environment, clinicians must rely on clinical experience to guide clinical judgments.

Figure 4. A Comparison of Feeding Milestone Achievements Across Infant Groups.



Note. Error bars represent standard deviation.

Study Limitations

Study limitations associated with this investigation provide directions for future research. Due to the retrospective nature of this investigation, clinical judgments, feeding position, number of nurses feeding, and documentation criteria were not controlled. Variability between groups may have occurred due to differences in crib-side clinical experience, subjective judgments, interventions, medications, and/or severity of illnesses. The unexpected low incidence of reporting the selected variables may also reflect a large gap in shared knowledge amongst nurses and the evidence regarding feeding issues. Results may reflect reporting accuracy rather than the actual relationship between signs and aspiration. Other unknown confounding variables could also account for variability across groups. Finally, data was collected from a small infant sample obtained at a single research site, which limits generalizability.

Conclusions

The degree of neural maturation and diminished stress responses in the presence of repeated exposure to small amounts of aspiration (Johnson et al., 1999) contribute to silent aspiration (Newman et al., 2001). Based on the Synactive Theory of Development, interruption within the five interdependent subsystems is manifested in infant behavior. Therefore, infant behavior may be used to determine increased risk for aspiration. Future research that investigates the signs of aspiration (overt and silent) in preterm infant behavior is needed to support the practices of clinical crib-side clinicians. The end goal is to improved health status of preterm infants who aspirate by identifying evidence-based signs/symptoms that directs prompt management designed for prevention. Our results provide a foundation for further prospective investigation of signs for aspiration in preterm infants.

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