

Infant-Guided, Co-Regulated Feeding in the Neonatal Intensive Care Unit. Part I: Theoretical Underpinnings for Neuroprotection and Safety

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ABSTRACT

The rapid progress in medical and technical innovations in the neonatal intensive care unit (NICU) has been accompanied by concern for outcomes of NICU graduates. Although advances in neonatal care have led to significant changes in survival rates of very small and extremely preterm neonates, early feeding difficulties with the transition from tube feeding to oral feeding are prominent and often persist beyond discharge to home. Progress in learning to feed in the NICU and continued growth in feeding skills after the NICU may be closely tied to fostering neuroprotection and safety. The experience of learning to feed in the NICU may predispose preterm neonates to feeding problems that persist. Neonatal feeding as an area of specialized clinical practice has grown considerably in the last decade. This article is the first in a two-part series devoted to neonatal feeding. Part 1 explores factors in NICU feeding experiences that may serve to constrain or promote feeding skill development, not only in the NICU but long after discharge to home. Part II describes approaches to intervention that support neuroprotection and safety.

KEYWORDS: Premature neonates, feeding, neuroprotection, infant-guided, cue-based

Learning Outcomes: As a result of this activity, the reader will be able to (1) describe factors inherent in neonatal intensive care unit care that impact oral feeding; (2) list three signs of newborn stress during oral feeding; (3) discuss the impact of feeding problems on the family unit.

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Approximately 11.7% of neonates are born preterm each year in the United States and may require intensive care for the first few days, weeks, or months of life.¹ Neonates born less than 37 weeks' gestational age (GA) are considered preterm, and supporting their progression to discharge requires the care of multiple professionals. Criteria for discharge are based on physiologic parameters, including both good weight gain patterns, maintenance of body temperature, and feeding without cardiorespiratory compromise, as well as active parental involvement and planned follow-up to support growth and development.² The rapid progress in medical and technical innovations in the neonatal intensive care unit (NICU) has been accompanied by concern for the developmental trajectories of neonates and infants graduating from the NICU. Although advances in neonatal care have led to significant changes in survival rates of very small and extremely preterm neonates, improved survival rates bring an increased risk for nutritional, growth, motor and sensory problems.^{3,4}

The delay in acquiring feeding skills is the most frequent cause of prolonged hospitalization in the NICU.^{5,6} This is especially true for many preterm newborns who are less mature at birth (at or under 28 weeks' gestation), have extremely low birth weight (at or under 1,000 g), and have complex medical conditions, including respiratory, airway, neurologic, and digestive comorbidities.⁶⁻⁸ The number of medical comorbidities or medical complications correlates significantly with length of transition from gavage to full oral feedings.^{6,9} Yet achieving full oral feedings is a primary competency required for discharge of preterm neonates from the NICU to home.²

Although in utero the sensory-motor underpinnings for oral feeding begin as early as 17 weeks of life, neonates born preterm are at a disadvantage.¹⁰ Not only are early feeding difficulties associated with the transition from tube feeding to oral feeding prominent,¹¹ but feeding problems often persist beyond discharge to home. Indeed, the incidence of enduring feeding problems in preterm newborns is estimated to be from 19 to 80%.^{12,13} Research suggests that feeding and feeding problems remain worrisome for parents of

former preterm neonates well into the toddler years and beyond.¹² Such problems may include feeding refusals, prolonged feeding times, poor acceptance of textured foods or family's diet, coughing/choking, more lengthy feedings, oral-motor problems, poor chewing, and the need for ongoing feeding therapy services.¹⁴ After discharge to home, mothers of former preemies report their own discomfort during feeding. They describe trouble "reading" their neonate's or infant's feeding cues and continue to have many unanswered questions related to feeding.¹⁵ Given the potential for adverse feeding outcomes, it is important to explore what it is about the experience of learning to feed in the NICU that may predispose preterm neonates to feeding problems that persist. The purpose of this article is to explore factors in NICU feeding experiences that may serve to either constrain or promote feeding skill development in the NICU and after discharge.

FEEDING EXPERIENCES AND NEUROPROTECTION

Progress in learning to feed in the NICU, as well as continued growth in feeding skills after the NICU, may be closely tied to fostering neuroprotection.¹⁶ There is growing concern that the often-routine and well-intentioned practice to measure newborn or infant feeding progress based primarily on volume intake (i.e., a volume-driven focus) creates a negative experience for NICU neonates, who are extremely vulnerable to stressful experiences. Alternatively, a careful sensitive approach is essential to support the preterm newborn's oral feeding journey in alignment with their neurodevelopment and to avoid potential aversive feeding behaviors in the future.¹⁷

Neuroprotection encompasses interventions that promote brain development and prevent the onset of iatrogenic neuronal injury in the developing premature neonate related to stress and/or pain.¹⁶ The premature neonate's brain is developing and being influenced by his or her experiences in the NICU, not in mother's womb. Research shows that there is rapid change in the brain during the last trimester, whether in the womb or in the NICU.¹⁸ Connections in the brain are made with

dendritic growth, synaptic connections, apoptosis, myelination, and finally, pruning. During the time premature newborns are learning to feed in the NICU, they are in the process of developing motor and sensory neuropathways. Every early experience affects the developing brain.¹⁹ Unused pathways are pruned and those that are used, be they positive or negative, are reinforced.²⁰ Modulated via the amygdala, the onset of fear or stress responses during feeding can activate the “fight-or-flight” response and cue the adrenal glands to release stress hormones into the bloodstream.²¹ Repeated stressful feeding experiences in the NICU (i.e., ones that adversely affect both physiology and pleasure/pain responses) have been shown to alter the architecture of the newborn’s brain. Increased exposure to stressful events in the NICU is associated with alterations in both neurobehavior and brain structure at term equivalent ages.²²

Repeated stressful experiences during feeding are believed to establish altered pathways in the developing brain that guide the newborn away from feeding, lead to maladaptive behaviors, and adversely affect the ability and desire to feed both in the NICU and after discharge home.^{23,24} These adverse experiences may inadvertently be fostered by well-intentioned caregivers who do whatever is necessary to “get infants to eat” so they can go home.²⁵ This leads to physiologic stress and negative feeding behaviors, as the newborn or infant struggles either to fight the flow to breathe or to be fed despite disengaging. The undue stress associated with trying to orally feed predisposes the neonate or infant to safety issues and altered sensory-motor pathways in the brain, which may in turn lead to a long-term, learned feeding refusal.²³ The neonate or infant may experience these effects not just in the NICU but after discharge if parents have been taught to focus on emptying the bottle as their goal during feeding.²⁶

Caregivers impact the premature neonate’s brain with every interaction. Interventions that promote adaptive neuronal connectivity or “mapping” are essential to protect the developing brain and avoid onset of maladaptive behaviors. NICU caregivers can protect the developing brain by being in the moment, being

present, decreasing stress, supporting coping skills, reducing pain, offering well-graded positive touch, promoting sound sleep and kangaroo care, educating parents to understand and respond to the newborn’s communicative cues, and incorporating family-centered care.²⁴ Preterm neonates are establishing their learned experiences with each feeding, and therefore, every feeding experience must be as positive as possible.^{27,28} One negative stressful feeding experience can change the brain of the developing preterm neonate and an associated impression is left for the rest of the child’s life.¹⁶ In summary, supporting neuroprotection during oral feeding means reducing the stress experienced by the preterm neonate while facilitating the newborn’s emerging competence. With frequent opportunities to learn to feed in the NICU, the premature neonate’s brain can be best supported through nonstressful feedings utilizing a co-regulated infant-guided approach.²⁹

DYNAMIC SYSTEMS THEORY AND CO-REGULATED FEEDING

Feeding safely and achieving adequate intake for growth requires the dynamic integration, maturation, and coordination of multiple subsystems. In a dynamic systems model, physiologic stability is considered the foundation for organizing movement, behavioral state, attention/interaction, and self-regulation (see Goldfield et al, this issue).³⁰ These subsystems are the underpinnings for safe and efficient feeding as observed in the neonate’s arousal, physiologic regulation, posture, oral structures, upper airway function, and suck-swallow-breathe patterns. For the preterm neonate, these subsystems are in the process of maturing along convergent, but not always synchronous, time lines.³¹ Responsiveness to the neonate’s competencies, vulnerabilities, and thresholds is critical.^{31,32} The newborn’s responses and behaviors guide the caregiver in understanding neonatal thresholds of stress versus stability, as these subsystems are constantly interacting.³¹

Neonatal behaviors during feeding are a direct reflection of dynamic system interactions and are best interpreted from that perspective.³² For example, newborns whose breathing is

disrupted may compensate by changing their sucking pattern or moving into a light sleep state. They may try to reduce the amount of fluid entering the mouth by limiting their jaw and tongue movements, pushing the nipple out, or purposefully stopping sucking altogether. The newborns exhibit these behaviors because physiologic instability affects the drive to suck and the stamina to stay alert. It is important to remember that neonates behave in certain ways during feeding in response to a stimulus. A caregiver who does not realize certain behaviors (e.g., refusal of the nipple) are compensatory strategies may mistakenly interpret the behavior as a sucking problem and may apply an intervention—such as increasing the flow rate of the nipple—that ignores the underlying issue and can override the newborn's working compensatory strategy.²³ If each feeding is as stress-free as possible, however, the neonate learns to respond positively to feeding.

Contingent interventions are used to maintain subsystem stability and enhance self-regulation, development, and coping skills. The co-regulation between caregiver and newborn forms the foundation for a positive infant-guided feeding experience. This approach to feeding as described by Shaker includes observing the newborn from moment to moment during feeding for cues of stress versus stability specific to swallowing, breathing, physiologic stability, postural control, and state regulation and then continuously modifying the feeding approach through individualized interventions contingent on the neonate's cues.²³

TRANSFORMING THE CULTURE OF FEEDING IN THE NICU: VOLUME-DRIVEN TO INFANT-GUIDED FEEDING

With the increased awareness of neuroprotection and dynamic systems theory, most NICUs have introduced “cue-based” feeding to promote individualized feeding experiences based on the neonate's cues. A growing body of evidence suggests it is paramount that professional caregivers in the NICU appreciate the meaning of neonatal behavior.³³ Sensitivity to the neonate's subtle communicative nuances is essential, so all aspects of care, including oral

feeding, are provided in a supportive manner.³⁴ Research has shown that the ability to feed well is closely related to the caregiver's ability to understand and sensitively respond to the newborn's physiologic and behavioral communication.¹⁵ Through trust in the meaningfulness of neonatal behavior, the traditional task-oriented mode of care is transformed into a collaborative model, with newborns, as active participants, guiding caregivers during oral feedings.

Although studies have shown cue-based feeding leads to earlier achievement of full oral feeding,^{35,36} the successful implementation of cue-based feeding continues to be constrained by the volume-driven culture, which has existed for many years in the NICU. This culture was built upon the notion that a “better” caregiver is one who can “get more in,” and neonates who are “poor feeders” are ones who “can't take enough.” In a volume-driven culture the focus is on intake, rather than on enhancing quality of feeding or the neonate's experience of feeding.³⁷ Caregivers may feed past the newborn's “stop signs,” which communicate “I am done,” with minimal regard for neonatal communication. Strategies to transfer volume often include (1) increasing the nipple's flow rate; (2) “encouraging” sucking (e.g., jiggling the bottle), which takes away the newborn's active sensory-motor control over feeding and delivers unanticipated liquid flow into the neonate's oral cavity and/or pharynx; (3) putting the neonate's head back to use gravity to help empty the bottle, which increases the risk for bolus misdirection and airway compromise; and (4) unswaddling the newborn to “keep the infant awake,” taking away critical postural support of the head and neck for the swallowing mechanism. The neonate may be expected to continue feeding, despite subtle signs of physiologic instability that suggest swallowing and breathing are starting to uncouple. Signs might include drooling, gulping, nasal flaring and blanching (onset of whitish color), the lack of a series of deep breaths, chin tugging (frequent head/neck extension pattern used to biomechanically open the airway), and changes in eye gaze pattern.²³ Signs of disengagement though clear may not have meaning to all caregivers. These signs may include pushing the nipple out, pulling off the nipple, no active rooting or sucking, arching, shutting down/inability to realert, or

purposeful use of a weak suck on the neonate's part to signal a preference for return to only pacifier sucking.²⁹

Some professional caregivers may value efficiency over the newborn's experience of feeding. This leads to postfeeding ratings such as "well, fair, poor," reflecting only intake. The neonate who feeds faster is viewed as more skilled in this task-oriented approach. The pressure to "get it in" the neonate is often then passed along to parents, for whom feeding becomes something they do "to" their newborn, instead of a relationship-based experience through which communicative interactions build trust.²⁶

Conversations change as the culture of feeding is transformed. In a volume-driven culture, parents are often told their newborn can go home when he or she is "taking all his or her bottles." As the culture of feeding changes, that requirement is carefully followed by reinforcement of the complexity of learning to feed and the need for both the patience and the supported learning required. Without that caveat, parents can be suddenly transformed into volume-driven caregivers. Parents in a volume-driven culture may be told that they should not worry, because "the lightbulb will suddenly come on" (i.e., their neonate will suddenly "figure it out" and therefore "know how to feed"). In a culture that is no longer volume-driven, parents are supported through guided participation and reflective thinking to appreciate that learning to feed is a complex developmental process that requires carefully titrated interventions that build neonatal skill and competence.²⁶

In a volume-driven culture, conversations at NICU discharge planning rounds focus solely on "percent PO taken" and weight gain. In a transformed infant-guided culture, the quality of feeding is also discussed, as are observed events of decompensation that suggest the need for a consult to the neonatal therapist to support the neonate and the entire team. Although intake is clearly an important measure of feeding integrity required for discharge from the NICU, intake must be viewed in the context of the newborn's developmental strivings, and as the by-product of a quality feeding.²⁸ This is the difference between "being fed" and "being supported to feed" through infant-guided co-regulation. Cue-based feeding

becomes more than learning to respond to neonatal distress; it is learning from the newborn how to anticipate what will be needed for neuroprotection and safety.³⁸

SAFETY

Breathing and swallowing share a common space, so their lack of synchrony may compromise safety, efficiency, or adequacy of nutritional intake.³⁹ Safe feeding implies a minimal risk for aspiration and effective suck-swallow-breathe coordination.⁴⁰ This coordination may appear as early as 32 weeks' postmenstrual age,^{35,41} when it is rudimentary and precarious, and it continues to progress in its refinement well after discharge.²⁸ Efforts to coordinate sucking, swallowing, and breathing may compromise physiologic stability and lead to a loss of coordinated feeding behaviors as the neonate attempts to protect his or her airway. Immature suck-swallow-breathe rhythm and ineffective swallow-breathe integration may lead to feeding difficulties and indeed to aspiration.^{42,43} Respiratory rate and phase of respiration interruptions during the pharyngeal swallow have been identified as relevant factors to aspiration risk.⁴⁴ Typically, delays in achieving full safe oral feeding arise from concern for physiologic, often cardiorespiratory, instability or because of ineffective esophageal and airway protective mechanisms.⁶

Work of breathing, oxygen saturation, heart and respiratory rates, and suck-swallow-breathe synchrony are sensitive physiologic indicators of the preterm neonate's ability to cope with the stress of feeding. The challenge of feeding can quickly trigger changes in any of these parameters. The caregiver must utilize watchful vigilance to avoid potentially serious consequences of instability (i.e., apnea, bradycardia, tachypnea, color change, and loss of state arousal and/or postural control).^{23,45} If feeding provides a significant challenge to physiologic stability, there may be a resulting negative effect on the control of the larynx, pharynx, and esophagus. The consequence of this deterioration is the potential for laryngeal penetration or indeed aspiration (i.e., the misdirection of fluid below the level of the true vocal folds).²³ In addition, the potential for silent aspiration is

heightened in this fragile population.^{46–48} This likely relates to the dynamic interaction of neural, musculoskeletal, airway, and pulmonary immaturities, which together predispose the neonate to incoordination of the suck-swallow-breathe sequence. The most recent data suggest that over 94% of aspiration events in the pediatric population are silent, or asymptomatic, without any outward sign such as coughing.⁴⁶ Neonates with respiratory problems and complex medical conditions are at even greater risk for ineffective interfacing between swallowing and breathing.^{45,46} This disruption may be the pathway to aspiration and its attendant sequelae in the preterm neonate.

Poor coordination of swallowing with breathing creates the conditions for fluid threats to the airway, extended airway closure and pattern of insufficient rate and depth of breathing.^{49,50} This may lead the preterm neonate, in a protective maneuver, to use adaptive or compensatory strategies to reduce bolus size, such as limited jaw and tongue excursions, or weaker compression-only sucking,⁵¹ or purposefully expelling excess fluid out of the oral cavity. Recognizing these disruptions in neonatal system synergy increases the likelihood the caregiver will address the underlying issue versus applying an arbitrary intervention that may override the neonate's own beneficial compensatory mechanism and create safety issues related to airway protection.⁴⁹ Using a faster-flow nipple, or providing cheek or jaw support in response to the newborn's purposefully limited sucking,⁵² will deliver a larger uncontrolled bolus passively toward the airway, possibly eliciting apnea and/or bradycardia.⁵³

The dynamic nature of feeding requires the caregiver to partner with the neonate during feeding (i.e., the newborn and the caregiver together co-regulate the feeding). Barnard's model of reciprocal interaction between neonate and caregiver describes the communicative interaction that occurs when the newborn offers behavioral and physiologic signs to a caregiver.⁵⁴ The caregiver then interprets the neonate's communication within a problem-solving context, provides opportunities for and reflects upon the meaning of the neonate's communication, then selects contingent interventions that support and strengthen the neonate's efforts and

respects the newborn's limits.⁵⁰ The neonate informs the caregiver about the flow of milk; ability to tolerate bolus size; if the sucking burst is too long; if more postural support is needed; if realtering or calming is needed; when feeding should be started, paused, or stopped; and if swallowing and breathing are becoming uncoupled.^{50,55} This communicative interaction helps anticipate the newborn's needs throughout the feeding, thus supporting airway protection and avoiding the need to suddenly "rescue" a neonate whose incoordination results in a major event of physiologic instability.

Events of overt decompensation during feeding are worrisome for aspiration. When the author observes clinical signs of decompensation (such as apnea, bradycardia, choking, coughing, color change) when preterm neonates are oral feeding, there is typically aspiration during a subsequent videofluoroscopic swallowing study (VFSS). Ferguson conducted a retrospective study to identify potential clinical signs of aspiration in preterm neonates based on crib-side nursing documentation.⁵⁶ When the crib-side nurse had documented (1) coughing, (2) compromised oxygen saturation levels, and (3) tachypnea, the subsequent VFSS revealed aspiration. These compelling clinical correlates of aspiration suggest the need to carefully assess swallowing safety throughout an oral feeding.

Risk factors for airway compromise have been identified for preterm neonates. Swallowing dysfunction is more closely correlated with GA than postmenstrual age,^{41,57} meaning that age when learning to bottle-feed is not as predictive as GA at birth. This may be due to an increasing risk for medical comorbidities that accompany GA.⁶ Lee and colleagues reported that up to 70% of very low birth weight neonates (birth weight < 1,500 g) demonstrate swallowing difficulties and up to 30% have impaired airway protection.⁵⁸ The impact was most apparent for those preterm neonates with significant respiratory comorbidity,⁴⁸ because breathing efforts are the last to be integrated into a successful feeding episode for preterm neonates,⁴² especially those with chronic lung disease (CLD).^{59,60} The author has observed that those newborns with CLD are more likely to aspirate during an VFSS than preterm neonates without CLD. Due to most aspiration

events in preterm neonates occurring silently,^{46,61,62} the adverse effects of ongoing aspiration may have a cumulative effect. Aspiration can lead to a wide range of problems, from pneumonia to damage of developing lungs to worsening chronic lung disease.^{61,62}

SUPPORTING FAMILY-CENTERED CARE AND THE FEEDING RELATIONSHIP

Despite the evolution in NICUs away from a volume-driven culture, feeding preterm neonates may still be viewed by some professionals as a routine task rather than a critical element of care. Feeding may be delegated to the least experienced professional caregiver, such as a new nurse or patient care assistant, or in some settings, to a volunteer. Yet skilled professional caregivers are critical in fostering the parent–infant relationship through guiding positive feeding experiences for the neonate and family. Indeed, a goal of family-centered care is to enhance the attachment between the neonate and family, which improves the long-term physical, emotional, psychological, and feeding outcomes of the preterm neonate. George et al proposed that when the parent is supported in understanding the newborn’s behaviors and responding promptly and appropriately, trust is established, and the parent–infant relationship thrives.⁶⁴ Neonatal feeding, associated with nurturing, development, and growth, offers one of the earliest opportunities to support this connection between parent and neonate.⁶⁵ The NICU experience can either jeopardize or enhance the parents’ ability to understand, support, and parent their preterm neonate. With respect to feeding, the parent–infant interaction can also be adversely affected by lack of consistency in information provided to parents or a lack of continuity in the approach to feeding advocated by professional caregivers, which can then interfere with development of parental competence and confidence.⁶⁵ The preterm neonate’s health care team must communicate with each other about feeding so that information from various disciplines will not differ substantially, which has the potential to confuse or worry parents. Professional caregivers in the NICU who feed newborns, in-

cluding nurses, developmental specialists, and neonatal therapists, can promote development and parent–infant attachment by modeling and supporting consistent quality feeding experiences.

DOES AN INFANT-GUIDED, CO-REGULATED FEEDING APPROACH MAKE A DIFFERENCE?

Research has looked at the impact of an infant-guided co-regulated feeding approach to guide feeding duration, frequency, and volume. McCain reported that healthy preterm neonates at 32 to 34 weeks’ postmenstrual age when fed based on physiologic and behavioral responses achieved full bottle-feeding sooner compared with those fed per volume-based standard care.⁶⁶ McCain elsewhere reported similar results for neonates with CLD born at <24 weeks’ gestation.⁶⁷ Thoyre et al noted newborns with lung disease born at <32 weeks’ gestation fed with an infant-guided co-regulated approach had more stable oxygen saturations, less heart rate fluctuation and decline, improved swallowing, and less excessive breathing effort.⁵⁰ Davidson et al reported that chronically ill, high-risk newborns achieved full oral feedings via an infant-guided co-regulated approach an average of 10 days sooner compared with those fed via a provider-driven protocol.³⁶ Thoyre and colleagues elsewhere reported on implementing a method to guide mothers in providing co-regulated, cue-based feeding for their hospitalized preterm neonates.⁶⁸ Using guided participation, they taught mothers to read neonatal cues, co-regulate breathing pauses, regulate milk flow, support motoric stability, and provide rest periods. Skill was developed through utilizing joint attention, opportunities for mother to learn about her newborn’s behavioral and physiologic cues, competencies to address her newborn’s needs, and creating confidence in problem-solving. Unique to the study was the addition of auditory cues via a tiny microphone system that amplified breathing and swallowing sounds and videotaped feedings replayed to more deeply explore issues and reflect on feedings.^{50,68} Interventions aimed at guiding mothers in supporting coordinated neonatal feeding

behavior have been shown to have positive benefits beyond the NICU.⁶⁹

THE ROLE OF THE NEONATAL SPEECH-LANGUAGE PATHOLOGIST

Speech-language pathologists (SLPs) have had a primary role in the evaluation and treatment of neonates and infants with feeding and swallowing disorders for more than five decades.⁷⁰ The NICU SLP is in a unique position to advocate for the pivotal role of preterm neonatal communication. Although SLPs typically focus on feeding readiness and feeding experiences in the NICU,^{23,70,71} they can also advance the need for individualized neuroprotective care during all interactions with preterm neonates.^{58,72} This means advocating to minimize physiologic stress in the NICU in general, as well as that associated with learning to feed both in the NICU and indeed after discharge. It further means supporting and educating staff (from neonatologists, to nurse practitioners, to bedside nurses) about changing the culture of feeding in the NICU from “volume-driven” to “infant-guided.” SLPs can foster neuroprotective, safe feeding through dialogue, in-service, role modeling, conversations at the bedside, collaboration, and bringing the current research to the team. Through partnering with parents, SLPs can help parents understand their newborn’s unique communication during feeding and respond contingently to reduce stress and promote safety.

CONCLUSION

Every experience matters in the NICU, especially every feeding experience. Infant-guided, co-regulated feeding practice recognizes the critical role of preterm neonatal communication. Sensitive caregivers minimize stress for the newborn, provide opportunities for and reflect upon the meaning of the newborn’s communication, and then select contingent interventions that support and strengthen the neonate’s efforts and respect the newborn’s limits. In Part II of this series, evidence-based interventions to support neuroprotection and safety are explored.

DISCLOSURES

Catherine Shaker is the owner of and a paid presenter for Pediatric Resources Inc., an ASHA continuing education provider, which offers seminars related to article content. She receives a salary from Florida Hospital.

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