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Nursing networks in the NICU and their association with maternal stress: A pilot study

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Abstract

Aims: This pilot study explored how maternal stress experienced in the neonatal intensive care unit (NICU) is affected by the individual nursing structure and the network that provides care to extremely preterm infants.

Background: Mothers experience high stress when their extremely preterm infants are hospitalized in the NICU. This often translates into maladaptive parenting behaviours that negatively affect the long-term cognitive, social, and emotional development of the infant. Efforts to identify modifiable sources of maternal stress in the NICU could lead to improvement in maternal engagement and, ultimately, long-term neurodevelopmental outcomes.

Method: Time- and date-stamped nursing shift data were extracted from the medical record and transformed into five structural nursing metrics with resultant nurse data networks. These were then analysed for associations with maternal stress outcomes on the Parental Stressor Scale (PSS: NICU).

Results: Infants experienced highly variable nursing care and networks of nurses throughout their hospitalization. This variability is associated with the PSS: NICU (a) Sights and Sounds and (b) Altered Parental Role subscales.

Conclusion: Nursing structure and the resultant caregiving network have an impact on maternal stress.

Implications for Nursing Management: Changing the pattern of nurse staffing may be a modifiable intervention target for reducing maternal stress in the NICU.

KEYWORDS

extremely premature infants, neonatal intensive care unit (NICU), network science, nurse caregiving, nurse staffing, nursing structure

1 | INTRODUCTION

Parenting an extremely preterm infant in the neonatal intensive care unit (NICU) is an acutely stressful endeavour. Extreme prematurity (defined as a gestational age <27 weeks) is often accompanied by a wide range of medical complications from brain haemorrhage and infection to bronchopulmonary dysplasia and feeding intolerance (Glass et al., 2016). Treatment plans involve advanced respiratory support and often surgery, which results in hospitalizations that can last up to six times longer (Hintz et al., 2010) than the typical preterm population. In addition, the NICU environment is a trauma environment (Coughlin, 2016). The care procedures, invasive equipment, sleep deprivation, and isolation that these infants experience during hospitalization create toxic stress. Early and prolonged exposure to this environment has been shown to be detrimental to the psychological, emotional, and developmental health of both the extremely preterm infant and the family (Arpi & Ferrari, 2013; Glass et al., 2016; Hutchinson, DeLuca, Doyle, Roberts, & Anderson, 2013; Johnson & Wolke, 2013; Subedi, Deboer, & Scharf, 2017).

In particular, disruptive patterns of maternal psychological distress (Holditch-Davis et al., 2016) can occur due to the inability of mothers to cultivate fundamental social and developmental aspects of the relationship with their newborns. While trying to navigate their altered parenting role, mothers of extremely preterm infants also report distress related to the sights and sounds of the NICU, and over how their babies look or act (Miles, Funk, & Carlson, 1993). For many NICU mothers, this distress can translate into post-traumatic stress disorder up to one-year after discharge (Aftyka, Rybojad, Rosa, Wróbel, & Karakuła-Juchnowicz, 2017). Further, these experiences can result in decreased maternal sensitivity to the infant, fewer positive perceptions about their child, and missed opportunities for mother-infant engagement and learning (Feldman, Eidelman, & Rotenberg, 2004).

As the adverse impact of the NICU environment on patient and family wellbeing has become increasingly clear, associations between parental distress and specific aspects of the NICU have been identified (Miles et al., 1993; Stasik-O'Brien, McCabe-Beane, & Segre, 2017). However, traditional studies of the NICU environment have focused primarily on exploring aspects of equipment use, unit sounds, room space, and other physical elements. Our work aims to expand the concept of environment by focusing on the effects of the human interactional elements of nursing care on infant and parent outcomes.

Our motivation for this shift is grounded in an emerging set of works that have explored characteristics of relationship-based care (Faber, 2013), continuity in nursing care (Spruill & Heaton, 2014), and microsystem care structures (El Helou et al., 2017) in the NICU. The premise of these models of care is that more consistent care, defined as fewer different nurses caring for a patient, will improve patient outcomes and overall satisfaction. These models have considered aspects of consistent, primary care, and highlighted the potential for such care structures to positively impact outcomes including family satisfaction and perception of care. Our work extends these models.

Previous researchers have defined care consistency as the percentage of NICU shifts by the most frequent caregiver (Mefford & Alligood, 2011) or have created an index calculation of the total number of different nurses divided by the total number of shifts (Spruill & Heaton, 2014). In this study, we employed a network theory approach to examine the network (overall staffing pattern) of nurses providing care for extremely preterm infants in the NICU. We described not only the number and percentage of times nurses provided care but also the degree to which nursing care was centralized and consistent.

The purpose of this pilot study was to examine various features of the caregiving networks of NICU nurses and their associations with maternal stress outcomes. We hypothesized that nursing consistency could be quantified using network science and that nurse caregiving networks that were more centralized and consistent would be associated with lower maternal stress scores.

2 | STUDY POPULATION

This was a prospective pilot study of a convenience sample of 17 extremely preterm infants (gestational age <27 weeks) admitted to a Level IV all-referral NICU with 114 patient beds staffed by over 350 nurses. Of these nurses, 61 were specifically designated as "small baby nurses" who had specialized training in the care of extremely preterm infants. In the participating institution, typical hospitalizations for extremely preterm infants involve initial admission to the small baby NICU with eventual transition to a step-down unit after stabilization and 32 weeks corrected age, followed by either discharge home or transition to other units for longer term care.

3 | MEASURES

The data collected for this study were broken down into three principal categories. These included comprehensive shift records for the nursing care of each infant, an objective measure of stress collected from each mother, and maternal and infant demographic data. Details of each category can be found in the sections that follow.

3.1 | Nurse caregiving structure and the nursing network

Date- and time-stamped nursing shift data were extracted from the electronic medical record (EMR) of each infant for each day of its hospitalization from date of admission to the date that the maternal stress instrument was administered. From these data, five structural metrics were calculated and a nursing network was built for each infant. The nursing network was defined as the pattern of assignment of nurses who cared for each individual infant for the duration of the infant's hospitalization. Our five derived structural metrics included: *total number of shifts* experienced by the infant during hospitalization, *number of unique nurses* entering the network during the hospitalization, *time until first repeat shift* (number of shifts until the infant was cared for by a nurse already in network), *average shifts* (average number of shifts each nurse accounted for with respect to a specific infant during hospitalization), and a*verage +1 shifts* (average shift count including only those nurses who recorded more than one shift in the network).

The temporal nature of the shift data also allowed us to construct patient-based, one-mode (one-direction) networks of nursing handoffs for each infant. Such networks typically consist of a set of entities known as nodes, and connections between pairs of nodes, known as edges. In the context of these care networks, each node represents a unique nurse who cared for an infant, while an edge connects two nurses each time one nurse handed off her shift in one direction (one mode) to another nurse.

Through such networks, numerous statistics can be computed to capture various properties of these handoffs. However, for this study, we focused on aspects of care consistency utilizing measures of centrality (Freeman, 1979). Centrality refers to the extent to which the network has a group of nurses who repeatedly handoff to each other, i.e. fewer nurses new to that infant/mother. Although betweenness centrality is often utilized to analyse networks similar to ours, it is a metric that elicits a measure more representative of a true primary nursing structure model (Mattila, Pitkanen, & Alanen,

TABLE 1 Summary statistics of the infant and maternal population under study (n = 17)

Variables	%
Gestational age (weeks)	
23	24 (4)
24	41 (7)
25	6 (1)
26	29 (5)
Birthweight (g)	
<600	29 (5)
601–800	24 (4)
801–1,005	47 (8)
Gender	
Male	53 (9)
Female	47 (8)
Length of stay	
>110 days	53 (9)
<110 days	47 (8)
Race	
White	82 (14)
Black	18 (3)
Maternal age	
≤20 years	12 (2)
21–29 years	71 (12)
≥30 years	17 (3)
Education level	
High school	59 (10)
College	18 (3)
Bachelors	23 (4)
Household Income	
≤$25,000	35 (6)
$26,000–$50,000	30 (5)
≥$50,000	35 (6)

2014), in that it helps to identify the central node(s) (i.e., nurses) connecting the network. The unit we studied did not use formal primary nursing, so we sought to capture care consistency and the interconnected nature of care through repeat nursing. To do so, we utilized the measure of average degree centrality, colloquially defined as the proportion of other nurses in the infant's care network with whom each nurse is connected, relative to the rest of the network. A higher degree of centrality means that a higher number of the handoffs were between the same group of nurses. Infant care networks having higher average degrees of centrality (scoring between 0 and 1) represented a higher consistency of care.

3.2 | Maternal stress

The level of maternal stress was prospectively measured at, on average, 30 days after admission using the Parental Stressor Scale: Neonatal Intensive Care Unit (PSS: NICU) (Miles et al., 1993). This instrument is a standardized, valid, and reliable 45-question parental self-report tool that assesses the level of stress that parents experience in the NICU. Items follow a five-point Likert scale and are categorized across three subscales: Sights and Sounds of the Unit, Infant Appearance and Behaviour, and Parental Role Alteration. Individual responses range from a score of 1 ("not at all stressful: the experience did not cause me to feel upset, tense, or anxious") to a score of 5 ("extremely stressful: the experience upset me and caused a lot of anxiety or tension"). An overall summed stress score and summed scores for each of the three subscales were computed for each mother. Overall stress scores could range from 34–170, with each subscale ranging from 6–30 (Sights and Sounds); 17–85 (Infant Appearance and Behaviour); and 11–55 (Parental Role Alteration).

3.3 | Infant and maternal demographics

Infant birthweight, gestational age, and length of stay were extracted from the EMR by study staff. Parents completed a demographic form for maternal age, maternal education, maternal ethnicity, total household income, and the number of additional children in the household.

4 | DATA ANALYSIS

We used a novel two-dimensional network approach (Gray et al., 2010) to explore the relationship between nursing structure (and resultant nursing networks) and maternal stress (PSS: NICU). First, we identified patterns in the five derived structural metrics and resulting nursing networks for each infant. Second, we tested these structural metrics and networks for associations with PSS: NICU scores. The goal was to not only analyse the individual structural components of nurse caregiving but also to begin understanding how the overall system of components might impact maternal stress.

4.1 | Pattern identification within the nursing structural metrics

Each infant's nurse caregiving structure was first analysed by identifying patterns within the five derived structural metrics discussed in the Measures section—(a) *total number of shifts*, (b) *number of unique nurses*, (c) *time until first repeat shift*, (d) *average shifts*, and (e) *average + 1 shifts*—and the overall network configuration.

4.2 | Pattern identification of network configuration

Next, we explored how aspects of repeat nursing manifested within network structures. Networks of nursing shift handoffs were created for each infant and patterns of repeatability were identified. Through these networks, care consistency could be comprehensively quantified and compared and we could begin to see how infants could experience different, distinct levels of care consistency.

4.3 | Network analysis and maternal stress

Our final analysis examined associations between (a) nursing structural metrics and resulting network data and (b) maternal stress scores. Associations were analysed for those infants whose mothers scored in the upper or lower 25th percentile on any of the three individual PSS: NICU subscales and/or the total score on the instrument. This resulted in eight distinct groups for study. The average value for each of the five derived metrics, as well as the structural centrality measures, were computed for each infant and compared between those with mothers scoring in the upper and lower quartiles of each groups. Due to the nature of the pilot study and the small number of infants in each category, normality of the underlying distribution could not be accurately assessed (Ghasemi & Zahediasl, 2012; Oztuna, Elhan, & Tuccar, 2006). Consequently, comparisons between the distributions of each metric were computed using the Mann–Whitney *U* test. In line with the recent work by Greenland et al. (2016), it is important to emphasize that determining statistical significance in these differences is not a binary operation. Rather, the computed *p* values convey a level confidence that the distributions truly differ. As a result, in light of the pilot nature of the study, we provide all computed *p* values and highlight those found significant at three confidence levels of 90%, 95%, and 99%. This offers researchers a set of promising avenues through which they can select variables when designing future studies.

5 | RESULTS

Across the 17 extremely preterm infants included in the pilot study, gestational ages ranged from 23 to 26 weeks with an overall median of 24 weeks. The average birth weight was 757 g, and the average length of stay was 109 days. Most of the mothers were white, were in their twenties, and had achieved a high-school diploma as their highest level of education (see Table 1).

5.1 | Pattern identification—network structural metrics

In our first analysis, we found the general nursing care patterns to be highly variable (Table 2). On average, infants received care from 34 (±9) different nurses with five shifts (±3) occurring before an infant received care from a repeat nurse. The majority of infants (n = 70.6%) received care by a repeat nurse during ≤50% of their hospitalization. In other words, half of the infant's care during hospitalization came from a nurse who was new to their network.

5.2 | Pattern identification—network configuration

Next, we found that the individual network configurations revealed similar patterns of high variability among the infants. In particular, the repeat nursing structures were clearly represented in the underlying network configurations and resultant average degrees of centrality. Network configurations fell into three distinct categories. The majority of infants were classified into the low repeat category and included infants (64.7%; n = 11) who received care from a repeat nurse during 30%–38% of their hospitalization. Mid-level repeat infants (23.5%; n = 4) received care from a repeat nurse during 39%–50% of their hospitalization. High level repeat infants (11.8%; n = 2) received care from a repeat nurse during 51% or more of their hospitalization. Figure 1 illustrates representative structures of low, mid-level, and high repeat caregiving with average degree centrality presented for each structure.

5.3 | Network analysis and maternal stress

The maternal stress Sights and Sounds subscale was associated with Number of Unique Nurses in a network (H = 3.70, p = 0.054), average + 1 shifts (H = 7.5, p = 0.006), and the degree centrality of the caregiving network (H = 6.5, p = 0.010). In addition, the Altered Parental Role subscale was associated with the Number of Unique Nurses (H = 3.12, p = 0.070) and degree centrality (H = 3.94, p = 0.047). Associations between nursing network structure indices

TABLE 2 Descriptive statistics of structural and network metrics for each infant's nurse caregiving network

Structural metrics	*N*	Minimum	Maximum	Mean	*SD*
Average total number of shifts	17	27.00	86.00	59.59	18.19
Number of unique nurses	17	18.00	53.00	33.47	9.34
Number of shifts to first repeat shift	17	2.00	13.00	4.88	2.52
Average shifts	17	1.42	2.79	1.79	0.33
Average + 1 Shifts	17	2.12	5.00	2.96	0.72
Network metric					
Centrality Index		0.06	0.28	0.16	0.05

Note. Average shifts = average number of shifts each nurse accounted for with respect to a specific infant. Average + 1 shifts = average shift count including only those nurses who recorded more than 1 shift in the network.

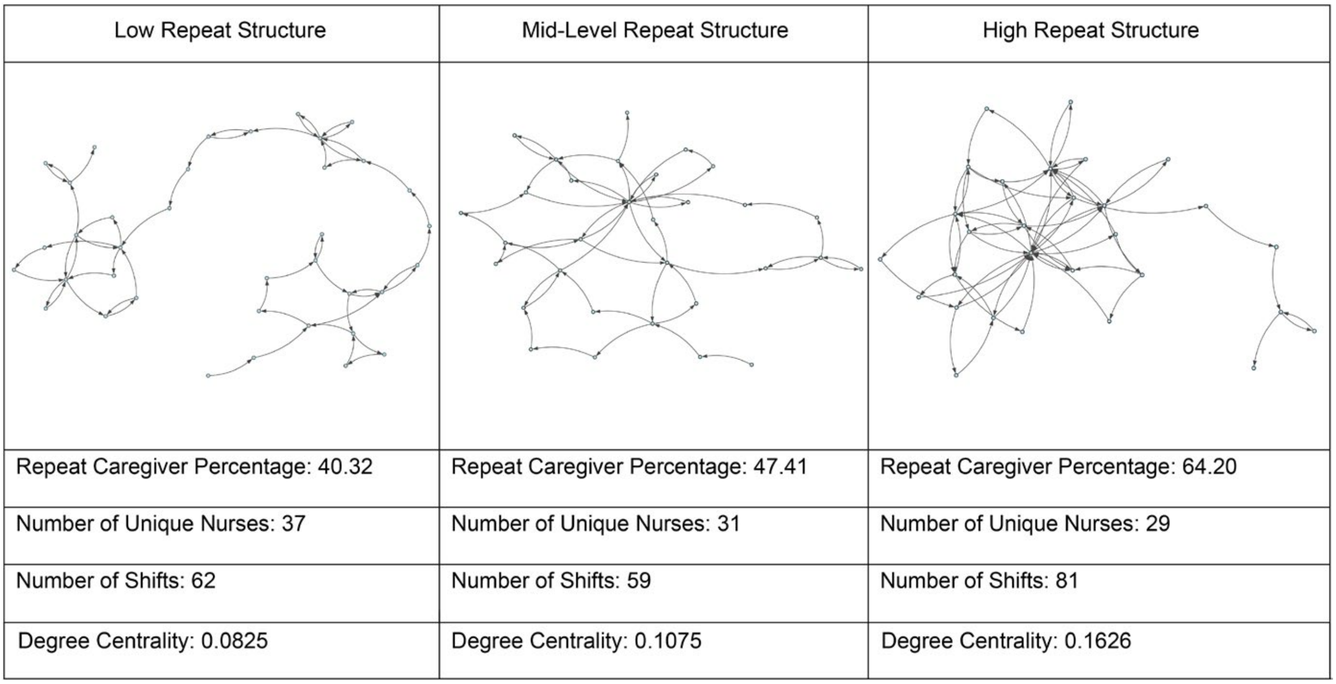

FIGURE 1 Nursing network structures for three of the infants: dots (nodes) represent individual nurses with arrows (edges) representing handoffs in one direction from one nurse to another nurse; networks are presented in increasing density and illustrate three distinct levels of repeat caregiving structure

TABLE 3 Associations of nursing care metrics and network structures with scores on the PSS: NICU

	Sights and sounds subscale score test value (*p*)	Infant behavior subscale score test value (*p*)	Altered parental role subscale score test value (*p*)	Total score test value (*p*)
Time until first repeat shift	0.57 (0.45)	0.68 (0.41)	1.13 (0.29)	0.28 (0.59)
Number of shifts	0.85 (0.36)	0.16 (0.68)	1.86 (0.17)	1.86 (0.17)
Number of unique nurses	3.7 (0.054)*	0.17 (0.68)	3.12 (0.07)*	1.09 (0.29)
Average shifts	0.01 (0.92)	0.05 (0.83)	0.32 (0.57)	0.057 (0.811)
Average + 1 shifts	7.5 (0.006)***	0.53 (0.46)	0.27 (0.60)	0.535 (0.46)
Degree centrality	0.08 (0.01)**	0.11 (0.37)	0.07 (0.03)**	0.09 (0.11)

Note. Comparisons made using Mann–Whitney *U* tests.
*$p \leq 0.1$ **$p \leq 0.05$ ***$p \leq 0.01$.

did not reach significance for either the Infant Behaviour subscale or the Total Stress score (see Table 3).

6 | DISCUSSION

In this study, we investigated structural components and networks of nursing care (i.e., the pattern of nurse assignments to an infant) in the NICU and their associations with self-identified maternal stress. We found that for the majority of our study infants, more than half of their first 30 days of care in the hospital was provided by a nurse who was new to them and their mothers, and that the nursing structure throughout hospitalization was highly variable. This variability may well have implications for the amount of stress felt by mothers. We found that a structure resulting in more caregiving by nurses who were new to the infant's network (and consequently the mother) was associated with more maternal stress. Specifically, a lower number of repeat nursing shifts, higher number of unique nurses, and a lower degree of network centrality were each associated with increased maternal stress, specifically the stress associated with the sights and sounds of the NICU and of the altered parental role.

The environment of the NICU has long been recognized as a source of stress for parents (Baia et al., 2016). Mothers who have extremely preterm infants in the NICU often experience depression, anxiety, and acute stress, which can have a long-lasting impact on how they interact with their infants, with subsequent effects on infant development (Baia et al., 2016; Feldman & Eidelman, 2007; Lean, Rogers, Paul, & Gerstein, 2018; Woodward et al., 2014). While many aspects of the NICU environment have been explored as potential targets for reducing maternal stress, this study explored an aspect of the NICU environment that has received little attention: the structure for providing nursing care—that is, the network of nurses who provide care to infants during their hospitalization.

Our findings are consistent with the few previous studies that have documented the effects of nursing structure on parent response to the experience of a hospitalized infant or child. Parents of children with complex health conditions being cared for in paediatric intensive care units reported that having the same nurses care for their child allowed them to relax at the bedside, whereas having new nurses increased their stress and heightened their vigilance (Baird, Rehm, Hinds, Baggott, & Davies, 2016). A study of nursing structure in NICUs used a network analysis similar to that used in the current study, finding that when there was a greater number of shifts between repeat nurses, parents had less confidence and trust in the infant's nurse and were less likely to be certain as to which nurse was responsible for their infant's care (Gray et al., 2010). Similarly, Goldschmidt and Gordin (2006) reported on the creation of smaller team units within a large NICU (42 beds). Fixed schedules and assignment of small nursing care teams to specific four- to six-bed pods resulted in an increase in parental confidence in the ability of the nurses to care for their infants. Consistency of caregiver was assumed by virtue of the model of care developed but was not measured. Although the items in these studies did not specifically measure parental stress, each of them could be expected to contribute to a reduction in the parent's experience of stress during their child's hospitalization. Finally, Mefford and Alligood (2011) found that consistency of nurse caregivers in the NICU significantly reduced length of stay, duration of mechanical ventilation, and parenteral nutrition. Again, parental stress was not specifically measured. However, improving infant outcomes through more consistency in care providers would be expected to be associated with reduced parental stress.

Our study advanced the study of nurse caregiving structure in the NICU in two specific ways. First, we used a novel approach for defining and measuring nursing care consistency. Using network analysis provided a logical and precise method of describing complex interactions between nurse caregivers in a busy NICU and enabled identification of potential areas for change.

Second, our study investigated associations between nursing care consistency and maternal stress outcomes. As described above, previous assessments of effects of changes in nursing structure have primarily focused on patient/parent satisfaction. Our use of specific measures of stress is an important contribution to the literature. Delineating relationships between nursing care structure and specific patient and parent outcomes provides concrete evidence for planning and decision making for continuously improving the care we provide vulnerable infants and children. Making explicit the relationships between how we complete the function of assigning nurses to patients and the ultimate outcomes of those patients and families brings valuable evidence to assist with a routine, yet critically important, task.

Improving consistency of care is challenging in the current nursing-practice environment. Institutional barriers, including 12-hr shifts with resultant three-day work weeks, and an increase in part-time employment among professional nursing staff (Baumann, Hunsberger, & Crea-Arsenio, 2013) contribute to less consistency of care. In addition, competing demands and priorities enter into decision making about nursing care assignments. At least one model of nursing care delivery emphasizes matching nurse competencies with patient care needs in order to enhance patient outcomes (Curley, 2007), which often results in less consistent assignments. Clearly, matching nursing skill to patient needs is vital, particularly in an intensive-care environment. However, when it is not possible to assign a consistent nurse, optimal communication between nurses during the handoffs is essential. Communication between nurses must include not only the infant's specific technical care needs but also information that improves nurse knowledge about that unique family and infant (Baird et al., 2016; Siow, Wypij, Berry, Hickey, & Curley, 2013), potentially enabling consistency of care provision among multiple nurses. There is also evidence in intensive care settings of an inadequate focus on the development of relationship skills with families in crisis compared with the development of the necessary technical skills (Baird et al., 2016). Improving our ability to provide care focused on relationship building must become as much of a priority as providing excellent care using our technical skills. The challenges we face to improve the consistency of care provided to our most vulnerable patients and families are not insurmountable. Identifying specific strategies for successfully meeting these challenges requires additional focused research and institutional commitment to staff education and reducing family stress.

Our pilot study is limited by the small sample size, and the results are not likely to represent broad generalizable findings. However, as noted above, the goal of this study was to provide an exploration of the relationship between care patterns and various aspects of maternal stress, from which larger studies could be conceived. Our results provide a promising direction for future investigations by demonstrating that a network-based approach is viable for capturing and quantifying nursing care consistency. It might also be argued that variables such as severity of illness, length of stay, and the varying number of shifts that the infants experienced could impact our results. With respect to illness severity, all infants included in this work were extremely preterm and were transferred to this unit as a result of critical acuity requiring transport to a level IV NICU. Second, although it is true that the length of stay could bias the results in terms of the number of nursing shifts, average shifts, etc., we accounted for this, by only utilizing shift data up until the mother was asked to take the survey. Depending on when parents visited and other care factors, this typically occurred at around 30 days after admission for each child, allowing for relatively equivalent care opportunities.

In this context, we would also like to highlight an additional point. The lack of significance for some testing is actually a positive result. In particular, we found the associations between the number of unique nurses and both the "Sights and Sounds" and "Altered

Parental Role" subscales to be significant but there were no significant associations with Number of Total Shifts. This helps us guide our thoughts about what really might impact maternal stress and how care consistency, rather than totality, may be a more promising target for intervention. This framework also allows for expanded investigations beyond maternal stress outcomes and might include longer term psychological and developmental outcomes of infants and mothers, as well as the nurses who care for them.

7 | NURSING IMPLICATIONS AND CONCLUSION

In a vulnerable population that is inherently at high risk for developmental delay and disability, understanding how to identify and mediate the effects of NICU-imposed maternal stress remains a critical aspect in supporting the long-term neurodevelopment of extremely preterm infants. How nursing care is structured in the NICU may be a critical, targetable component in mitigating the effects of maternal stress on infant neurodevelopment. This pilot study indicates that nursing care that is consistent and centralized, not necessarily around one nurse but rather a core team of nurses, may be beneficial in reducing maternal stress and may hold the promise of positively impacting additional infant, family, and nursing outcomes.

ETHICAL APPROVAL

This study was approved by the affiliated Institutional Review Board (IRB 11-00579) as an expedited study with adherence to all informed consent requirements. Mothers provided informed consent for their own and their infant's participation.

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