NCPD 3.5 ANCC Contact Hours

DATA-DRIVEN NURSE STAFFING IN THE NEONATAL INTENSIVE CARE UNIT

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Abstract

The challenge of nurse staffing is amplified in the acute care neonatal intensive care unit (NICU) setting, where a wide range of highly variable factors affect staffing. A comprehensive overview of infant factors (severity, intensity), nurse factors (education, experience, preferences, team dynamics), and unit factors (structure, layout, shift length, care model) influencing pre-shift NICU staffing is presented, along with how intra-shift variability of these and other factors must be accounted for to maintain effective and efficient assignments. There is opportunity to improve workload estimations and acuity measures for pre-shift staffing using technology and predictive analytics. Nurse staffing decisions affected by intra-shift factor variability can be enhanced using novel care models that decentralize decision-making. Improving NICU staffing requires a deliberate, systematic, data-driven approach, with commitment from nurses, resources from the management team, and an institutional culture prioritizing patient safety.

Key words: Hospital; Infant; Intensive care units; Missed nursing care; Neonatal; Newborn; Nurses; Nurse staffing; Nursing staff; Patient acuity; Patient safety; Workforce; Workload.

Background

Neonatal intensive care unit (NICU) nurse staffing can be improved by data-driven strategies. Nurse staffing is crucial in patient safety, workforce satisfaction, fiscal responsibility, and overall operations. As health care systems redefine practices and priorities to improve patient outcomes in a shift to value-based care, care models that govern availability of clinicians need further scrutiny. Registered nurses (RNs) are the most critical contingent for patient safety. Staffing guidelines are based upon expectations that a nurse serves as the primary source of direct patient care (Duffield et al., 2008). Determination of how many nurses are needed and their patient assignment represents a continuous challenge in acute care settings driven by a diverse set of factors influencing care needs and operational considerations (Saville et al., 2019). In the NICU, it is especially challenging to develop safe staffing plans because NICU babies have dynamic medical and surgical needs from admission to discharge, including end-of-life care; NICUs generally operate with a higher bed capacity than other hospital units (resulting in significant variations in census); new patients are admitted across all days and shifts, and range from stable to critically ill (high variation in work intensity across a wider window of time); and NICU nurses are commonly pulled away from bedside care to support transport and neonatal resuscitation teams for attendance at birth, or for training with an expansive array of equipment (high variability in short-term coverage needs).

In 1981, a U.S. Department of Health and Human Services' (DHHS) report, *Factors Affecting Nurse Staffing in Acute Care Hospitals: A Review and Critique of the Literature*, found complex, ever-changing dynamics of hospital care made nurse staffing difficult (Young, 1981). In 1999, in response to DHHS recommendations for greater elaboration, the American Nurses Association (ANA) published a structure for evaluating nurse staffing. *Principles for Nurse Staffing* (ANA, 1999), now in its third edition (ANA, 2020), and a companion publication, *Utilization Guide for the ANA Principles for Nurse Staffing* (ANA, 2005), provide a framework for planning and allocating nurse staffing. Comprehensive nurse staffing standards specific to neonatal-perinatal settings, including NICUs, were established by the Association of Women's Health, Obstetric, and Neonatal Nurses (AWHONN) in *Guidelines for Professional Registered Nurse Staffing for Perinatal Units* (AWHONN, 2010) and recently updated in *Standards for Professional Registered Nurse Staffing for Perinatal Units* (AWHONN, 2022). These nurse staffing standards built upon those originally published by the

TABLE 1. KEY FACTORS IN NICU STAFFING PLANNING

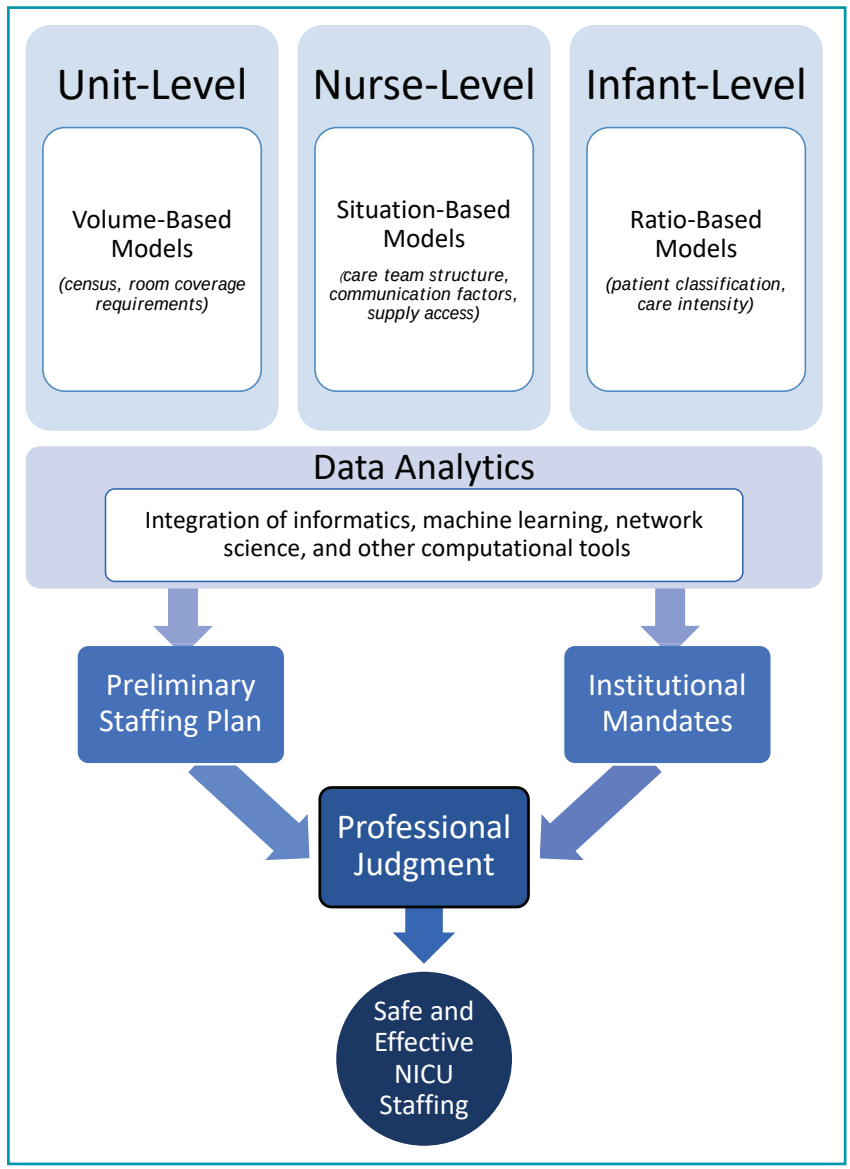
Unit & Institutional Factors	
Factors Informing PRE-SHIFT Staffing Plans	***Factors Informing INTRA-SHIFT Staffing Plans***
• Unit census • Unit configuration and resources • Hospital pharmacy and lab logistics • Hospital support services • Facility policies and practices • Staff availability • Models of care and shift length	• Admissions and discharges • Care coordination • Unscheduled meetings and education • Requests to "float" nurses • Use of flex space; isolation and overflow Rooms • Equipment malfunction
Nursing Factors	
Factors Informing PRE-SHIFT Staffing Plans	***Factors Informing INTRA-SHIFT Staffing Plans***
• Nurse education level • Nurse experience and skill-mix • Multi-language fluency • Delivery room and transport team expertise • Oversight of orientees and students • Nurse preferences and "primaries" • Availability of ancillary personnel	• Deployment of transport team • Unanticipated birth and procedure coverage • Nurse injury, illness, or emergency leave • Care-team membership changes • Interpersonal issues
Infant Factors	
Factors Informing PRE-SHIFT Staffing Plans	***Factors Informing INTRA-SHIFT Staffing***
• Mandated staffing ratios • Infant acuity measures • Workload intensity and estimated task time • Scheduled procedures and surgery • Scheduled patient conferences • Multiples	• Mandated staffing ratios • Infant acuity measures • Workload intensity and estimated task time • Scheduled procedures and surgery • Scheduled patient conferences • Multiples

American Academy of Pediatrics (AAP) and the American College of Obstetricians and Gynecologists (ACOG) in 1983 and updated every 5 years until 2007 (AAP & ACOG, 1983, 2007).

Underlying nurse staffing guidelines are assumptions that relevant information is fully available pre-shift as assignments are created; and assignments are robust enough to address variability throughout the day. In practice, pre-shift assignments are often made using only a subset of relevant information and typically only consider a single cross-sectional or static view of infant, nurse, and unit factors when operationalizing nursing assignments.

A comprehensive discussion of factors affecting pre-shift staffing needs and how these factors manifest intra-shift variability that must be accounted for to maintain effective and efficient staffing assignments is presented beginning with a brief overview of NICU nurse staffing and discussion of challenges affecting achievement of staffing goals and brief review of staffing models. Two key topics underlying staffing challenges are included (Table 1). *Factors Affecting Pre-shift NICU Staffing Plans* highlights complexity in collection and use of data relative to pre-shift planning. *Intra-shift Variability of Staffing Factors* introduces a parallel driver of staffing complexity relative to intra-shift dynamics.

FIGURE 1.



Nurse Staffing in the Neonatal Intensive Care Unit

The primary goal of nurse staffing in the NICU has been identified as "delivery of safe and effective neonatal nursing care" (National Association of Neonatal Nurses, 2021, p. 2). Although an interprofessional team is essential to patient-family centered care, and ancillary personnel provide essential services within this team, the premise for optimal NICU outcomes is that each patient has a *nurse* who coordinates direct care. There is substantial evidence supporting better patient outcomes in units with adequate nurse staffing as compared with units that are short-staffed (AWHONN, 2022; Ball et al., 2018; Ball & Griffiths, 2021; Griffiths et al., 2019; Lasater et al., 2021; Needleman et al., 2011; Needleman et al., 2020). Consistent with evidence in other acute care hospital settings, understaffing in NICU is a recognized risk of omission, partial completion, or delay of essential aspects of nursing care (Lake et al., 2020; Tubbs-Cooley et al., 2019), medical errors (Beltempo et al., 2018), morbidity (Cimiotti et al., 2006; Lasater et al., 2021; Rogowski et al., 2013), and mortality (Beltempo et al., 2018; Küng et al., 2019; Rogowski et al., 2013; Tawfik et al., 2020; Watson et al., 2016).

Staffing Models and Approaches

Staffing planning requires consideration of nursing workload, the product of individual patient needs, and number of patients the nurse is assigned. Several general models for quantifying nursing workload have been described (Carayon & Gurses, 2008; Hurst, 2003; Qureshi et al., 2019). A nurse staffing plan, with evidence that it is adequately resourced, actively managed, and that its effectiveness is regularly evaluated, is essential to patent safety

(National Quality Forum, 2010). No single model has emerged as sufficient to develop a safe and efficient staffing plan. Optimal staffing planning appears to require a convergence of workload models, a data integration task that can be enhanced by technology, as well as professional judgment (Figure 1). An overview of key approaches to staffing and measures of workload follows.

Ratio-Based Staffing Models

Ratio-based or patient classification approaches to nurse staffing use patient acuity scores, disease conditions, or treatment type to classify patients and develop safe and effective nurse staffing levels. Ratio-based nurse staffing guidelines for the NICU were first published in the *Guidelines for Perinatal Care* (AAP & ACOG, 1983) and have since been used to inform many electronic tools used in NICU staffing development. Recommendations for nurse staffing of infants range from 1:1 for critically ill infants, to 1 nurse for 5 well newborn infants needing routine care (AWHONN, 2022). Technologies that allow care of smaller and sicker infants and other advances have prompted further categorizations. The *Guidelines for Perinatal Care* (AAP & ACOG, 2007) and the AWHONN (2022) nurse staffing standards provides a classification of infants that has been used to inform patient-to-nurse ratios in NICU. These guidelines describe the provision of "intensive care" for critically ill infants who require constant nursing care and continuous cardiopulmonary and other support, "intermediate care" for infants who require 6 to 12 hours of nursing care daily, and "continuing care" for convalescing infants (AAP & ACOG, 2007; AWHONN, 2022). Standards for nurse-to-patient ratios for NICUs are listed in Table 2.

Legislation of a minimum nurse-to-patient ratio to support patient safety and quality care has been an ongoing national discussion (Lasater et al., 2021; Wallis, 2013). In 2004, California became the first (and remains the only) state to enact specific nurse-to-patient ratios for all hospitals (California Code of Regulations, 2004). Included in the mandate is a final ratio of 1 nurse to 2 patients in NICU. California's mandate has been associated with controversy among clinicians, unions, and professional organizations. Critics point to the lack of standardized acuity tools, incomplete information about nurse workload and workload variability, and insufficiency of patient acuity or severity of illness as a suitable measure of workload (Olley et al., 2019).

Volume-Based Staffing Models

Volume-based nurse staffing approaches use minimum staffing policies, historical data, and core staffing figures as a basis for the staffing plan. Core staffing refers to the number of nurses needed on each unit, for each shift, based on a predetermined number related to a unit's census history (AWHONN, 2022). The nursing hours per patient day (NHPPD) method classifies hospital units using characteristics such as patient complexity, emergency and elective patient mix, and patient turnover. Once classified, NHPPD are allocated for each unit (Twigg et al., 2011). Volume-based approaches may consider a unit's physical layout (e.g., single-patient rooms, "pods," or open bay design), as configuration influences the minimum number of nurses needed, regardless of patient characteristics.

TABLE 2. APPROACHES AND STANDARDS FOR DEVELOPING NICU NURSE STAFFING

Ratio-Based (Patient Classification) Method	
Applicable Standard	***Recommendations***
Standards for professional registered nurse staffing for perinatal units (AWHONN, 2022) *Guidelines for Perinatal Care* (AAP & ACOG, 2017)	Nurse-to-patient ratios standards are described as follows: • 1 nurse to 3-4 infants requiring continuing care • 1 nurse to 2-3 infants requiring intermediate care • 1 nurse to 1-2 infants requiring intensive care • 1 nurse to 1 infant requiring multisystem support • 1 or more nurses to 1 unstable infant requiring complex critical care • 1:1 nurse-to-patient ratio for infant undergoing circumcision or other surgical procedure during the immediate preoperative, intraoperative, and immediate postoperative periods
Volume-Based (Core Staffing and Historical) Method	
Applicable Standard	***Recommendations***
Minimum RN Staffing in NICUs, (NANN), 2021	When fewer than 6 intermediate care newborns or 4 intensive care neonatal care newborns are in the special care nursery or NICU, at all times neonatal specialty care requires a minimum of 2 registered nurses with neonatal expertise and training.
Professional Judgement Method	
Applicable Standard	***Recommendations***
Utilization Guide for the ANA Principles of Nurse Staffing, American Nurses Association (ANA), 2005	Professional judgement is critical in evaluating staffing requirements when using a classification system, considering nursing needs of the patient on any given unit.

Situation-Based Staffing Models

Situation-based (or "intensity-based") approaches to staffing conceptualize nursing workload are highly data-driven (Carayon & Gurses, 2008; Qureshi et al., 2019). In answering the question of how many nurses are needed, situation-based staffing considers not only the number of patients assigned to a nurse and the classification of these patients, but also the facilitator and barriers that contribute to the work experience of the nurse. Physical layout of the NICU (single room vs. pods, distance between resources and patient), environment of the NICU (noisy vs. quiet, daylight exposure vs. windowless), communication among team members (effective vs. ineffective), availability of supplies, and extent of family needs, all inform situation-based workload for the nurse. This model of workload is multidimensional, with different barriers and facilitators affecting the nurse experience in different ways, on different shifts, for different patients. Situation-based nursing workload is amenable to human factors engineering such as the optimization of complex systems with respect to human physical and cognitive performance limitations (Carayon & Gurses, 2008; Qureshi et al., 2019).

Professional Judgment

The ANA's *Utilization Guide for the ANA Principles for Nurse Staffing* (2005) describes the need for professional judgment to develop and evaluate nurse staffing plans. Professional judgment should add to the data set available to develop a staffing plan, and not replace the need to look at the full set of data, although this may be an unrealistic expectation in practice. Emotion and sentiment are well-recognized to affect decision-making processes (Lerner et al., 2015). Evidence-informed staffing decision-making may be challenged by a higher value placed on emotionally weighted data points. For example, it is unknown how charge nurses prioritize a parent or staff nurses' request for a specific assignment relative to other relevant staffing data.

Data-Integration

Technology is required to incorporate, monitor, and manage data to better plan and update the processes of patient care. Technologies that support safe staffing must use the science of data management and the art of integrating multiple dynamic variables (Fasoli et al., 2011; Fasoli & Haddock, 2010). Operational research use quantitative or qualitative models to aid decision-making in complex implementation problems (Monks, 2016). Operational research has supported traditional manual techniques for nurse staffing planning including development of numerous patient classification and acuity systems or workload management systems. There is great operational research opportunity to automate manual processes for nurse staffing, particularly for the dynamic NICU environment. As acuity and other data become increasingly accessible, informatics will have a greater role in creating evidence-based staffing plans (Hyun et al., 2008); however, until consensus can be reached on the definition of nursing work, the measurement of nurse workload, and better identification of nurse-sensitive outcomes, contribution of automation will be limited (Fasoli & Haddock, 2010).

Challenges Affecting Safe and Effective Staffing

A limitation to achieving safe and effective NICU nurse staffing is that a composite measure representing the totality of nursing care for an individual patient has yet to be developed. "Missed care" has been examined as a proxy for ineffective care. Numerous studies have examined the association of missed or incomplete care with staffing or workload in NICU. A growing body of evidence demonstrates the negative effect of inadequate NICU nurse staffing on infant feeding, breastfeeding, patient assessment, pain management, parent counseling, emotional support and teaching, and discharge planning (Hallowell et al., 2016; Lake et al., 2020; Ogboenyiya et al., 2020; Rochefort et al., 2016; Tubbs-Cooley et al., 2019; Tubbs-Cooley, Pickler, & Meinzen-Derr, 2015; Tubbs-Cooley, Pickler, Younger, & Mark, 2015).

Setting and achieving staffing goals are balanced by a need to steward institutional financial resources (Welton, 2011). Regular review and adjustment of staffing levels and patterns such as number of full-time-equivalents supported by a unit budget based upon staffing requirements to meet goals over time is an important aspect (Hunt, 2018). Robust institutional financial resources are associated with availability of an appropriate mix of nurses to meet staffing needs. For even financially well-resourced hospitals, the COVID-19 pandemic has now positioned nurse availability as a separate challenge. Unprecedented levels of clinician exposure, illness, and turnover, and restricted nursing school admissions, have advanced the national nursing shortage to a critical level. This challenge is exacerbated in NICU, where an extended period of specialized training beyond basic nursing education and hospital orientation is necessary.

High rates of nurse resignation have extended interest in staffing outcomes to include promoting nurse satisfaction and reducing turnover costs. Inadequate nurse staffing has been identified as the most common stressor facing NICU nurses (Fiske, 2018). Work stress in NICU contributes to decreased morale, fatigue, and burnout that ultimately leads to job dissatisfaction and turnover (Braithwaite, 2008). Nurses in better-staffed hospitals during the COVID-19 pandemic reported less burnout, less job dissatisfaction, and with lower intent to leave their employer (Lasater et al., 2020). Reducing nurse turnover and increasing nurse staffing levels have been associated with net reduction in institutional costs (Moseley et al., 2008).

Factors Affecting Pre-shift NICU Staffing Plans

Patient assignment is a time-sensitive, manual, labor-intensive process occurring prior to each shift and overseen by a charge nurse. A multitude of factors applicable to patients, available nurses, and unit environment must be

simultaneously considered to identify a best match between nurses and patients in the context of skill mix and experience (AWHONN, 2022). There is limited capacity for considering multiple factors manually and variation in how different charge nurses weigh and process multiple factors, as well as limitations in the number of factors incorporated into currently available automations.

Infant Factors Affecting Staffing

The ability to safely staff a NICU is linked to infant acuity. Patient acuity, the amount of nursing effort required to provide safe and effective care, is a primary factor in determining standard nurse-to-patient ratios (AWHONN, 2022). Despite its core role in nearly all staffing guidelines, obtaining a comprehensive measure of acuity remains elusive. Concept analysis recognizes acuity as encompassing elements of severity and time sensitivity, a patient's physical and psychological needs, complexity of care required to address these needs, and intensity of clinical workload as defined by resources and skills (Brennan & Daly, 2009). Ability to obtain quantitative measurements and operationalize knowledge representing each of these domains to inform NICU staffing is challenging.

Severity and Risk Scores

The most widely explored component of infant acuity is *severity*. Over a dozen NICU severity scores have been developed using an array of demographic and clinical factors spanning simple measures of birthweight and gestational age to complex measures of oxygenation index and respiratory distress (Dorling et al., 2005; Garg et al., 2018; Patrick et al., 2013). Severity scores offer a degree of objectivity in assessment of infant condition; however, they are statistically derived and calibrated to align with *risk* of downstream mortality and morbidity. Severity scores are useful for risk stratification, representing an important but fractional element in defining patient acuity classification, but fall short of predicting nursing effort required to provide safe and effective care.

Awareness of an infant's risk for significant adverse health events can act as a proxy for an infant's impact on a unit's workload, as severity is strongly associated with overall resources needed (Shah et al., 2015). Severity tracking may allow for building assignments with additional buffer for high-severity infants, recognizing that rapid clinical compromise may occur. There are limitations in using these scores for staffing because clinical risk prediction from severity models incorporates longitudinal data. The time frame for data collection can easily exceed duration of the nursing shift, presenting a problem in using severity data for staffing decisions. With separate risk scores now available for multiple conditions (e.g., central line infection, intubation), it is increasingly difficult to synthesize severity data into a singular measure that predicts the need for increased care.

Workload and Intensity

Infant-level workload is driven by *intrinsic* factors arising from a plan of care, *extrinsic* factors such as parent involvement, and logistical factors, such as tracking down equipment. Incorrectly balanced staffing workloads are associated with delayed and missed care, which is linked to adverse outcomes (Lake et al., 2020; Ogboenyiya et al., 2020; Rochefort et al., 2016; Tubbs-Cooley et al., 2019; Tubbs-Cooley, Pickler, & Meinzen-Derr, 2015; Tubbs-Cooley, Pickler, Younger, & Mark, 2015).

NICU nursing care includes many simple and complex tasks. *Workload* represents an understanding of which tasks must be completed for an infant and how tasks are expected to be completed. This involves a contextualization of each task with time and resources potentially required. Workload estimates must consider difficulty of completing tasks, even for low-risk infants. For example, a low-severity infant may require only interval feeding, yet workload may vary depending on the difficulty of feeding such as an infant who does not complete a feeding after 20 to 30 minutes and may need tube feeding. Workload estimates must consider temporal elements of interventions such as transporting an infant to surgery and interprofessional bedside care. These estimates are intertwined with attributes for individuals performing tasks, a concept discussed in detail in the section on care team functions.

Intensity means workload can be measured by considering magnitude or complexity of nursing effort based on patient need and can be quantified by measuring time it takes to provide nursing care and degree of difficulty of the work (Brennan & Daly, 2009; Brennan et al., 2019; Larson et al., 2017). It is important to capture intensity because nurse-to-patient time is compounded across an increasing number and complexity of tasks assigned to nurses.

Estimates of workload are complicated by extrinsic factors, such as the variable effort associated with parent interactions. Descriptions of family-centered care reference higher staffing requirements to invest more time and have more flexibility in parent-focused nursing activities such as teaching, and psychological support (Franck et al., 2022). It is challenging to estimate time and impact of these variable extrinsic factors on workload when designing nursing staffing plans.

Data

Data required to obtain reliable *acuity* measures are multifactorial and often maintained in disparate systems. Given the central role that acuity and patient classification measures play in multiple staffing protocols, it is essential that significant efforts be made to improve the depth and breadth of data around the complementary measures of severity and workload.

Use of robust software interfaces with common electronic medical record (EMR) systems has facilitated more rapid calculation of physiologic risk scores to determine severity (Masino et al., 2019). Implementation of these models is dependent on local infrastructure for ensuring data elements extracted to develop scores are defined in the same manner as those elements used to create and validate the model. This is a nontrivial task, as local capacity and practice can vary significantly between institutions

(Kelly et al., 2019). Although many severity-associated elements can be automatically inputted such as machine-monitored vital signs and extracted from the EMR, some data such as blood gas values require intervention, manual processing, and lab confirmation prior to EMR extraction, lagging reliability of severity scores at any point in time.

There are few validated measures of overall nursing *workload* (Lemieux-Bourque et al., 2020; Qureshi et al., 2019; Sawatzky-Dickson & Bodnaryk, 2009), and even fewer measures that can be used in routine staffing planning without interval self-report by nurses. Unlike severity scores which are primarily generated from a centralized EMR, factors comprising nursing workload often span an array of disparate systems such as infusion pumps and physical actions such as securement of an intravascular device. Significant system integration efforts would be needed for this information to be readily available (Ivory, 2015). Monitoring of tasks may present concerns for autonomy and privacy of nurses.

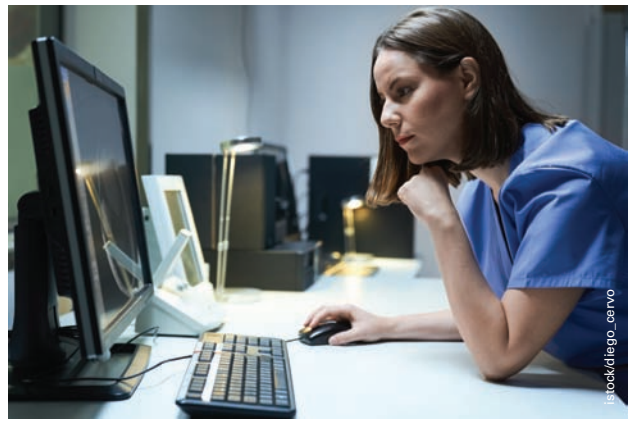
Nursing and Care Team Factors Affecting Staffing

Together with staffing guidelines that require consideration of infant, nurse, and unit factors, there is a general effort to match care team characteristics to needs of infants being admitted to or receiving care in NICU (Rogowski et al., 2015). These factors include educational preparation, experience, language capacity, and skill mix. There are also a host of deeper, latent, nurse and team characteristics that affect health care practice such as interpersonal and team dynamics, care preferences, and nurse satisfaction.

Education, Experience, and Skill Mix

Delivery of safe and effective nursing care "requires assurance of a sufficient number and an appropriate mix of nurses to attend to emergent and complex care requirements of critically ill and convalescent infants" (National Association of Neonatal Nurses, 2021, p. 2). Extensive research has found a relationship between higher educational level (proportion of RNs with a bachelor's degree) and better hospital patient outcomes (Aiken et al., 2014), although staffing patterns in NICU have not been shown to substantively focus on nurse education (Rogowski et al., 2015). Nurse education is often determined at the hospital employment level such as a bachelor's degree required for employment, precluding need to consider it in staffing planning at the unit level.

Nurse experience appears to be a proxy for effectiveness or efficiency and is a common consideration in developing NICU staffing assignments. Less experienced nurses are generally less able to meet a given level of work intensity. Setting a lower core staffing level based upon efficiency of a more experienced team, however, is recognized as punishing success (Griffiths et al., 2020) and fails to address succession planning. A threshold of nurses who can provide orientation oversight to newer nurses, or who have experience across higher patient



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technologies, must be reached. Adjustments in staffing are often needed to provide time for nurse-to-nurse mentorship, nursing student oversight, and allow for skill development in independent but novice nurses.

A health workforce that is representative of the diversity of the population being served will improve the quality of services (Health Resources and Services Administration, 2017). Staffing assignments may consider nurse ethnicity and culture. It is increasingly common to match patients to nurses who understand firsthand their unique customs and experiences.

There is a relationship between greater nursing skill mix and better patient outcomes (Aiken et al., 2017). The definition of skill mix, however, is vague in the literature (Cunningham et al., 2019), having both interprofessional (e.g., nurse + respiratory therapist) and intraprofessional (e.g., nurse + nurse's aide; or novice nurse + experienced nurse) application. There is no universal definition for skill mix in NICU context.

Preference, Policy, and "Primaries"

Consideration of nurse preferences such as for certain diagnoses, for acute versus chronic illness, or for certain infants plays an important role in nurse satisfaction, although the process to incorporate nurse preference is often obscure in staffing planning guidelines. Where *primary nursing* is the model of care, consistency in nurse–patient assignments may take precedence over other unit, nurse, or infant factors. Accommodating needs of nurses who are pregnant, nursing, or with certain disabilities may be required by policy or law. For example, assigning a pregnant or lactating nurse to cover a long transport may violate requirements to provide accommodations

for certain conditions, such as outlined in the Fair Labor Standards Act of 1938 (FLSA, 29 U.S.C. § 207). Staffing assignments in the NICU can also be influenced by the need to develop appropriate assignments for novice nurses or orientees. Experiential learning is often guided by senior nurses or mentors who request specific clinical assignments for nurses needing certain experiences.

Team Dynamics and Structure

As neonatal care moves to an increasingly interprofessional care model, dynamics between team members such as nurses, nurse practitioners, physicians, resident physicians in training, technicians, and respiratory therapists can directly affect staffing efficacy and represent an important element in providing safe care (Thomas et al., 2004). Team structure and membership influences neonatal care (Gray et al., 2010). In many NICU settings, ancillary clinicians such as medication technicians, nurses' aides, licensed practical nurses, and phlebotomy technicians provide support to nurses. As per *AWHONN Staffing Standards*, addition of ancillary personnel to staffing numbers does not preclude the requirement to meet RN staffing standards, and absence of ancillary support personnel may require staffing with additional nurses (AWHONN, 2022).

Data

Despite formal and informal recognition that nurse's education and experience have a pronounced impact on quality of infant care, there are limited mechanisms to quantify these factors in pre-shift staffing planning. Information on nurse educational attainment and credentialing is typically well-structured and stored in digital human resources systems, yet not readably accessible by nurses or systems directly. Even if such data were accessible, credentials offer an incomplete view of assignment fit without context provided by experience-related factors. In many studies, nurse experience is crudely represented as time since licensure, or since employment. Although reasonable as a proxy, experience is more nuanced than an extrapolation of time, requiring knowledge of prior assignments and proficiencies. Validated measures of nurse experience are not available as discrete data or scale. There are fundamental barriers to measurement of interpersonal and team dynamics. Many of the core traits which underly effective teamwork are intangible, such as trust and respect built from established working relationships. They are dynamic and require repeated assessment if used in nurse staffing protocols. More research is needed to optimize team dynamics and match infant assignments to nurse experience so they can be used in a way that does not require extensive institutional knowledge by charge nurses.

Administrative and Institutional Factors Affecting Staffing

Bridging nursing and infant factors are an assortment of administrative, unit, and organization factors affecting staffing needs. These factors present constraints in how staffing protocols are actualized and include fixed structural aspects of the NICU, logistic elements of shift timings, and unit-level nursing care delivery (Corchia et al., 2016; Paulsen, 2018; Porcel-Gálvez et al., 2021). They represent practical implications of ideal staffing protocols in real-world clinical settings; however, multiple competing factors driving balanced unit staffing are essential in the broader discussion of optimal NICU staffing.

Unit Structure and Layout

The most direct impact of organizational structure on the planning and provision of patient care is the physical configuration of the NICU. These range from completely open-bay (with single-room isolation capacity) to pod-like groupings of single-family rooms (O'Callaghan et al., 2019). Based on recent data from Vermont-Oxford member centers (n = 1,066), 27% of NICUs are configured with over 90% of patient spaces as single-family rooms, 61% with less than 10% of patient spaces as single-family rooms, and 11% distributed across this range (Vermont Oxford Network, 2020).

An extensive body of literature has explored tradeoffs associated with nurse satisfaction, staffing planning, and patient outcomes related to structural layout (Doede et al., 2018; Winner-Stoltz et al., 2018). Single-family rooms have consistently been found to improve privacy and enhance interactions with parents, which may improve these aspects of workload. However, there has been extensive concern both perceived and empirical on the relationship of this layout to excessive walking and fatigue (Obeidat et al., 2022), nurse responsiveness, and ability to monitor infants (Acar & Butt, 2016). As per a recent review, nurses in multiple studies found "interaction among the care team, staff communication, or teamwork significantly decreased in single-family room NICU layouts" (Doede et al., 2018, p. 112).

Unit layout features must be contextualized together with the total unit bed count, including potential for isolation or overflow, to fully understand how assignments for total nursing workload can be made within constraints of an open bay model or rooms of a pod cluster. Single-patient rooms call for modified staffing protocols allowing for more cross-over between nurses assigned to a given pod and may affect assignment of higher technologies and patients with greater complexity to novice nurses (Doede et al., 2018).

Characteristics of the larger organization can influence staffing, including hospital teaching status (e.g., pediatric residency or neonatal fellowship) and ownership (nonprofit, for-profit, public). These factors are often associated with external guidelines and additional nurse responsibilities, thereby indirectly influencing nurse staffing needs (Rogowski et al., 2015).

Shift Length, Unit Education, and Timing

The most direct impact of organizational operations on nurse staffing is shift length, which defines how often unit census and available workforce must be reviewed and assignments created. With common institutional shift

TABLE 3. COMMON MODELS OF PATIENT CARE

Individual Patient Allocation	
Features	***Comments***
One-to-one nurse-patient relationship per shift.	Variation is **Primary Nursing**, where there is a one-to-one nurse-patient relationship per shift and *over time*.
Focus is on RN as autonomous professional who provides majority of patient care.	Consistent assignment of nurse to patient over time may be unsustainable, and instead reserved for select patients.
	Requires higher ratio of RNs to other clinicians to achieve overall patient care.
Functional Nursing	
Features	***Comments***
Patient care tasks allocated from a centralized authority point, regardless of any nurse-patient relationship.	Responsive to constraints in hiring RNs and availability of technical clinicians and ancillary personnel.
Mix of RN and other technical and unlicensed clinicians to achieve patient care needs.	Use of a central authority to delegate non-nursing tasks preserves nurse time for professional practice, potentially improving job satisfaction, and circumvents difficulty nurses have experienced in delegating.
Team Nursing	
Features	***Comments***
Nurse-patient relationship and associated tasks organized within a team construct.	Responsive to varied nursing skill mix; optimized model for inexperienced RNs to develop.
Decentralized team leader coordinates patient care tasks.	While not guaranteed, consistent assignment of core team of clinicians to the same NICU pod may be more sustainable over time than consistent assignment of primary nurse to a set patient.
Care team may be configured with only RNs or RN and other clinicians.	Has been associated with lower rates of medication errors and adverse intravenous outcomes *(Fernandez, 2012)*.

lengths of 8 and 12 hours, nurse staffing considerations for full-time (32–40 hours per week) nursing positions are often nuanced, with a combination of nurse shift lengths needed. Contributing to variability in shift length and nurse availability is inclusion of per-diem, agency, and overtime staff nurses who may have work-hour limits, requiring assignment modification. Because of nurse shift variability, there may be a nonuniform distribution of nurses throughout the day, requiring complex day-to-day alignment of shifts and assignments for constraints around infant characteristics and staffing protocols or nurse-to-patient ratios. There are associations between shift length and burn-out, job dissatisfaction, and safety events (increased risk for longer shifts), which have indirect links to long-term nurse availability (Dall'Ora et al., 2015; Stimpfel et al., 2013).

Change of shift highlights complexities of nurse handoffs (Gephart, 2012). Introduction of a new nurse into the care team requires some level of startup in which a nurse requires time to review patient records and medication schedule, check monitors and equipment, and conduct a thorough physical assessment. Addition of extra shift changes in 8-hour institutional shift configurations compared with 12-hour configurations influences overall workload.

Further complicating staffing planning is requirement for assignment coverage so nurses can receive continuing education (Coventry et al., 2015). This education is required to ensure that nurses are appraised of updated guidelines and prepared to use new equipment, as well as to maintain competence (e.g., neonatal resuscitation skills) and fulfill annual regulatory mandates (e.g., patient confidentiality, government and accreditation organization regulations, patient rights, workplace safety). Ensuring coverage of nurse staffing assignments during blocks of nurse absence *within* a shift requires considerable foresight in planning.

Models of Patient Care

Interwoven with shift timings are different models of patient care, such as individual patient allocation and primary nursing, team nursing, and functional nursing, each imposing their own set of benefits and challenges (Fairbrother et al., 2015; Fawcett, 2021). Alternative and combined approaches are worthy of consideration particularly when nursing shortage or an influx of novice nurses affects staffing. See Table 3 for common patient care models.

Individual patient allocation features patient assignment on a one-to-one basis, with the bedside nurse meet-

ing the total care of the patient (Fairbrother et al., 2015). In an extension of this model, *primary nursing* involves assignment of total patient care to a single bedside nurse with the goal that the nurse–patient relationship continues over the course of the hospitalization (Fairbrother et al., 2015). The need for consistent nurse assignments across days or weeks ofttimes adds a level of complexity to staffing planning, and instead may be reserved for select patients. When patient care is centered on the autonomous nurse–patient relationship, it is difficult to achieve high levels of collegial support and mentorship for inexperienced nurses (Fairbrother et al., 2015).

Functional nursing involves division of work into tasks assigned to nurses and ancillary clinicians based upon licensure and skill set (Tiedeman & Lookinland, 2004). Elements of functional nursing are in place in many NICUs, where one clinician is assigned by a charge nurse or unit policy to cover time-sensitive tasks across numerous patients such as phlebotomist draws morning labs, IV team places intravascular devices, and float nurse hangs parenteral nutrition.

Team nursing is an extension of functional nursing with a greater emphasis on humanistic values. Team nursing features a group of collaborative clinicians with various levels of education and skill, with at least one RN, who work collaboratively and cooperatively under an RN team leader to deliver care to a group of patients. Although a team leader makes most decisions about task allocation within the team, a charge nurse makes shift-to-shift assignments of nurses and other clinicians to teams (Tiedeman & Lookinland, 2004).

There is limited research on efficacy of any model of nursing care, or relationship of staff mix or structural layout to effective model implementation, in the NICU. Below target levels of nurse staffing have been associated with higher patient mortality, regardless of model of patient care (Ball et al., 2018; Ball & Griffiths, 2021; Griffiths et al., 2019; Lasater et al., 2021; Needleman et.al., 2011; Needleman et al., 2020). In NICU, there is evidence that caregiver consistency including a group of caregivers can decrease length of stay and minimize comorbidities during long hospitalizations (Mefford & Alligood, 2011).

Facility Policies, Practices, and Culture

Organizational policies, processes, and practices require ongoing evaluation for their impact on workload and staffing planning (ANA, 1999, 2020). For example, nurse staffing is affected depending on institutional support for pharmacy and lab logistics, unit stock such as linens, supplies, and nutritional items, wheelchair transportation, EMR maintenance, language translation, orientation of newly hired nurses including length of orientation, nurse educator support, and support for ethical decision-making (Hunt, 2018).

Data

Often operating at least one level removed from direct patient care, organizational data required to measure and act upon these factors exist outside of the EMR, isolated in a multitude of distinct software platforms, or in many cases not collected. Broad classification of a unit's layout, however, can be stored, and architecture rarely changes. Utility of unit type alone is limited, as each unit is unique in its specific setup and floorplan. Although there is potential for computational resources to account for layout-related workload, capturing distances between objects to estimate travel time such as patient beds assigned to one nurse or from bed-to-linen cart, represents a difficult task, made increasingly complex by the variable placement of mobile items. Resource monitoring using radio frequency identification is a promising technology; however, ethnical concerns and issues of scalability must be addressed (Sundaresan et al., 2015). Although data are available to link specific infants to bed assignments, data linking infants to nursing assignments are often maintained in separate staffing software. This precludes computational systems from informing clinical drivers of workload at the time of staff planning. Even in cases where assignment data *could* be linked to an infant, expected shift lengths of a nurses are not typically available, rendering any form of potential optimization useless.

Intra-Shift Variability of NICU Staffing Factors

Underlying infant, nurse, and organization factors influencing NICU staffing needs are often overlooked but critical elements of how these factors fluctuate throughout the day (Gray & Kerfoot, 2016). Nursing assignments must account for a degree of intra-shift fluctuation. With the objective of providing best care and constrained by nurse availability and a preference to not reassign nurses mid-shift, addressing changes at any level represents a nontrivial and highly constrained balancing act.

Infant-Level

Changes in infant acuity represent the primary and most direct driver of nursing activities (Rogowski et al., 2015). It has long been recognized that "many babies intermittently demand the almost undivided continuous attendance of an experienced nurse for two or more hours, and routine staffing levels need to flexible enough to copy with such fluctuations in need" (Northern Neonatal Network, 1993, p. 542). Overall severity demand can stem from episodes of patient deterioration, where life-threatening events can cause significant disruption to standard operations. This may require rapid redeployment of nurses to a single infant, whereas other nurses cover a wide range of assignments. Improvements in infant condition can generate updates to a plan of care that necessitates rebalancing of nursing assignments.

Collection of relevant data and calculation of acuity scores is time-consuming, limiting ability for these scores to be rapidly and repeatably computed to reassess intra-shift appropriateness of staffing assignments. Changes in scores provide no actionable path for reorganization of assignments, but rather require synthesis from a charge nurse for whom standardization and guidance is lacking.

TABLE 4. POTENTIAL DATA SOURCES FOR DATA-DRIVEN NICU NURSE STAFFING

Data Source	Applicability		Level of Data		
	Pre-Shift Planning	Intra-Shift Planning	Unit	Nurse	Infant
Electronic Medical Record (EMR), including: • Automatically and manually entered physiologic data • Laboratory data • Medication administration • Feeding and plan of care • Rate and duration of EMR access	✓	✓			✓
Bedside Devices, including: • Infusion pumps • Ventilator and monitoring alarms • Patient monitoring tools	✓	✓			✓
Ancillary Medical Systems, including: • Pharmacy systems • Imaging systems • Risk score algorithms and other derived data	✓	✓			✓
Clinical Scheduling Systems, including: • Operating room and pre-op times • Imaging procedure times	✓	✓	✓		✓
Administrative Scheduling, including: • Care conferences • Skin-to-skin care sessions	✓	✓	✓		✓
Location Tracking Technology, including: • Nurse locators and pedometers • Room entry monitors		✓	✓	✓	✓
Human Resources Records, including: • Staffing profiles • Certifications	✓			✓	
Time Tracking Software, including: • Ancillary care team availability • Shift lengths		✓	✓		
Bed Tracking, including: • Current nursing assignments • Census reports and admissions and discharges	✓	✓	✓		
Resource Monitoring, including: • Formula scanning • Resource dispensing		✓	✓		
Architectural Information, including: • NICU structure and layout (single family rooms, pods) • Distance between beds and resources	✓	✓	✓		
Institutional Policies and Laws, including: • Staffing ratios • Overtime limits	✓	✓	✓		

Nursing Availability

Throughout the day, personnel fluctuations may occur as nurses attend to emergency events, most prominently in staffing birth or surgery activity, and transport teams. In ideal scenarios, dedicated teams are available to respond to these requests; however, in reality, efficient allocation of personnel may require reorganizing existing assignments to cover these events. A recent study of challenges for transport teams found nurses "were frequently pulled from other assignments or delivery room coverage, and this delayed times to departure for transport teams and left gaps in coverage for inpatient care" (Akula et al., 2020, p. 397). Temporary assignment coverage must account for nurse skillset on the newly formed team and in the contracted NICU nurse pool while maintaining a desired nurse-to-patient ratio and necessary coverage of a NICU pod. The complexity of this task may be compounded by a need to assign only certain (i.e., credentialed) nurses to certain ad hoc procedures (e.g., dialysis, extracorporeal membrane oxygenation, central line placement) and the desire to optimize interprofessional team-level dynamics.

If more nurses are preemptively scheduled to ensure adequate coverage of expected workload, institutional needs may require intra-shift ad-hoc flexibility, as units must respond to hospital-level requests for "float" nurses. Depending on policy, a float nurse may be preselected in a rotation, potentially precluding best matching of their skillset with patient needs.

Unit Census

At the organizational or unit level, overall census is the most common impact to variability (Bingham & Ruhl, 2015). New patients may be expected such as planned birth of a premature infant or unexpected such as respiratory distress at birth. Even for expected admissions, infant acuity frequently deviates from prediction. This intra-shift variability can significantly upset otherwise well-planned assignments.

Although anticipatory assignment of admissions, for example specifying the nurse for the first, second, third, etc. admission, may smooth process at the time of these events, this form of set assignment may not be consistent with goals of matching infant and nurse characteristics and promoting targeted skill development in novice nurses. Numerous consecutive or simultaneous admissions (e.g., twins, triplets) may require opening of annex or overflow areas in NICU, affecting workloads and patient monitoring at a broader scale.

There is significant variability in staffing requirements for planned and unplanned discharges. "NICU discharge readiness is defined as the masterful attainment of technical skills and knowledge, emotional comfort, and confidence with infant care by the primary caregivers at the time of discharge" (Smith et al., 2013, p. 415), and it is often challenging to integrate the expected time to prepare the baby and ensure parents feel prepared to take their baby home in preemptive staffing plans. Infant transport to a higher level NICU involves a similarly high degree of variability in preparing the infants.

Future Perspectives

Efforts to staff a NICU represent a constrained optimization problem. A complete picture of the infant's condition and required tasks, elements of the unit, and attributes of the caregivers must be considered. Yet, driven by time pressures, lack of standardized tools, complex ethical considerations, and not-trivial measurement of data, nurse leaders in NICU units are forced to make the best staffing decisions possible using the subset of information available at any given time. With increasingly limited resources, there is a clear need to improve the modalities, granularity, and frequency of data collected, while continuing to remain flexible of expected intra-shift variability pervasive in acute care settings.

Using Data to Inform Pre-Shift Staffing Factors

No amount of available data or computational optimization are likely to capture the nuance and institutional knowledge provided by an experienced charge nurse. Yet, by integrating larger, more diverse datasets to provide real-time context to nurses there is a significant role for this methodology to augment development and management of staffing workflows. See Table 4 for potential data sources for integration in NICU nurse staffing planning.

Emerging technologies and research have begun to address challenges in several important domains. Real-time physiologic risk score calculations can integrate EMR data with streaming telemetry-based monitoring to calculate up-to-date severity scores (Rothman et al., 2013). Along with recent research using EMR data to access patterns and orders to better estimate workload (Meyer et al., 2020), there is potential to use more comprehensive informatics models to generate acuity measures for pre-assignment staffing and implement automated alerts for infants experiencing a high variance throughout a given day.

Continued efforts on system interoperability may offer access to scheduling software, allowing insight into available shift lengths for scheduled nurses across the unit and clinical factors such as operating room schedules (Ivory, 2015; Lehne et al., 2019). These data are well-poised to allow for numeric optimization techniques that have already found success in procedure scheduling (Fairley et al., 2019). The potential to capture skillsets in a more defined manner represents an exciting path forward in defining multi-criteria optimizations such that coverage of expected tasks can be matched to available nurses. There is similar potential for optimization at the unit-level, for example, bed assignments, distances between various objects and rooms, and care bundles to minimize logistical overhead in nurses' ability to perform their core role (Bai et al., 2018).

The role of predictive analytics must be explored, particularly in the context of time-aware models. Although uncertainty of predictions must be accounted for, ability to estimate short- and long-term demands on a unit may help gain a better understanding of a relevant time frame of various actions. For example, knowing a 1:1 ratio in-

CLINICAL IMPLICATIONS

- Determination of how many nurses are needed, and their patient assignment is a continuous operational challenge that must be deliberately and constantly managed at the unit and institutional level.
- Despite a lack of agreement on how to best determine staffing levels for safe and effective nursing care, there is recognition that technology is required to incorporate, monitor, and manage data to better plan and update the processes of patient care.
- Effective nurse staffing models must incorporate a broad data set to develop pre-shift plans and be robust enough to address intra-shift variability pervasive in NICU setting.
- Preemptive assignment for new admissions is an area for reconsideration and innovation because of the need to match yet-unknown patient characteristics with an appropriate skill mix in the context of other varying factors.
- Effectiveness and efficiency of nurse staffing decisions affected by intra-shift variability of infant, nurse, and unit factors can be addressed using novel functional and team nursing care models decentralize decision-making.
- Professional judgment is needed to add to the data available to develop a nurse staffing plan.

fant will be discharged after 1-day versus an expected 15-day stay may prompt units to preemptively schedule more nurses. Similarly, estimates of postoperative care such as tracheostomy tube placement may help to determine the expected workload more accurately for an infant at the time of scheduling, allowing charge nurses to proactively balance assignments rather than adapting reactively.

Reducing Intra-Shift Variability of NICU Staffing Factors

There is opportunity to improve the effectiveness and efficiency of nurse staffing decisions affected by intra-shift variability of infant, nurse, and unit factors using novel care models that take steps to decentralize decision-making. Team nursing provides a platform for mentoring novice nurses in high-turnover environments, incorporating technical clinicians and other ancillary personnel into the care team, and addressing patient deterioration or escalating care needs more efficiently through decentralized team leadership. In large NICUs where staffing shortages, rotating shifts, and unit geography impede achievement of primary nursing, team nursing has been shown to foster continuity and allow parents to develop sustained trusting relationships with a predictable nursing care team within the larger unit group of nurses, while adding a mid-level nurse team leader who can rapidly address infant, nurse, and unit-level variations within the smaller "microsystem" (El Helou et al., 2017; Reis et al., 2009).

In a team model, the unit is partitioned into spaces that optimize team member proximity and communication. Changes in infant acuity warranting a transient or sustained assignment adjustment can be more efficiently and effectively optimized within the team than within a large unit. Team leaders can advocate for placement of certain complex patients on their team to promote targeted skill development within their team and can collaborate with other team leaders to address census changes, unit education, and variations more efficiently in other unit-level factors.

Team nursing also has the potential to improve the need to match new admissions to NICU with an appropriate nurse. Rather than routinely assigning a newly admitted patient to an individual nurse, admissions (first, second, third, etc.) are distributed by the charge nurses to a team. The team leader can locally adjust assignments, based on nurse skill-mix and infant condition.

Enhancements for single-family room designs have significant potential to reduce workload (e.g., ease of monitoring and moving between infants) while optimizing nurse situational awareness, which in turn optimizes patient stability for further impact on workload. Structural changes, such as targeted placement of half walls or windows instead of full walls, and technology enhancements, such as multiple monitor viewing and military-grade communicators, can provide for greater nurse interaction including more provisions for mentoring and skill development of novice nurses (O'Neill et al., 2020).

Conclusions

Despite an ongoing need to inform nurse staffing plans with complete information, there are structural barriers in obtaining and operationalizing data in health care settings. As resources become continually constrained in an increasingly complex care model, robust quantitative measurements of the totality of a unit's infants, nurses and other clinicians, and structure will be a foundation on which effective and efficient staffing can be developed. Collection of data alone is insufficient to improve nurse staffing. It is impractical to expect any single individual to synthesize such a wide array of factors at any given point. Informatics and machine learning tools must be explored as methodologies to augment existing workflows within units, working in tandem to contextualize information relevant to developing preemptive nurse staffing plans that are consistent with staffing standards, and reacting to and adjusting for intra-shift variability. Health care is a human endeavor and optimizing the staffing of NICUs to achieve the delivery of safe and effective neonatal nursing care requires a deliberate, systematic approach with commitment from nurses, physicians, and other clinicians, resources from the management team, and an institutional culture of patient safety all working to improve the efficiency and effectiveness of care for infants in the NICU. ✣

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