4.7.2 NICU spaces and their relationships

4.7.2.1 Patient spaces

Patient units usually include larger or adjoining rooms for twins and triplets, as approximately 20 to 25 percent of the NICU population are multiple births (White, 2011b). Units of eight or fewer beds, whether private rooms or open bays, may negatively impact staffing collaboration, while larger clusters will require frequent patient transfers to maintain ratios (White, 2011b). Clusters larger than 12 rooms may be geometrically challenging. While Chapter 5 discusses research studies involving single family room care, a variety of authors have provided case studies and informal descriptions of this experience (e.g. Bruns and Klein, 2005; Carlson et al., 2006; Cone et al., 2010; Henry Bowie et al., 2003; McGrath, 2005; Milford et al., 2008).

4.7.2.2 Family spaces

NICU families and visitors experience high levels of stress and are very vulnerable to the critical care environment (Leibrock and Harris, 2011). Families often spend extended time in NICUs due to the long length of stay of some infants. As such, the needs of these families are significant. White (2004) proposes the following environmental features in support of family spaces:

- Access to the baby that doesn't conflict with equipment.
- Care area with privacy.
- Space to participate in rounds and a place to sit while engaged in conversations with the physician.
- Location to leave written or verbal messages for staff.
- An area where a family member can make phone calls, take a nap, get a midnight snack.
- Family sleep space.
- Places to meet with extended family that include refreshments, educational library, and play area for siblings.
- Ceiling-mounted equipment or equipment on articulating arms to provide ready access of families to babies (White, 2004).

4.7.2.3 Staff spaces

The issues discussed previously regarding centralized versus decentralized nurse stations in PICUs apply equally to NICUs. Historically, the nurses' station was directly integrated with the incubators in an open bay. Decentralized nursing stations are now more commonly distributed throughout an open bay or distributed near SFRs. One of the biggest challenges to SFRs has been assuring nurses that through decentralization and remote observation infants can be adequately cared for.

Working in a NICU is a highly stressful job. Provision of respite spaces in this context is likely more important than any other inpatient setting. Lounge spaces and access to nature away from the public may be an effective way of enabling staff to recuperate from intense experiences on the unit.

4.7.2.4 Support spaces

As with PICUs, satellite pharmacies have been recommended for NICUs to reduce errors (Kaushal et al., 2001; Lobas et al., 1991; Raju et al., 1989). In terms of supplies, a variety of models exist regarding centralized versus decentralized location, although some decentralization is present in all contemporary units. Neither central nor satellite laboratories may be the right solution for NICUs. Evidence suggests the effectiveness of an in-line point-of-care testing device (Alves-Dunkerson et al., 2002), as a means of reducing over-drawing that results in anemia.

4.7.2.5 Equipment

As equipment has become more advanced, parents have become more marginalized (Marshall-Baker, 2011). The protocol of skin-to-skin care, or kangaroo care, has been institutionalized in many settings, partially in response to this distancing between family and child resulting from the incubator. In addition to enhancing the emotional interaction between mother and child, researchers have reported improvements in the baby's perceptual-cognitive and motor development and improved parenting skills (Feldman et al., 2002; Whitelaw, 1990).

The primary piece of equipment in the NICU is the baby incubator. Recommended alterations to this equipment include the introduction of color and pattern to support individualization, arm rests, areas underneath for seating, less institutional material, and the ability to raise and lower the device to enable pulling a chair up to the isolette (Marshall-Baker, 2011). Antonucci et al. (2009) suggest that contemporary incubators have not resolved issues regarding temperature, noise, light, and electromagnetic fields. Ferris and Shepley (2012) describe incubator proposals generated by students who gathered ergonomic and social factor data at a NICU (see Figure 4.12). The design of the equipment in a NICU must be part of a systems approach, as described in Ferris' guest author essay.

Figure 4.12: *Example of incubator designed by engineering and architecture students (Source: Author. Design by Cameron Christian, Tanya Singh, and Kara Wetzel)*

Systems-oriented design considerations for the NICU

Thomas K. Ferris, PhD

A mother's womb is a complex system. The primary goals of this system – the healthy growth and development of the fetus – are achieved when several biological subsystems "work together" in concert to provide the necessary environmental conditions and perform necessary care functions effectively. Similarly, a NICU may be thought of as a prosthetic womb in which the environmental conditions and care functions are provided by a system of humans and technologies within a controlled care setting. The growth and development of preterm or ill infants being cared for in a NICU depends in large part upon how effectively the synthetic system (human caregivers and technologies in the care setting) replicates the environment and functions of the biological system (the womb).

With the growing emphasis on evidence-based design approaches in healthcare (e.g. Ulrich et al., 2008), it is important to note that the qualities of interest in this branch of design – such as patient outcomes, worker productivity, patient and worker satisfaction, and safety – are not solely attributable to individual "components" of a healthcare system; instead, these qualities need to be considered as emergent properties of the entire system, viewed holistically. To understand how components of the NICU system – such as clinical care providers, patients, family members, technologies, care tasks, organizational culture, and the physical NICU environment – contribute to systems-level properties, the components should not be studied in isolation, but rather in a context that also analyzes the relationships and interactions among them. At the system level, the role of each component is defined as much by these relationships and interactions as by its individual characteristics.

For example, to understand how replacing an existing technology with a "new and improved" version would impact a system-level property such as quality of care, one must first understand how each technology is currently being or would be used by different user groups (e.g. nurses, physicians, perhaps family members or patients themselves) within the care setting of interest. These patterns of use represent one type of interaction among at least three system components (human users, technologies, and the environment). The outcome of this interaction is a degree of positive or negative support for the performance of cognitive and physical tasks that ultimately contribute to the overall quality of care. Often a technology may indeed be "new and improved" when a side-by-side isolated comparison is made with an existing technology, but from a systems perspective the new technology may not improve the overall quality of care (or, worse: it may diminish the quality).

This perspective reflects a problem-solving approach known as *systems thinking*, a dogma central to the emerging fields of systems engineering and systems-oriented design, and also familiar to a family of design fields that include human factors: engineering, human–computer interaction, and user-centered design (e.g. Wickens et al., 2004). To guide systems-oriented analysis and design in a NICU, PICU, or similar system, one may find it useful to consult systems models that have been tailored for analysis in the healthcare domain. One example, the Systems Engineering Initiative for Patient Safety

(SEIPS) model (Carayon et al., 2006), provides a framework to facilitate understanding of how patient safety is an emergent property of many components of the healthcare work system as well as the interactions among them. Following the SEIPS model (with core model components *in italics*), a NICU system could be defined as groups of *people* (e.g. infant patients, nurses, neonatologists, other clinical personnel, family members) interacting with *tools and technologies* (incubators, ventilators, feeding and medication delivery machines, physiological monitoring sensors and displays) to perform necessary *tasks* (controlling environmental conditions, monitoring and managing the patient's physiological state, promoting familial bonding) within the care *environment* (NICU physical space, layout of rooms and beds and nursing station, ambient lighting and sound levels, air quality), all under the context of larger *organizational conditions* (safety culture, team work among employees, policies regarding the involvement of family members in infant care). While the SEIPS model emphasizes patient safety as the systems-level property of interest, the analysis of our NICU system may instead emphasize the same goals as the biological system it approximates: the healthy growth and development of its infant patients.

NICU design efforts will often be limited to focusing on one or only a few of the many components that interact in complex ways to affect the growth and development of infant patients. In addition, time and budgetary constraints will likely dictate that the depth of system component analyses be far short of exhaustive. These limitations do not preclude a systems-oriented design approach, nor do they diminish its value. The spirit of this approach can almost always be incorporated into a design process by following three summary recommendations:

1. Judge the qualities of system components within the work context, rather than in isolation.
2. Recognize that changes to one component may have important implications for many other interacting components, and these implications may be difficult to foresee prior to implementing the changes. As much as possible, test in situ before fully committing to a design change.
3. Understand that many components have individual measures of quality, and sometimes design changes that are good for some components are bad for others. In these cases, what is important – and what should drive design considerations – is how changes impact the systems-level qualities of interest that are defined by the design goals.

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