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Impact of the design of Neonatal Intensive Care Units on neonates, staff, and families: A systematic literature review

ABSTRACT

Background: Newborn intensive care is for critically ill newborns requiring constant and continuous care and supervision. The survival rates of critically ill infants and hospitalisation in neonatal intensive care units (NICUs) have improved over the past two decades due to technological advances in neonatology. The design of NICUs may also have implications for the health of babies, parents and staff. It is important therefore to articulate the design features of NICU that are associated with improved outcomes.

Aim: The aim of this study was to explore the main features of the NICU design, and to determine the advantages and limitations of the designs in terms of outcomes for babies, parents and staff, predominately nurses.

Design: A systematic review of English language, peer-reviewed articles was conducted for a period of 10 years to January 2011. Four online library databases and a number of relevant professional websites were searched using keywords.

Results: There were two main designs of NICUs, that is, open bay and single family room. The open bay environment develops communication and interaction with medical staff and nurses and has the ability to monitor multiple infants simultaneously. The single family rooms were deemed superior for patients' care and parent satisfaction. Key factors associated with improved outcomes included increased privacy, increased parental involvement in patient care, assistance with infection control; noise control, improved sleep, decreased length of hospital stay and reduced re-hospitalization.

Conclusion: The design of NICUs has implications for babies, parents and staff. An understanding of the positive design features needs to be considered by health service planners, managers and those who design such specialized units.

Keywords: NICU, health care design, single family room, open bay, infant, preterm, staff, parent

Precis: A systematic review was conducted to explore the impact of the design of Neonatal Intensive Care Units on neonates, staff, and families.

INTRODUCTION

Preterm infants, that is, those less than 37 completed weeks of gestation, account for about 7% of the 280,000 births in Australia (1). In the USA in 2008, preterm births account for 12.3% of births (2). Many of the preterm babies will be admitted to a neonatal intensive care unit (NICU) to provide care and ongoing support. Neonatal intensive care units are highly technological spaces that incur considerable costs due to the critical nature of the care provided. In recent years, many new units have been built in Australia and other similar countries and there is ongoing refurbishment of older units. Since the emergence of Neonatal Developmental Supportive Care in the early 1980s, many NICUs have had to reconsider their physical layout in order to support this model of care (3). It is therefore essential that the design of NICUs be considered in terms of the contribution to outcomes for babies and experiences for parents and staff.

In the past two decades, there has been an increasing interest on the design features of acute hospital facilities including NICUs. A positive, physical, health care environment is said to be a healing environment and has been shown to have beneficial effects on the well-being of patients, the caregiving process, and family comfort (4-5). Many studies highlight the potential effect of physical health care environments on the health outcomes and well-being of patients in health care settings (4). The physical environment has been shown to play a significant role in healing and contributes to clinical, operational, and social dimensions in healing (6).

In light of these changes, the design of acute health care environments needs to be considered. One acute care area that has received some attention is the NICU. Both Walsh (7) and Carlson et al (8) have reviewed the history of NICU design. Original designs of NICUs had multiple bassinets organized in an open space without fixed partitions or walls between them. During the 1970s and 1980s, the significance of parent involvement in patient care was established in the field (9). This was a change in the philosophy of care and a gradual evolution in design took place from open-bay wards, to pods, pin wheels and divided bed spaces open on one side, to finally completely private patient rooms for neonates and their families. Single family rooms were established as they were seen as being better for babies (10) as they enhance privacy (8, 11-

12), facilitate parental participation in care (13), control infection (7, 10, 14), control noise (7, 14-16) and reduce length of hospitalization (11, 13). While single family rooms are growing in popularity in many hospitals, there are concerns about the isolation of neonates and their parents away from other families and the potential lack of social support that single rooms may inadvertently cause. Anecdotally, staff in some NICUs with a single room design report feeling isolated from their colleagues and experience an increased amount of walking as the NICU is usually larger to accommodate single rooms. Staff perceive a decreased ability to monitor multiple infants in separate single rooms and have difficulty providing support to each other while simultaneously monitoring one's own patients.

With these issues in mind, we undertook a systematic literature review to explore these issues. The aim of the review was to describe the main features of NICU design, and determine the advantages and limitations of the design in terms of outcomes for babies, parents and staff.

METHODS

A systematic review of English language, peer-reviewed articles was conducted. The PICO principles (Population, Intervention, Comparison and Outcome) were used to formulate clinical questions that guided the search strategy. The questions were: What are the benefits associated with different designs (O) for babies who are admitted to a NICU (P) comparing different design features, for example open bay (I) versus single family room (C). Essentially, the positive and negative design features of the NICU were explored.

We searched through four main online databases for health, that is, CINAHL (Cumulative Index to Nursing and Allied Health), Ovid MEDLINE, Science Direct, and the Cochrane Library. Keywords used were hospital design, single (patient) room, open ward, healing environment, built, environment, developmental care, health outcomes, neonatal intensive care unit, unit design, nurse, physician, family, and health care.

The reference lists of included articles were checked to determine other articles for inclusion. The inclusion criteria were all studies written in English that evaluated NICU design features and

impacts on infants, staff and families; involved a comparison group (randomized control trials, cohort studies, and before and after studies) and published from January 2000 to January 2011. Studies that did not report specific design features of the NICU and their impact on outcome measures were excluded. Figure 1 provides an explanation of the search strategy and the number of articles located at each point.

Types of outcome measures

A number of outcome measures were examined in the study based on the work of Ulrich et al (5). Ulrich et al (5) conducted a comprehensive literature review that linked characteristics of the physical environment of hospitals to staff stress, quality of care delivered and patient outcomes. The main outcome measures examined are described in Table 1.

Data extraction

After the search, studies reporting physical interventions were grouped by four major categories of design intervention to determine the advantages and limitations of the design in terms of outcomes for babies, parents and staff. A narrative summary was undertaken to report the findings. A meta-analysis was not undertaken because of insufficient number of studies and the lack of numerical data.

FINDINGS

The initial search retrieved 1080 studies. After excluding the duplicates of articles, the titles of 744 papers were read and 697 were excluded as they did not relate to NICU facilities. Of these 47 potentially relevant articles, we excluded 35 studies as they did not study the impact of NICU design on infants, staff, and families (Figure 1).

Twelve papers met the inclusion criteria. This included one randomized control trial (RCT), four prospective comparative studies, three before and after studies, three cross sectional or descriptive studies and one qualitative study. The 12 studies addressed the five outcome categories, that is, infection control; length of stay; noise; workload and communication; and, privacy and comfort. Some studies addressed more than one outcome category (Table 2).

NICU environment and effect on infants

Patient medical progress including infection control

Three cohort studies (7, 10, 14) and one RCT (13) addressed the link between the built environment, infection, and patient progress in NICU. Domanico et al (14) undertook a study comparing infants in single rooms with those in an open bay area. Apnoea-prone infants' who were less than or equal to 36 weeks of post-menstrual age had a 57% reduction in apnoea events when in single family rooms compared with those in open bays. Furthermore, mechanical ventilation, positive air pressure, and apnoea events were reduced in single family rooms (14).

Different factors were identified or implicated as contributing to improved health outcomes in single family rooms. Ortendstrand et al (13) undertook a randomised controlled trial of two contrasting unit designs, that is, standard care or open bays, versus single family rooms. This trial showed a lower risk of moderate-to severe bronchopulmonary dysplasia in the group randomised to the single family rooms compared with open bays. Parents of infants in the single rooms were able to stay 24 hours per day whereas parents whose infants were in the open bays had limited opportunities to stay overnight. This extended parental access may have contributed to improved outcomes for the babies.

Outcomes for patients cared for in single rooms reveal a consistent pattern of reduced infection rates compared with shared rooms. One study in the USA showed a reduction in catheter-associated bloodstream infections from 10.1 per 1000 device days to 3.3 per 1000 device days over a nine month period after babies were moved from an open bay environment to a single family room (7). In the studies by Walsh (7) and Cone (10), staff perceived an improvement in hand washing in single family rooms compared with open bays due to installing sinks or hand-cleaner dispensers in each patient room.

Length of stay and re-hospitalisation

At least three studies using a single family room approach showed decreased NICU length of stay (11, 13) and lower re-hospitalisation rates compared with open bays (17). One before and after study undertaken (11) evaluated the length of stay in single family rooms or open bays. More than one half of infants (59%) cared for in an open bay had a length of stay of less than 14 days. Once the NICU was moved to a new environment with single family rooms, 76% of infants had a length of stay of less than 14 days. It is possible that single rooms facilitate greater parent involvement in care and enable practices such as breastfeeding and skin-to-skin care more readily than open bays. The resulting enhanced parental participation may be a factor in the reduced length of stay.

There was only one RCT included in this review. Ortenstrand et al. (13) randomised 366 infants born before 37 weeks of gestation in two NICUs. The two groups were standard care which was provided in open bays compared with family care, that is, single rooms with unlimited parent presence. The total length of hospital stay for premature infants born before 37 weeks of gestation was 5.3 days shorter in the family care group (single room) compared with infants in the standard care group (13).

The availability of individual rooms seemed to promote parental interaction with the baby and led to decreased rates of re-hospitalization (18). One prospective cohort study was conducted with two groups of mothers in two different hospitals. Mothers who stayed with their preterm infants (Group I) in single bay areas were compared with mothers who were not staying overnight with their preterm infants who were cared for in open bay areas (Group II). The findings demonstrated that infant re-hospitalization rates were significantly lower (12.9% vs. 34.5%) when infants had been cared for in the single family rooms. Erdevé et al (18) also noted that the major cause of re-hospitalization in infants whose mothers were not staying with them in hospital was feeding difficulties. Although family centered care can be successfully implemented in open bay wards, single family rooms provide more opportunity for rooming-in prior to discharge (18). These three studies highlight that the increased involvement of parents in the single rooms may influence outcomes for the babies.

Noise

Four studies focused on noise in the NICU and examined environmental interventions in reducing noise and its effect on outcomes. Noise was found to be not only detrimental for infants but has also been identified as a stressor for staff and families (7, 15). Despite the broad impact of noise, no studies examined the effect specifically on staff. The studies below focused on the impact on the neonates.

Noise in NICU is a highly negative environmental characteristic that increases neonates' heart and respiration rates, contributes to sleep disturbance, hearing impairment, decreases oxygen saturation (15-16) and has a negative impact on nervous system development (14).

Ambient noise levels in open-bay settings were found to be greater than in single family rooms (14-15). Using a cohort study design, Chen et al (15) measured noise levels continuously, over 24 hours a day, in two separate NICU designs. Their study indicated that noise levels in the open space were greater than that in an enclosed space, that is, a single room. Another cohort study (14) found the most important sources of noise in open bay area came from = staff and visitor activity and was loudest in areas close to the NICU entry or the nurses' desk during visiting time and shift change.

Krueger et al's (16) before and after study of sound levels reported that sound levels after reconstruction to a single room were lower than in an open plan ward. Although the study demonstrated the positive impact that single rooms can have on sound levels, additional interventions may be required to reduce the current standard noise level in NICUs. Environmental interventions which have been found to be effective in mitigating noise include providing single rooms rather than open bays, continuously monitoring the sound levels (15), installing soft vinyl floors, having sound absorbing materials in the ceiling and making an ongoing effort to reduce noise (7, 16). Single rooms, in particular, reduce the sound level by having fewer people and machines in a concentrated area. They also provide families with the feeling of enhanced privacy (15).

NICU environment and the effect on staff

Workload and Communication

The NICU environment can be highly stressful for healthcare staff, suggesting that, to reduce stress, the facility layout must support their activities. Five studies examined the impact of NICU design on staff. In particular, four studies examined the walking required by staff in the different designs. All these studies (7, 8, 10, 19) showed that the layout of the NICU (single room versus open bay) impacted on the time required to travel from room to room and the perceptions of care by the nurses. Nurses working in open bay NICUs walked less and were able to monitor infants visually from the nursing station (7, 19), whereas, nurses providing care in single family rooms found that it was unsettling not to be aware of the progress and status of other patients (8). Walsh et al (7), in a before and after study of 127 nurses' perceptions after a move into a NICU with single rooms, reported that the majority of nurses (70%) believed that having single rooms was physically harder and stated that the additional walking required to cover the unit added to their workload. Regardless of patient acuity, there was a consensus agreement that patient assignment in single rooms should be limited to no more than two per nurse to account for the increased distances and feelings of isolation (7, 10).

Four studies examined the effectiveness of communication in NICU settings (7, 10, 19). In one study of 21 staff, one year after moving into a single room design, the single room layout was perceived to separate staff from one another and reduced opportunities for talking, support and ongoing education (19). Concerns about decreased communication and staff interaction were mostly related to the single room design compared with open bay designs. A number of strategies were proposed to address these issues including ensuring the nurses' station and medical work areas are adjacent to the patient rooms (10) and providing adequate or sufficient staffing (7).

Privacy and comfort

Three studies have linked the design of the NICU to family comfort (8, 11-12). A study conducted by Carlson et al (8) in the United States indicated that within six months after moving to a single family room design, parents reported improved privacy compared with the previous

open bay layout. Parents reported feeling like visitors in the open bay design. They felt a lack of privacy to express their joy and sorrow. However, the parents felt like a family unit in a small room. The experience of comfort and being shielded from the other parents' emotional expression and from the noise simulated feelings of privacy (12). Another cohort study by Carter et al, again in the USA, showed that privacy in a single room design may have been affected by two factors, the greater physical space and unlimited parental visitation (11).

DISCUSSION

The design of the NICU does impact on outcomes for patients, families and staff although only a limited number of studies were found that specifically addressed this issue. Single family rooms are associated with shorter length of stay, increased privacy and opportunities for parental interaction and fewer patient infections compared with open bay wards. Parents preferred the intimacy of a single family room and the noise levels were also decreased. While staff valued the reduced noise in the single family rooms, this was balanced with concerns about increased distances between infants and the diminished opportunities for staff interaction.

When considering NICU design and unit configuration, it is important to remember that families and staff have different needs. The family needs include an emphasis on privacy and individualised care, whereas the staff needs often emphasise efficiency and visibility. A number of studies on design configuration in the NICU unit examined workload and communication. The majority of these studies showed that communication happened naturally and constantly among nurses and physicians in an open-bay ward, while in the single family room design, the level of constant communication and patient monitoring was often reduced.

The nurses in the single room NICU design expressed concerns that the decreased visibility of infants would affect their workload and infant outcomes. The nursing staff believed that single rooms were physically harder due to time spent walking which increased as the overall footprint of the unit increased. To remedy this problem, clustering patients and having centralised supply areas are suggested (10). Ulrich (5) found that a design which placed patient rooms close to one

another (in a radial or circular design) and decentralised nurses' stations were able to reduce staff walking and fatigue, increase patient care time and improve staff communication.

Ulrich et al's (5) systematic review of the design and health literature demonstrated that, single rooms allow more privacy for parent-infant interactions and protected them from environmental noise. Environmental noise is a significant cause of stress in health care facilities and strategies to reduce noise should be implemented. Noise levels can be substantially reduced by implementing environmental interventions, which includes the installation of sound absorbing materials in ceilings and the removal of noise sources. Establishing a quiet environment in NICU is essential, in particular to improve the infant's sleep, control heart and respiration rate and enable families to have a peaceful time with their infants.

Although a small number of studies demonstrated benefits in comparing open bay versus single family rooms there are a number of limitations which need to be considered. Overall, there were few studies undertaken in this area. Only 12 studies directly examining design in NICU were identified out of more than 1000 initially identified. Only one study was a randomised controlled trial and few were comparative studies. The level of evidence in the available studies was not high – many were before and after studies which have the potential for significant bias. While randomised controlled trials are difficult in this area, research designs that reduce bias need to be undertaken to strengthen the evidence-base in this area.

Given the considerable amount of resources spent on building, refurbishing older units and caring for infants in these units, very little research has been undertaken on the actual design of the NICU which limits this review. Most of the studies were conducted in the United States, and while their findings are probably generalizable to other developed nations, more research that addresses specific contexts and settings in other countries is required to increase the evidence-base.

CONCLUSION

The findings of this review collectively link a range of aspects of the physical environment of NICU to well-being of patients, family comfort, and the caregiving process. This paper recommends that consideration of the design and environment is important for the health and wellbeing of neonates in the NICU, including noise control, infection control, and privacy. Provision of single rooms per se is a more controllable environment for preterm infants and improves health progression over open bay units. Parental involvement in single rooms not only minimized hospitalization and rehospitalization rates but enabled parents to feel more comfort and privacy. Potential limitations of the single family room design are that they increased staff workload, reduced the visibility of infants to staff, and reduced communication among staff. These would be mitigated by improved design lay out and de-centralised nursing stations.

Further research needs to those aspects of single room design that decrease staff communication and patient visibility. This literature review provides information to assist a range of disciplines including architects, designers, and health service managers who are involved in NICU design. An interdisciplinary sharing of knowledge between stakeholders such as clinicians, managers and architects could ensure that research evidence was applied in the design of NICUs. Research into ways to improve the environment for babies, parents and staff is needed including developing and testing innovative designs that reduce the distance that staff need to walk while ensuring privacy and intimacy for parents and examining the most effective ways to ensure families have social support, perhaps from other families, in a NICU that has single rooms. Exploring the best way to improve staff to staff communication is also needed whether this be through having central workspaces, using interactive media such as video or instant messages systems or changing management systems to reduce the size of the functional unit. Future research also needs to examine the impact of specific issues such as noise on the staff and families. This needs to explore which aspects of noise create stress and anxiety for families and staff and how this can be mitigated. For example, a better understanding of whether the stress-creating noise is from alarms that may also highlight health concerns with the baby or whether background and staff-produced noise itself create stress. Such future studies could have significant impacts on the design of NICUs and on future cost effective models of care in these settings.

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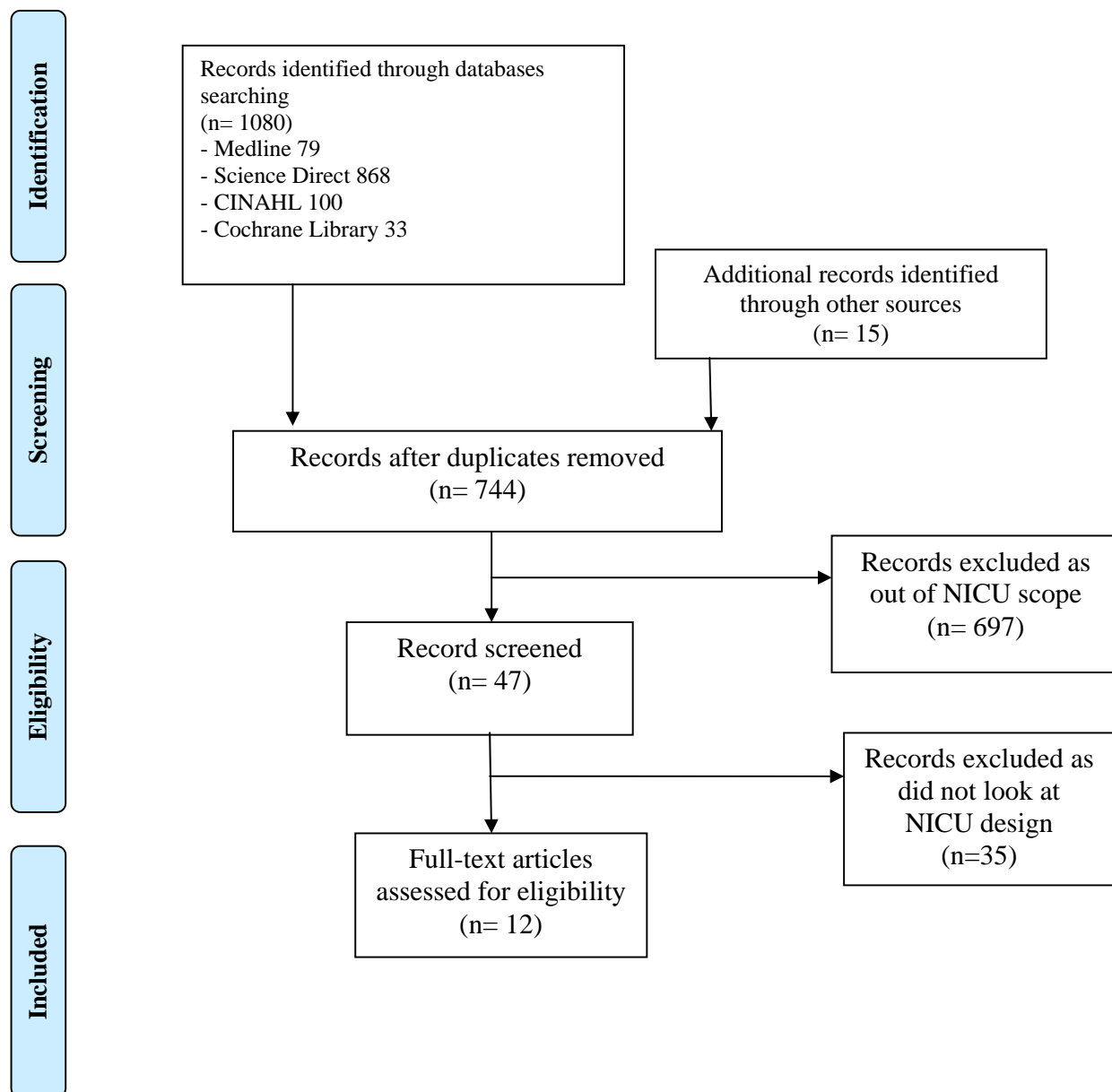
Figure 1: Flowchart to explain the search strategy and final articles

Table 1: Outcomes measures examined in the literature review

Main outcomes examined	<ul style="list-style-type: none">• staff stress and effectiveness in delivering care• patient safety• health outcomes• overall health care quality
Other outcomes examined	<ul style="list-style-type: none">• infection control• length of stay and re-hospitalisation• noise on neonates• workload and communication between staff• privacy and comfort for parents

Table 2: Included studies by outcome and author, year, country and study design

Trial (author and date)	Country	Design
Infection control (n=3)		
Cone <i>et al.</i> (2010)	USA	Cross sectional survey
Walsh <i>et al.</i> (2006)	USA	Descriptive cohort (quantitative)
Domanico <i>et.al</i> (2010)	USA	Prospective comparative
Length of stay (n= 3)		
Carter <i>et.al</i> (2008)	USA	Descriptive cohort (quantitative)
Erdeve <i>et.al</i> (2008)	Turkey	Prospective comparative
Ortenstrand <i>et.al</i> (2010)	Sweden	Randomised controlled trial
Noise (n= 3)		
#Walsh <i>et.al</i> (2006)	USA	Descriptive cohort (quantitative)
#Domanico <i>et.al</i> (2010)	USA	Prospective comparative
Kruger <i>et.al</i> (2007)	USA	Before and after (quantitative)
Chen <i>et.al</i> (2009)	Taiwan	Prospective comparative
Workload and Communication (n=5)		
#Cone <i>et.al</i> (2010)	USA	Cross sectional survey
#Walsh <i>et al.</i> (2006)	USA	Descriptive cohort (quantitative)
Shepley <i>et.al</i> (2008)	USA	Prospective comparative
Smith <i>et.al</i> (2009)	USA	Before and after (quantitative)
Carlson <i>et.al</i> (2006)	USA	Before and after (qualitative)
Privacy and Comfort (n=4)		
#Carter <i>et.al</i> (2008)	USA	Descriptive cohort (quantitative)
Beck <i>et.al</i> (2009)	Denmark	Qualitative
#Carlson <i>et.al</i> (2006)	USA	Before and after (qualitative)

These studies addressed more than one outcome category and so are included more than once in the Table