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Original Article

Reduced nosocomial infection rate in a neonatal intensive care unit during a 4-year surveillance period

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Abstract

Background: Hospital-acquired infections are a leading cause of morbidity and mortality in neonatal intensive care units (NICU). The aim of the study was to investigate the change of nosocomial infection rate in a NICU during a 4-year surveillance period.
Methods: We investigated the changes in nosocomial infection rates, infection sites, and microorganism species in a NICU before and after the unit was moved to a new location, extending from November 2008 to October 2012.The new facility was opened on November 1, 2010 and the old NICU was closed on the same day. In the meantime, three catheter-based bundles were implemented in the new NICU and all intensive care units in our hospital due to the new policy. Data collection was performed by independent, experienced infection control nurses.
Results: A total of 512 neonates were admitted to the NICU and enrolled in this study. There were 242 infants who were admitted to the old NICU, and 270 infants in the new facility. During the study period, the rate of infection episodes decreased from 19.0% to 11.1% ($P = 0.01$). Additionally, the average hospital-acquired infection rate decreased from 6.26 cases per 1000 patient-days to 4.09 cases per 1000 patient-days ($P = 0.03$). The most common infection site was blood stream infection, which decreased from 8.3% to 3.7% ($P = 0.03$). The total catheter-related infection rates of the blood stream, lower respiratory tract, and urinary tract decreased from 13.6% to 5.9% ($P = 0.003$). *Klebsiella pneumonia, E. coli*, Methicillin-resistant *Staphylococcus aureus* (MRSA), and Coagulase-negative Staphylococci (CoNS) were the most frequently found pathogens in the old NICU, whereas MRSA, CoNS, *E. faecalis,* and *A. baumannii* were the most frequently found pathogens in the new NICU.
Conclusion: The change in the environment and implementation of device bundles in the NICU might be associated with the nosocomial infection rate.

Keywords: Cross Infection; Environment; Intensive care units; Neonatal; Patient care bundles

1. Introduction

Critically ill infants who receive care in a neonatal intensive care unit (NICU) are at an increased risk of nosocomial infection due to immunological immaturity and a host of invasive diagnostic and therapeutic procedures.[1] Prior surveillance studies have shown that the rates of nosocomial infection in NICUs range from 8.7% to 74.3%.[2–6] In fact, a

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rate of 17.5% was reported in a tertiary hospital in Taiwan.[7] In spite of the use of various infection control strategies such as prophylactic antibiotics, immunoglobulins, and physical barriers,[4] the prevalence of nosocomial infections in NICUs still remains high. For several decades, there has been controversy over whether or not the inanimate environment of a NICU is associated with the risk of nosocomial infection, but there have been scant few studies on this issue.[6,8–11] Furthermore, the Institute for Healthcare Improvement recently developed the concept of "bundles" to help health care providers more reliably deliver the best possible care for patients undergoing particular treatments with inherent risks.[12–15] However, limited information is available on bundle care in neonates. Herein, we compared the nosocomial infection rates and the change of microorganisms in a tertiary NICU before and after the unit was moved to a new location. Catheter care bundle strategies were introduced to the new unit.

2. Methods

2.1. Study design

This study was conducted in the tertiary-level NICU of Taichung Veterans General Hospital (TCVGH), Taiwan. The old NICU was located on the fifth floor of a ten-year-old eleven-story building. It had a total of 14 infant beds and admitted an average of 130 infants each year. Most of the neonates in the NCIU were born in our delivery room, and a few of the neonates were referred from nearby obstetric clinics. A new unit located in a new facility on the same floor was constructed in the autumn of 2010. There were no differences in the total number of beds, the number of hand-washing facilities, the frequency of alcohol-based hand rubs, the number of non-contaminated trash containers, posters illustrating hand-washing instructions, and the ratio of nurses to patients (Table 1) between the two units. In the new unit, the distance between beds was decreased from 3.6 m to 3.0 m and the number of isolation rooms was reduced due to the limitation of space in the new unit (Table 1). The new facility was opened on November 1, 2010 and the old NICU was closed on the same day. Three catheter-based bundles were implemented in the new NICU due to the new policy for all intensive care units in our hospital; the central line bundle, the ventilator bundle, and the urinary tract bundle (Table 2). The primary purpose of the bundles was to prevent central line-associated blood stream infection, ventilator-associated pneumonia, and foley-associated urinary tract infection. According to the Institute of Healthcare Improvement, the definition of a bundle is "a small, straightforward set of evidence-based practices—generally three to five—that, when performed collectively and reliably, have been proven to improve patient outcomes".[16]

Table 1
Comparison of clinical setting in the old and the new Units.

Items	Old Unit	New Unit
Time of survey	2008/Nov.–2010/Oct.	2010/Nov.–2012/Oct.
Total beds	14 beds	14 beds
Ratio of nurse/patient	1/2–3	1/2–3
Distance between beds	3.6 m	3.0 m
Hand-washing facilities/beds	1/1	1/1
Figure of hand-washing steps/beds	1/1	1/1
Alcohol-based handrub/beds	1/1	1/1
Infected and non-infected trash cans/beds	One pair/1	One pair/1
Isolated rooms	2	1
Implementation device bundles care[a]	No	Yes

[a] Implementation three bundles care; central line bundle, ventilator bundle and urine tract bundle, in the new unit since Jan 1, 2011.

2.2. Measurements and data collection

An infection control monitoring sheet was designed to monitor every episode of nosocomial infection, infection site, and microorganism species in the study period. The sheet included such information as demographic data, use of invasive catheters, including central venous catheter, umbilical artery line, umbilical venous line, endotracheal tube and Foley, wound site, culture type, date of collection, and microorganism species. Data collection was performed by independent, experienced infection control nurses for 24 months before and after the NICU was moved to the new unit. The set of definitions proposed by the Centers for Disease Control and Prevention (CDC) in 1988 was adopted as the standard case definition.[17] Infections occurring after 72 h of hospital stay were assumed to be hospital-acquired; those resulting from passage through the birth canal or from transplacental

Table 2
The elements of catheter bundles.

Items	Bundle elements
General practices	1 Staff education (a routine part of staff induction)
	2 Hand Hygiene
	3 Bundle care checklist
	4 Review catheter necessity daily and remove promptly when indications are no longer met
Central line	1 Maximal sterile barrier precautions upon insertion
	2 Antiseptic skin preparation
	3 Sterile transparent semipermeable dressing or sterile gauze
	4 Daily evaluation of catheter insertion site
	5 Maintaining closed system
	6 Aseptic technique when changing intravenous tubing
Ventilator	1 Elevate the head of the bed
	2 Mouth care with normal saline and suction of oro-pharyngeal secretion
	3 Daily sedation vacation for sedated infant
	4 Sterile suction and handling of respiratory equipment
	5 Drain condensation from ventilator circuit
Urinary tract	1 Sterile technique during insertion
	2 The use of securing devices to prevent the movement of the catheter after its insertion
	3 Maintaining closed system
	4 Collection bag always lower than patient especially during transport

transmission were excluded. No environmental culture was performed. The isolation and identification of all microorganisms were performed by the Department of Pathology and Laboratory Medicine of TCVGH, which received laboratory accreditation from the College of American Pathologists in 2008.

2.3. Ethical considerations

The study was approved by the Research Ethics Committee of TC-VGH and the number was TC-VGH CF 13207.

2.4. Data analysis

Data were analyzed by descriptive and inferential statistics tests using SPSS 22.0 for Windows. Descriptive statistics were used to calculate infection rates, infective sites and the number of microorganism species. The Chi-square test of inferential statistics was used to compare demographic data between the two groups, and a two-sample *t*-test was used to compare infection rates between the old and new buildings. A *P* value below 0.05 was considered statistically significant.

3. Results

From November 1, 2008 to October 31, 2012, data were collected from the NICU of TCVGH. A total of 512 neonates were admitted to the NICU and enrolled in this study, with a male/female ratio of 1 to 0.91, respectively. Two hundred and forty-two neonates were admitted to the old NICU from November 1, 2008 to October 31, 2010, and 270 neonates spent time in the new facility from November 1, 2010 to October 31, 2012 (Table 3). The mean birth body weight of neonates was 1827 g in the old NICU group and 1798 g in the new NICU group, respectively. The most common gestational age was less than 32 weeks in both groups. The average hospital stay was 27.53 days in the old NICU and 25.82 days in the new NICU. There were no significant differences in gender ratio, gestational age, birth body weight, and the length of hospitalization between the two groups (Table 3).

Table 3
Baseline demographic data between old and new Units.

Items	Old Unit N = 242 (100%)	New Unit N = 270 (100%)	*P*
Gender			0.16
Male	127 (52.4)	141 (52.2)	
Female	115 (47.5)	129 (47.8)	
Gestational age (wks)			0.21
≦32	81 (33.5)	82 (30.4)	
32^{+1}–34 wks	43 (17.8)	63 (23.3)	
34^{+1}–37 wks	74 (30.6)	73 (27.0)	
>37 wks	44 (18.2)	52 (19.3)	
Birth body weight (g)			0.27
500–999	23 (9.5)	25 (9.3)	
1000–1999	105 (43.4)	103 (38.1)	
≧2000	114 (47.1)	142 (52.6)	
Mean length of hospitalization days	27.53 days	25.82 days	0.77

There were 46 episodes of definitive nosocomial infection in the old NICU group and 30 in the new NICU group (Table 4). There was no outbreak during the study period, based on the CDC definition of nosocomial infection outbreak.[17] The rate of nosocomial infection episodes decreased from 19.0% (46/242) to 11.1% (30/270) ($P = 0.01$). The average infection rate decreased from 6.26 cases per 1000 patient-days in the old NICU to 4.09 cases per 1000 patient-days in the new NICU, which was a significant decrease ($P = 0.03$). The most common infection site was bloodstream in both groups, which decreased from 8.3% in the old NICU to 3.7% in the new NICU ($P = 0.03$). The total number of the bloodstream infections, lower respiratory tract infections, and urinary tract infections declined from 13.6% (33/242) in the old NICU to 5.9% (16/270) in the new NICU ($P = 0.003$).

A total of 46 microorganism species in the old NICU group and 35 in the new NICU group were isolated, respectively.

Table 4
Comparison of infection rates, infection sites, and microorganisms species.

Items	Old Unit N = 242	New Unit N = 270	*P**
Infection incidence	6.26 (cases per 1000 patient-days)	4.09 (cases per 1000 patient-days)	0.03*
Infection sites (infection rate#)	46 (19.0%)	30 (11.1%)	0.01*
Blood stream	20 (8.3%)	10 (3.7%)	0.03*
Lower respiratory tract	9 (3.7%)	4 (1.5%)	0.11
Urinary tract	4 (1.7%)	2 (0.7%)	0.34
Gastrointestinal tract**	5 (2.1%)	5 (1.9%)	0.86
Eyes	4 (1.7%)	5 (1.9%)	0.86
Skin***	4 (1.7%)	4 (1.5%)	0.88
Catheters related infections!	33 (13.6%)	16 (5.9%)	0.003*
Microorganisms species	46 (19.0%)	35 (12.9%)	0.06
Gram stain positive bacteria	17 (7.0%)	16 (5.9%)	0.61
MRSA	5 (2.1%)	5 (1.9%)	0.86
S. epidermidis	3 (1.2%)	–	
CoNS	5 (2.1%)	4 (1.5%)	0.62
V. streptococci	1 (0.4%)	1 (0.4%)	0.86
E. faecalis	2 (0.8%)	4 (1.5%)	0.49
E. faecium	1 (0.4%)	2 (0.8%)	0.86
Gram stain negative bacteria	25 (10.3%)	16 (5.9%)	0.07
E. coli	6 (2.5%)	2 (0.7%)	0.11
K. pneumonia	11 (4.6%)	2 (0.7%)	0.01*
K. oxytoca	1 (0.4%)	–	
P. aeruginosa	–	3 (1.1%)	
A. baumannii	2 (0.8%)	4 (1.5%)	0.49
E. cloacae	3 (1.2%)	1 (0.4%)	0.27
S. marcescens	1 (0.4%)	2 (0.7%)	0.63
S. maltophilia	1 (0.4%)	1 (0.4%)	0.86
Burkholderia cepacia complex	–	1 (0.4%)	
C. parapsilosis	4 (1.7%)	–	
C. koseri	–	1 (0.4%)	
C. glabrata	–	2 (0.7%)	

*statistically significant difference, $P < 0.05$; # cases/the total number of patients; ! include blood stream, lower respiratory tract, and urinary tract infection; ** gastrointestinal tract infection such as peritonitis, necrotizing enterocolitis; *** including skin infections over umbilical cord area, and surgical wound area; MRSA: Methicillin-resistant *Staphylococcus aureus;* CoNS: Coagulase-negative Staphylococci.

Klebsiella pneumoniae was the most frequent pathogen in the old NICU group (Table 4), followed by *E. coli*, Methicillin-resistant *Staphylococcus aureus* (MRSA), Coagulase-negative Staphylococci (CoNS), *C. parapsilosis*, *S. epidermidis*, and *E. cloacae*. Methicillin-resistant *Staphylococcus aureus* was the most common pathogen in the new NICU group followed by CoNS, *E. faecalis*, *A. baumannii*, *P. aeruginosa*, *E. faecium*, *E. coli*, and *K. pneumonia* (Table 4). There was no statistically significant difference in the total number of microorganism species in both groups except *K. pneumoniae*. The infection rate of *K. pneumoniae* declined from 4.6% in the old NICU to 0.7% in the new NICU ($P = 0.01$). The most frequent microorganism species isolated from the blood stream was *K. pneumonia*e (30%, 6/20) in the old NICU group, followed by *E. coli* (15%), *C. koseri* (10%), MRSA (10%), CoNS (10%).*A. baumannii* (20%, 2/10), *P. aeruginosa* (20%), were the two most common pathogens isolated from the blood stream in the new NICU group followed by CoNS (10%), MRSA (10%), *E. faecalis* (10%), and *K. pneumoniae* (10%).

4. Discussion

The influence of the inanimate NICU environment and facilities on nosocomial infection has been the focus of discussion in recent years. Many factors have been linked to nosocomial infection in NICU patients, including understaffing, overcrowding, and poor access to sinks or wash basins; however, controversy exists as to whether or not the inanimate environment of the NICU has an influence on nosocomial infection.[6,8–11] Maki et al. reported that the inanimate hospital environment was thought to contribute only negligibly to endemic nosocomial infection.[11] In a four-year study, Von Dolinger de Brito et al. stated that the rate of nosocomial infection rose significantly after patients were moved to a temporary unit, which had a lower sink or wash basin to cot ratio and a higher monthly admission rate.[10]

The relocation of a NICU to a better-staffed facility with more space between beds, sinks or wash basins and isolation facilities was associated with a decrease in the infection rate.[6,9] The new NICU of our hospital was designed according to the guidelines recommended by regulatory and professional bodies for nursery design in terms of adequate space for preterm infants, better facilities, and an adequate number of wash basins (Table 1). In this study, the average rate of nosocomial infection decreased from 6.26 cases per 1000 patient-days in the old NICU to 4.09 cases per 1000 patient-days in the new NICU ($P = 0.03$). The rate of infection episodes decreased from 19.0% (46/242) to 11.1% (30/270) ($P = 0.01$).

Catheter-related infections are common nosocomial infections in an intensive care unit. Nosocomial infections of the bloodstream, lower respiratory tract, and urinary tract are closely associated with catheter insertion. In our study, bloodstream infection was the most common infection site in both NICUs, followed by lower respiratory tract and urinary tract infection, as shown in a previous study.[18] A bundle is a small group of specific care practices each essential for providing effective and safe patient care to a defined group of patients.[12] Significantly improved outcomes are expected to result from applying the combination of care practices and have been shown to reduce the rate of central line-associated bloodstream infections,[15] catheter-associated urinary tract infections,[19] and ventilator-associated pneumonia in children.[16]

Catheter-related bundle care was implemented in our new NICU on January 1, 2011 due to the new policy of whole intensive care units in our hospital. We did not analyze the true catheter-associated infection rate, but the total numbers of bloodstream infections, lower respiratory tract infections, and urinary tract infections declined from 13.6% (33/242) in the old NICU down to 5.9% (16/270) in the new NICU with bundle care practices ($P = 0.003$) (Table 4). Of particular note was the decrease in bloodstream infections from 8.3% in the old NICU to 3.7% in the new NICU ($P = 0.03$). The cases of nosocomial infections from the lower respiratory tract and the urinary tract were also reduced to half of the reduced ratio as the blood stream infection (Table 4).The reason the infection rates in the lower respiratory tract and the urinary tract did not reflect the statistical decrease might be attributed to the few cases in both groups. The other sites of nosocomial infections included the gastrointestinal tract, eyes, and skin, and these non-catheter-associated infections showed no statistically significant difference between the two groups. We could not clarify the exact reason for the decrease in incidence and rate of nosocomial infection from this study because of the replacement to a new facility and implementation of device bundles to the new NICU at the same time. The type of management implemented in the old and new facilities might play a role in the decrease of the incidence of nosocomial infection in this study.

Most infants in NICUs are hospitalized continuously from birth, and MRSA infections are largely considered to be horizontally transmitted.[20–23] Various studies had reported that viable MRSA can be found on the hands of up to 17% of healthcare workers, and on 59% of the environmental surfaces in rooms of patients with diarrhea.[24] A significant increase in *Staphylococcus aureus*, the appearance of *Pseudomonas aeruginosa*, and changes among species of Gram-negative bacilli were observed 8–11 months after a new building had been opened.[25] In this study, MRSA and CoNS were the major gram positive pathogens in both NICUs, but there was no statistically significant difference between the two groups. The fact is that the new environment did not reduce infection rate of MRSA and CoNS, which might be explained by the long period of the study (2 years) or healthworker factors,[26–28] and the low incidence or cases of nosocomial infection. We found that *Klebesiella pneumonia* was the most frequently isolated organism in the old NICU group and the Gram-negative bacteria were the predominant organisms. The result was the same with studies in Egypt and Turkey,[2,3,6] even in the tertiary NICU that just moved to a new building.[6] The microorganism species *K. pneumonia* significantly declined from 4.6% in the old NICU to 0.7% in the new NICU ($P = 0.01$). In general, the new environment might affect the change of Gram-positive microorganism infections and catheter-related bundle care

might affect the infections caused by Gram-negative pathogens.[16,21,28] The decrease of the infection rates of *K. pneumoniae* and blood stream infection might be more influenced by the factor of implementation of device bundles than the new environment in our study, due to the difference and change of microorganisms in both groups.

4.1. limitations

There were a number of limitations in this study. First, we did not conduct a clinical presentation analysis of the neonates. Second, surveillance of environmental bacteria was not performed. Third, we did not conduct a multiple factors survey. Larger cohort studies are needed to confirm the findings of this study.

In conclusion, our study revealed that infection control was a significant problem in the NICU. The change of the environment and the implementation of device bundles care might be associated with the nosocomial infection rate in a NICU.

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