Impact of relocation and environmental cleaning on reducing the incidence of healthcare-associated infection in NICU

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Background: **Hospital environment remains a risk for healthcare-associated infections (HAIs). This was a prospective study to evaluate the comprehensive impact of relocating a neonatal intensive care unit (NICU) to a new facility and improved environmental cleaning practice on the presence of methicillin-resistant *Staphylococcus aureus* (MRSA) on inanimate surfaces and the incident rate of HAIs.**

Methods: **New environmental cleaning measures were adopted after the NICU was moved to a new and better-designed location. The effect of moving and the new environmental cleaning practice was investigated by comparing the positive number of MRSA on ward surfaces and the incidence density of HAIs between the baseline and intervention periods.**

Results: **Only 2.5% of environmental surfaces were positive for MRSA in the intervention period compared to 44.0% in the baseline period ($P<0.001$). Likewise, the total incident rate of HAIs declined from 16.8 per 1000 cot-days to 10.0 per 1000 cot-days ($P<0.001$).**

Conclusion: **The comprehensive measures of relocating the NICU to a new facility design with improved environmental cleaning practice are effective and significantly reduce the incidence of HAIs.**

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Key words: **environmental cleaning; intervention; healthcare-associated infections; methicillin-resistant *Staphylococcus aureus***

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Introduction

Healthcare-associated infections (HAIs) are infections that patients acquire after receiving treatment for anther condition, and are not present at the time of admission.[1] HAIs remain a major cause of neonatal morbidity and mortality in neonatal intensive care units (NICUs).[2,3] Although it happens frequently among inpatients, approximately 30% of HAIs are preventable by particular health control measures.[4] To date, some related measures such as rational administration of antibiotics, control of hospital environmental sanitation and close monitoring of medical equipment have been proved closely associated with the decreased rate of HAIs.[5-7] A number of factors have been reported to contribute to the occurrence of HAIs, among which contamination of environmental surfaces in hospital rooms plays an important role in the transmission of several important healthcare-associated pathogens, such as methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus spp*. (VRE).[8,9] Therefore, effective control of HAIs in NICU is of utmost importance as critically ill newborns in NICU are subject to increased risks of HAIs due to immunological immaturity and a host of invasive diagnostic and therapeutic procedures.[10]

Environmental surfaces with hand contact are often contaminated with healthcare-associated pathogens and may serve as vectors for cross transmission.[9] Meanwhile, the therapeutic options of HAIs are limited due to the resistance of healthcare-associated pathogens to multiantibiotics.[11] Fortunately, improved hospital environment cleaning is attributable to a lower rate of HAIs; and Donskey et al[12] summarized a variety of interventions that are effective in improving the cleaning and disinfection of hospital room surfaces.

Our hospital relocated our NICU from an old building

to a new one in January, 2012. Thereafter a new set of environmental cleaning practices have been implemented. The aim of this study was to evaluate the comprehensive impact of relocation of the ward to a new facility and the changed environmental cleaning practices on reducing MRSA on inanimate surfaces and the incident rate of HAIs during this five-year period.

Methods

This study was conducted in the NICU of Women's Hospital, Zhejiang University School of Medicine. The old NICU had 45 cots with two open bays and one isolation room whereas the new NICU had 60 cots with four open bays and one isolation room.

We performed this five-year prospective study evaluating the impact of an environmental cleaning intervention. Surveillance was performed over two different periods: baseline period in the old NICU between January 2009 and December 2011; intervention period in the new NICU from January 2012 and December 2013.

During the baseline period, daily routine cleaning was performed by environmental service workers (ESWs) twice a day. A cotton cloth and bucket system was historically used. The same cloth was used for all high-touch patient care areas, patient-shared items, and common zones in one open bay. The cloth was washed in the bucket by hand when it was visibly contaminated or was to be used for the next cot. The water with detergent in the bucket was changed only when moving between two different bays. Routine disinfection of surfaces using a household bleach dilution (200 mg/L) was carried out once a day after daily cleaning. At the end of each working day, cloths and buckets were immersed in a 1:50 dilution of 5% household bleach (1000 mg/L) for 5 to 10 minutes, rinsed in tap water and air dried.

During the intervention period, daily routine cleaning was still carried out twice a day, but color-coded microfiber cloths replaced the cotton cloths. One microfiber cloth was used for one patient zone or one item only. The cloth was replaced by another one when it was visibly contaminated or used between different cots. One hour after morning cleaning, daily routine environmental disinfection was performed. Household bleach dilution (200 mg/L) was continued to be used for all floors. Disinfectant wet wipes, which were first introduced in the routine disinfection practice in our city, were used for other environmental surfaces including cot and incubator, monitor, Syringe pumps, cart and so on. Cloths and detachable mops were washed in a commercial washing machine at 90°C for 10 minutes. All were dried by hot air in the machine for 60 minutes and re-used within 24 hours. ESWs were trained for the new procedure of environment cleaning practice and for the cleaning method regarding re-usable items. One or two disinfectant wipes were used for each patient zone once a day. This disposable wipes were also used for isolation rooms and discharge cots. In the present study, the intervention did not include hand hygiene compliance and antibiotics stewardship, and data on hand product consumption were analyzed. The team of physicians, nurses and ESWs were the same between the two investigating periods. Table 1 compares the environmental cleaning measures between the two periods.

MRSA was the target bacterium in this study. Sterile swabs with traditional fiber tips wrapped by traditional fiber (COPAN, 167KS01, Italy) were moistened in sterile saline immediately before use. Swabs were moved three times over the environmental surfaces of patient zone, including cot rails, stethoscope, infant incubator, monitor, syringe pumps, and drawer handles. The swabs were inoculated at the point of collection on CHROMagarTM MRSA (CHROMagar, France), a chromogenic medium for MRSA detection, and incubated at 37°C for 24 hours.

The suspected purple colonies on CHROMagar plates were cultured in nutrient bouillon for 24 hours, and DNA were extracted by commercial kit (TaKaRa, Japan) as per the manufacturer's instructions. According to researches,[13,14] the PCR primers for *nuc* gene and *mecA* gene were detected.

HAIs were defined by clinical symptoms and positive laboratory test results according to the Chinese Diagnostic Criteria for Nosocomial Infection (draft version, 2001).[15] The incidence density of infection rates, including patient, patient-day, peripherally inserted central venous catheter (PICC) and ventilator-associated pneumonia (VAP) were collected by quarters. Consumption of products for hand hygiene was calculated as per 1000 cot-days in two NICUs.

Dichotomous variables were analyzed by using Chi-squared tests or Fisher's exact test. Data with normal distribution was described as mean and 95% confidence interval and analyzed by independent-samples *t* test.

Table 1. Comparison of environmental cleaning measures in old and new neontal intensive care unit (NICU)

Characteristics	Old NICU	New NICU
Cleaning cloths used	Thecotton cloths	Themicrofiber cloths
Whether change the cleaning cloths per cot	No	Yes
Washing methods of cloths	By hand	By washing machine
Drying methods of cloths	Air dried	Hot dried
Whether ESWs were trained	No	Yes
The use of disinfectant wet wipes		
Cot and incubator	No	Yes
Monitor	No	Yes
Syringe pumps	No	Yes
Cart	No	Yes
Isolation rooms	No	Yes

ESWs: enviromental service workers.

Time series analysis was used to for time series data. Statistical significance was defined by a *P* value of less than 0.05. The study was approved by the Research Ethics Board at Women's Hospital School of Medicine Zhejiang University.

Results

The new NICU was better-designed, with high efficiency particle arrestor central air conditioning and a larger floor areas than the old NICU (324.8 m^2 *vs.* 219.2 m^2) and the mean cot:area rose from 4.9 m^2 to 5.4 m^2. In the new NICU, three sinks were installed at the entrance of open bay with paper towels and automated faucets. The ratio of sink:cot was 1:3.3 in new NICU compared to 1:15 in old NICU. Table 2 summarizes the major differences between the old and new NICUs, which includes a rise in occupancy from 92.7% to 98.2%.

A total of 44 (44.0%) of 100 environmental surface samples were positive for MRSA in baseline period, whereas 20 (2.5%) of 800 samples were identified with MRSA in the intervention period (*P*<0.001). Recovery rate of MRSA ranged from 0.0% to 7.0% in the new NICU quarterly. The MRSA colonization rate has no significant difference between the old NICU and new NICUs (7.14% *vs.* 5.13%, *P*=0.707).

The overall mean length of stay was 8.2 days and 8.0 days in old and new NICUs, respectively (*P*>0.999). A total of 511 episodes of HAIs occurred in 3733 neonates among 30 452 cot-days in baseline period, compared to 432 episodes of HAIs in 5415 neonates among 43 012 cot-days in intervention period. A significant decline in the incidence density of HAIs was observed (*P*<0.001). Specifically, the infection rate caused by MRSA dropped sharply from 3.3 per 1000 cot-days to 0.8 per 1000 cot-days (*P*<0.001). The incidence density of VAP decreased from 5.4 per 1000 ventilator-days to 2.6 per 1000 ventilator-days (*P*=0.002). However, the incidence density of PICC-related infection increased from 3.4 per 1000 PICC-days to 7.5 per 1000 PICC-days (*P*=0.019). The Fig. shows the sequence chart of infection rate of HAI, PICC and VAP by quarter.

Table 2. Comparison of characteristics of two neonatal intensive care units (NICUs)

Characteristics	Old NICU	New NICU
Room number	3	5
Floor areas (m^2)	219.2	324.8
Cot number	45	60
Cot utilization rate (%)	92.7	98.2
Occupied area per cot (m^2)	4.9	5.4
Nurse:cot ratio	1:1.1	1:1.2
Sink:cot ratio	1:15	1:3.3
Consumption of liquid soap (L/1000 cot-days)	20.9	23.5
Consumption of alcohol rubs (L/1000 cot-days)	17.5	15.5
Consumption of paper towel (box/1000 cot-days)	0.15	0.14

Discussion

The cleanliness of any hospital environment is important for infection control and patient well-being. Various studies have demonstrated the impact of improved environmental cleaning and disinfection on HAIs.[12,16,17] Likewise, our study found the cleaning intervention reduced the MRSA positive rate on ward surfaces significantly from 44% to 2.5% and subsequently, the total incidence density of HAIs

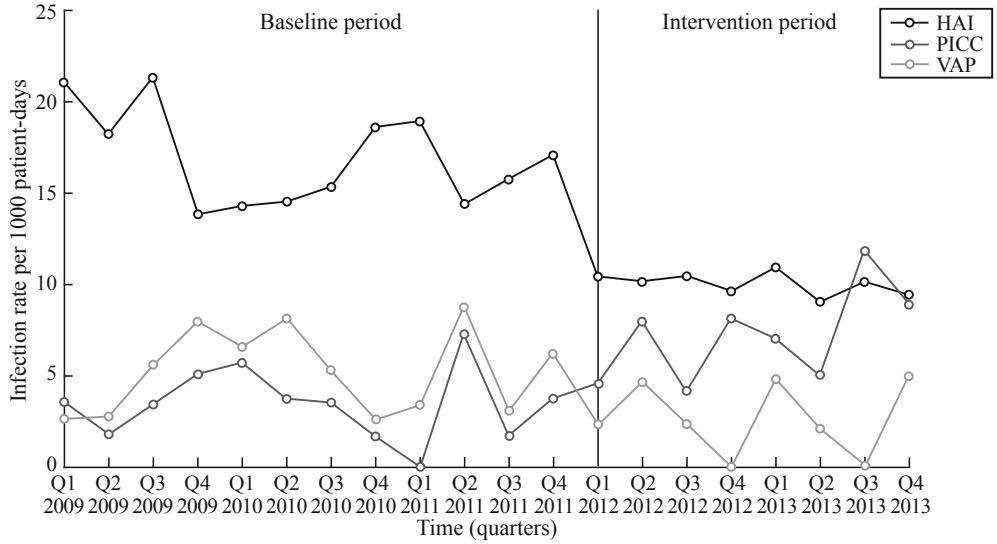

Fig. Infection rate of HAI, PICC and VAP per 1000 patient-days. HAI: healthcare-associated infection; PICC: peripherally inserted central venous catheter; VAP: ventilator-associated pneumonia; Q: quarter.

declined from 16.8 per 1000 cot-days during baseline period to 10.0 per 1000 cot-days during intervention period.

Best practices for cleaning and disinfection of surfaces have been widely reviewed in the literature.[8,18] One study revealed that enhanced ICU cleaning using the intervention methods may reduce MRSA and VRE transmission and the risk of MRSA acquisition due to an MRSA-positive prior room occupant.[19] However, a randomized crossover study carried out in the ICU of two hospitals showed that enhanced cleaning reduced environmental contamination and hand carriage, but no significant effect was observed on patient acquisition of MRSA.[20] On the other hand, Tekin et al[5,6] indicated that MRSA constitutes a low percentage of the causative agents. Besides, Aktar et al[7] revealed that the incidence of *Staphylococcus aureus* infections was declining rapidly in Turkish ICUs, with potential impacts on empirical treatment strategies.

In our study, environmental cleaning interventions focused on three aspects. Firstly, a "cleaning unit" was introduced in order to avoid cross-contamination, One cloth was used only for one patient zone or one item in the new NICU instead of using one cloth for one open bay containing several patient zones in the old NICU. Secondly, disinfectant wet wipes were applied in intervention period. The active ingredient in the disinfectant wipes was quaternary ammonium compound, which had excellent sustained activity against VRE and *Pseudomonas aeruginosa* for up to 48 hours after application.[21] There is also evidence that single-use wipes are more effective. Wiemken et al[22] compared the value of ready-to-use cleaning and disinfection wipes to the traditional towel and bucket method, and found compliance to be significantly higher and a more rapid cleaning and disinfection process when using ready-to-use, disposable wipes. Finally, washing machine was used for re-used cloths and detachable mops to assure the effectiveness of cleaning. A recent study showed that washing textiles at 70°C for 15 minutes followed by tumble drying at 78°C for 22 minutes reduced the bacterial numbers by up to 9 log 10 CFU.[23] Cleaning and disinfection in automatic machine with robust validation of the process is considered an effective and safe method to reprocess reusable cloths and mops and is most recommended to hospitals, but the in-use of the same cloth in multiple areas is not suggested. Unfortunately, the bucket-based cloth-washing was still popular in the mainland China currently.

Facility design change is another focus to lower HAIs. Vietri et al[24] found that radical facility design changes, which would be permissive of optimal infection control practices, were not sufficient, by themselves, to reduce the nosocomial spread of MRSA in their institution. Fahed et al[25] also found that moving a medial ICU to a newly constructed and geographically relocated, with optimal infection control measures, might result in a decreased incidence of nosocomial infections because new fixtures and surfaces may be much easier to clean as they are intact and undamaged.

In our present study, the intervention did not include hand hygiene compliance and antibiotics stewardship; however, there were some interesting findings. The ratio of sink:cot was markedly increased, from 1:15 in old NICU to 1:3.3 in the new NICU, but there was no difference on consumption of liquid soap, alcohol rubs and paper towel between the baseline and intervention periods, suggesting that increasing the availability of facilities for hand hygiene did not increase the performance. The total hand hygiene products (liquid soap and alcohol rubs) consumed was 39.0 L/1000 cot-days in the new NICU, which was almost equal to that in the old NICU (38.4 L/1000 cot-days). Therefore, improved environmental cleaning practice, other than hand hygiene compliance, mainly contributes to the decrease of HAIs in our study.

PICC treatment has been involved with potential risks such as catheter mechanical complications and nosocomial sepsis in very low birth weight and extremely low birth weight infants.[26] We found increased PICC infection rate in the new NICU. This may be related to other factors such as antiseptic for skin preparation or practice issues. Povidone-iodine solution was used in this NICU at the time of the study; but 20 years ago, Garland et al[27] found that 0.5% chlorhexidine gluconate in 70% isopropyl alcohol appeared to be more efficacious than 10% povidone-iodine for the prevention of PICC in neonates. In addition, Chaiyakunapruk et al[28] performed a meta-analysis and suggested that the incidence of blood-stream infections was significantly reduced in patients with central vascular lines who received chlorhexidine gluconate versus povidone-iodine solution for insertion-site skin disinfection.

Several limitations must be taken into account in this study. Firstly, molecular epidemiological relationship of MRSA from environmental surfaces and patients were not analyzed. Secondly, the present study design would not allow us to evaluate the effect of each aspect of environmental cleaning intervention individually and determine whether any intervention was more effective than the others; however, the bundle principle is to introduce a series of measures, which are effective. Thirdly, improvement in surface condition may have caused the surfaces to be cleaned more effectively and lastly, the relocation of the ward to a new building may have increased the motivation of ESWs to keep a new unit clean and thus improve the effectiveness of cleaning.

In conclusion, moving the NICU to a new location with better design and more convenient facilities for hand

hygiene is likely to be beneficial for nosocomial infection control. Applying a bundle of environmental control measures, including working on "cleaning unit" during routine cleaning, using disinfectant wet wipes and introducing a washing machine with validation for re-used cloths and mops, was effective and may contribute towards a decline in environmental bioburden and a decrease in healthcare-associated infections.

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