ARTICLE

# Impact of Staffing on Bloodstream Infections in the Neonatal Intensive Care Unit

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**Objective:** To examine the association between registered nurse staffing and healthcare-associated bloodstream infections in infants in the neonatal intensive care unit (NICU).

**Design:** Prospective cohort study.

**Setting:** Two level III-IV NICUs in New York, NY, from March 1, 2001, through January 31, 2003.

**Participants:** A total of 2675 infants admitted to the NICUs for more than 48 hours and all registered nurses who worked in the same NICUs during the study period.

**Intervention:** Hours of care provided by registered nurses.

**Main Outcome Measure:** Time to first episode of healthcare-associated bloodstream infection.

**Results:** A total of 224 infants had an infection that met the study definition of healthcare-associated bloodstream infection. In a multivariate analysis, after controlling for infants' intrinsic and extrinsic risk factors, a greater number of hours of care provided by registered nurses in NICU 2 was associated with a decreased risk of bloodstream infection in these infants (hazard ratio, 0.21; 95% confidence interval, 0.06-0.79).

**Conclusion:** Our findings suggest that registered nurse staffing is associated with the risk of bloodstream infection in infants in the NICU.

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HEALTHCARE-ASSOCIATED infections are a significant cause of morbidity and mortality among infants in the neonatal intensive care unit (NICU).[1,2] Infants hospitalized in the NICU have the highest rates of healthcare-associated infection among the pediatric population, with infection rates ranging from 6 to more than 30 infections per 100 patient discharges.[3] Among infants in the NICU, the bloodstream is the most common site of healthcare-associated infection in all birth weight groups.[4]

Evidence of a significant association between nurse staffing and adverse patient outcomes has been reported.[5-7] However, to date only a few studies have examined the association between nurse staffing and healthcare-associated infections in infants.[8-11] Furthermore, no prospective studies, to our knowledge, have specifically examined the association between nurse staffing and bloodstream infections in the NICU. This study examined the association between registered nurse staffing and bloodstream infections among infants in the NICU.

## METHODS

### DESIGN

This cohort study used data collected as part of a larger clinical trial to assess the effects of 2 hand hygiene regimens on healthcare-associated infections in infants in the NICU.[12] The study used a randomly assigned crossover design in which either a traditional antiseptic soap containing 2% chlorhexidine gluconate or a waterless hand rinse containing 61% ethyl alcohol was used by all staff and visitors sequentially for half of the study period (11 months for each product).

### SAMPLE AND SETTING

The study was conducted in 2 level III-IV NICUs located in New York, NY. Both NICU 1 (43 beds) and NICU 2 (50 beds) are affiliated with the New York–Presbyterian Hospital and provide specialized medical treatment to severely compromised infants. Data on nurse staffing were provided by the nurse staffing office of each NICU, and data were classified as follows: hours per day for full-time registered nurses, full-time other (ie, nurse managers), per-diem registered nurses, float registered nurses, and agency registered nurses. Staffing data were collected on all infants who were hos-



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pitalized in the NICU for more than 48 hours from March 1, 2001, through January 31, 2003. Institutional review board approval was obtained from the participating institutions.

## DATA COLLECTION

In this study, we examined only the first episode of healthcare-associated bloodstream infection. Data on bloodstream infections were collected by the study nurse epidemiologist, and the National Nosocomial Infection Surveillance System definitions were used.[13] Clinical data were obtained from infants' medical records, and laboratory, radiology, and pharmacy data were collected from the hospitals' computer information systems (ECLIPSYS; Eclipsys Corp, Boca Raton, Fla; WEBCIS; Columbia University Department of Informatics, New York; HealthQuest; McKesson Information Solutions, Alpharetta, Ga; and Eagle; Siemens AG, Munich, Germany). A computerized list of all blood cultures positive for organisms from infants was generated by the clinical microbiology laboratories and reviewed twice weekly by the nurse epidemiologist, who also made unit rounds at least once weekly.

Interrater agreement ($\kappa = 0.97$) regarding presence or absence of bloodstream infection was established by comparing data collected simultaneously by the study nurse epidemiologist and the hospital infection control staff for 3 months. Discrepancies regarding infection status were resolved by the consensus of 2 physician coinvestigators (including L.S.).

## RISK FACTORS

Four risk factors reported to be associated with bloodstream infection in infants were examined: birth weight,[14-17] intravascular catheterization,[16-19] major surgery,[20,21] and total parenteral nutrition.[17,19] Birth weight was stratified into 4 groups: less than 1000 g, 1000 to 1500 g, 1501 to 2500 g, and more than 2500 g. Catheters were classified as umbilical, tunneled (Hickman and Broviac), and peripherally inserted central. The performance of major surgery, defined as an operating room procedure other than circumcision or minor abdominal surgery,[22] was determined from the infant's diagnosis related group. Total parenteral nutrition was recorded as the number of days of total parenteral nutrition received before bloodstream infection, or on discharge in infants without a bloodstream infection.

Two additional variables were examined: (1) the hand hygiene product used by staff when each bloodstream infection was diagnosed and (2) registered nurse hours, defined as registered nurse care hours per infant per day. Registered nurse hours were adjusted for patient case mix based on diagnosis related group and nursing intensity weight as described elsewhere.[5-7,23] The 2001 nursing intensity weights, which reflect the amount of nursing care required for typical patients in each diagnosis related group, ranged from 1.96 to 32.40.

## DATA ANALYSIS

Continuous variables were presented as the mean and standard deviation and categorical variables were expressed as percentages. Infant characteristics were compared by $\chi^2$, Fisher exact, and unpaired *t* tests. Data from each day of each infant's admission were linked with the corresponding registered nurse staffing data (adjusted for case mix) for the same days before bloodstream infection or censoring (eg, death or discharged with no infection). The window of exposure was calculated as the mean of registered nurse hours from 48 to 144 hours before bloodstream infection.

A Cox proportional hazards regression model was used to identify risk factors associated with bloodstream infection. The proportional hazards assumption was validated both graphically and through fitting a discrete-time model as described by Allison.[24] Confounder selection was based on the criteria described by Mickey and Greenland[25]; variables significant ($P<.25$) in the preliminary analysis were included in the multivariate model. Intravascular catheterization, total parenteral nutrition, and registered nurse hours were modeled as time-dependent covariates.

In this analysis, the risk of bloodstream infection was modeled for each infant, and then parameter estimates of the covariates birth weight, intravascular catheterization, total parenteral nutrition, hand hygiene product, NICU site, and adjusted registered nurse hours were calculated for that same infant. If a neonate had more than one bloodstream infection, only the first was included in these analyses.

Because intravascular catheters in infants have been reported as a risk factor for bloodstream infection,[16-18] the incidence density was also defined as number of bloodstream infections per 1000 catheter days, as per National Nosocomial Infections Surveillance System protocol.[3] All calculations were performed with Stata release 9 statistical software (StataCorp LP, College Station, Tex).

# RESULTS

A total of 3155 admissions to the study NICU were recorded during the study period. After excluding infants who were admitted for 48 hours or less, the final sample included 2675 admissions. Of these, 224 infants (8.4%) had a total of 298 bloodstream infections. Coagulase-negative staphylococci (45.0%) were the most common pathogens, followed by gram-negative bacteria (23.2%), yeast (13.5%), *Staphylococcus aureus* (9.5%), and enterococci (7.7%). The incidence rate of bloodstream infection was 6.11 per 1000 patient days and 16.56 per 1000 catheter days. Of the 48 infant deaths that occurred during this study, 16 involved infants with a bloodstream infection.

## CHARACTERISTICS OF INFANTS

The characteristics of infants enrolled in this study are summarized in **Table 1**. Overall, 55.9% of the infants in this sample were male, their mean gestational age was 34.8 weeks (range, 23-42 weeks), and their mean birth weight was 2401 g (range, 428-5513 g). Overall, 309 infants (11.6%) had a birthweight of less than 1000 g; 330 (12.3%), 1000 to 1500 g; 812 (30.3%), 1501 to 2500 g; and 1224 (45.8%), greater than 2500 g. The length of stay before bloodstream infection ranged from 2 to 312 days (mean, 14.7 days). Central venous catheters were inserted in 1543 infants (57.6%): 783 (50.7%) were umbilical, 45 (2.9%) tunneled, and 715 (46.3%) peripherally inserted central catheters. In addition, 468 infants (17.5%) had major surgery and 1284 (48.0%) received total parenteral nutrition during their hospitalization.

## CHARACTERISTICS OF REGISTERED NURSE STAFFING

Nursing acuity and registered nurse hours are summarized in **Table 2**. Overall, the mean nursing acuity in the 2 NICUs was 5.3 (range, 2.04-32.4). The mean number of infants occupying beds in the NICUs was 37 (range, 21-49), and the mean number of registered nurse hours per infant per day was 10.8 (range, 7.3-15.0).



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**Table 1. Characteristics of Study Population by Neonatal Intensive Care Unit (NICU)***

| Characteristic | NICU 1 (n = 1550) | | NICU 2 (n = 1125) | |
|---|---|---|---|---|
| | No Infection | Infection | No Infection | Infection |
| No. (%) of infants | 1388 (89.5) | 162 (10.5) | 1063 (94.5) | 62 (5.5) |
| Birth weight, No. (%), g | | | | |
| <1000 | 134 (9.7) | 75 (46.3) | 66 (6.2) | 34 (54.8) |
| 1000-1500 | 153 (11.0) | 32 (19.8) | 131 (12.3) | 14 (22.6) |
| 1501-2500 | 433 (31.2) | 22 (13.6) | 349 (32.8) | 8 (12.9) |
| >2500 | 668 (48.1) | 33 (20.4) | 517 (48.6) | 6 (9.7) |
| Catheter, No. (%) | | | | |
| Umbilical | 394 (28.4) | 98 (60.5) | 253 (23.8) | 38 (61.3) |
| Tunneled | 18 (1.3) | 4 (2.5) | 15 (1.4) | 8 (12.9) |
| Peripherally inserted central | 372 (26.8) | 116 (71.6) | 178 (16.7) | 49 (79.0) |
| Catheter days, mean (SD) | 5.3 (11.4) | 16.4 (16.7)† | 3.8 (10.8) | 19.0 (13.5)† |
| Total parenteral nutrition, No. (%) | 823 (59.3) | 154 (95.1) | 200 (23.5) | 57 (91.9) |
| Total parenteral nutrition days, mean (SD) | 6.9 (20.0) | 15.0 (13.4)† | 3.0 (20.0) | 15.9 (13.4)† |
| Surgery, No. (%) | 305 (22.0) | 39 (24.1) | 111 (10.4) | 13 (21.0) |
| Length of stay, mean (SD), d | 12.8 (17.6) | 16.7 (13.3)† | 16.5 (17.6) | 23 (13.3)† |

*Because of rounding, percentages may not all total 100.
†Days to bloodstream infection.

**Table 2. Nursing Acuity and Registered Nurse Staffing by Neonatal Intensive Care Unit (NICU)**

| Characteristic | Mean (SD) | | | |
|---|---|---|---|---|
| | NICU 1 | | NICU 2 | |
| | No Infection | Infection | No Infection | Infection |
| Nursing intensity weight | 5.3 (2.6) | 7.8 (3.0) | 4.7 (2.1) | 8.5 (3.7) |
| Registered nurse h/d* | 10.7 (1.0) | 10.7 (1.0) | 11.0 (1.0) | 10.7 (1.2) |
| Infant census | 39 (4) | 39 (4) | 34 (5) | 34 (6) |

*Indicates registered nurse hours per infant per day.

**Table 3. Hazard Ratios Estimating the Risk of Bloodstream Infection**

| Variable | Hazard Ratio (95% CI) |
|---|---|
| Birth weight, g | |
| <1000 | 2.64 (1.77-3.94) |
| 1000-1500 | 1.82 (1.15-2.89) |
| 1501-2500 | 1.42 (0.85-2.38) |
| >2500 | 1.00 |
| Peripherally inserted central catheter | 1.83 (1.31-2.56) |
| Umbilical catheter | 1.33 (0.88-2.02) |
| Total parenteral nutrition | 12.62 (6.93-22.98) |
| Alcohol hand rub | 1.15 (0.84-1.58) |
| Chlorhexidine gluconate | 1.00 |
| NICU 1 | 0.07 (0.005-1.02) |
| NICU 2 | 1.00 |
| Registered nurse hours, NICU 1 | 1.53 (0.39-6.07) |
| Registered nurse hours, NICU 2 | 0.21 (0.06-0.79) |

Abbreviations: CI, confidence interval; NICU, neonatal intensive care unit.

## MULTIVARIATE ANALYSIS

In the preliminary analysis, surgery, tunneled catheters, and the hand hygiene product used by staff were not significantly associated with bloodstream infection (all $P>.25$). Risk factors significant in the preliminary analyses included birth weight, 2 catheter types (umbilical and peripherally inserted central catheters), total parenteral nutrition, NICU site, and registered nurse hours. We found a significant NICU site × registered nurse hours interaction effect (hazard ratio [HR], 7.12; 95% confidence interval [CI], 1.23-41.42). On the basis of this finding, we adjusted our model in an attempt to obtain an accurate representation of registered nurse staffing in each NICU as described by Greenland and Rothman.[26]

These significant variables and the hand hygiene product were further analyzed in the multivariate Cox regression model. The hand hygiene product, although not significant in the preliminary analysis ($P=.26$), was included in the multivariate model because it was the intervention in the parent clinical trial. A summary of results from the multivariate Cox regression model is provided in **Table 3**. In this model, 3 risk factors were independently associated with bloodstream infection. Birth weight of less than 1000 g (HR, 2.64; 95% CI, 1.77-3.94), birth weight of 1000 to 1500 g (HR, 1.82; 95% CI, 1.15-2.89), number of days of peripherally inserted central catheter use (HR, 1.83; 95% CI, 1.31-2.56), and number of days of total parenteral nutrition use (HR, 12.62; 95% CI, 6.93-22.98) were significantly associated with an increased risk of bloodstream infection. Among the 4 birth weight groups, infants weighing less than 1000 g were 2.64 times



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more likely to develop bloodstream infection than the highest birth weight group (>2500 g). Further analysis of the catheter data showed that infants with bloodstream infection had peripherally inserted central catheters in place for significantly more days than uninfected infants (mean, 12 and 3 days, respectively; $P<.001$).

In addition, the number of registered nurse hours in NICU 2 was significantly associated with a decreased risk (HR, 0.21; 95% CI, 0.06-0.79) of bloodstream infection. We found that more registered nurse hours per nursing intensity weight was associated with a 79% reduction in the risk of bloodstream infection in NICU 2. Umbilical catheter use, hand hygiene product, NICU site, and registered nurse hours in NICU 1 were not associated with risk of bloodstream infection. A survival curve comparing registered nurse hours at NICU 2 and number of days to first bloodstream infection is shown in the **Figure**.

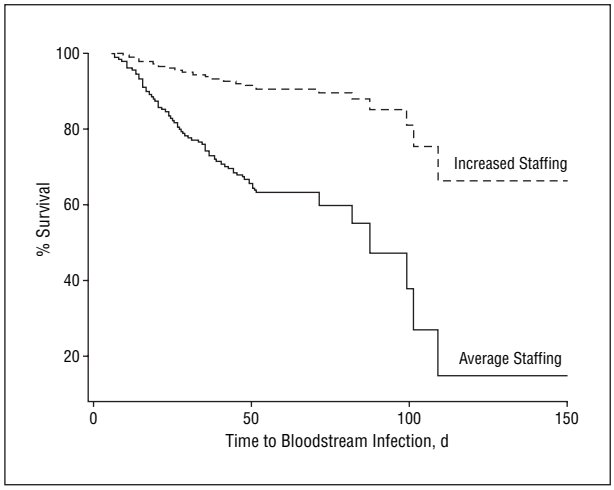


**Figure.** Survival estimates of 1125 infants in neonatal intensive care unit 2, showing the typical changes in survival after increasing registered nurse hours.

## COMMENT

To our knowledge, this is the first prospective study to examine registered nurse staffing and the risk of endemic bloodstream infection in infants in the NICU. We found low birth weight, peripherally inserted central catheters, and total parenteral nutrition to be significantly associated with bloodstream infection. These findings are consistent with previous research on infants in the NICU.[17,19,27-33]

After controlling for infants' intrinsic and extrinsic risk factors, we found that the number of hours of care provided by registered nurses was significantly associated with the risk of bloodstream infection in one of our study NICUs. This finding is consistent with other studies on nurse staffing. Nursing workload has been associated with higher rates of infection[34-36] and increased mortality.[37,38] The use of pooled or temporary nurses has been significantly associated with infection,[8,34,39,40] possibly because of lapses in aseptic technique by those unfamiliar with the routine care policies of the nursing unit. In the NICU, it has been reported that bloodstream infection is associated with understaffing, overcrowding, and the moving of infants between rooms.[8,9,11] Furthermore, understaffing has been linked to several infectious outbreaks[8,11] and the transmission of antibiotic-resistant organisms among premature infants.[8,10] Our findings suggest that increasing registered nurse staffing by 1 full-time equivalent could possibly reduce the risk of bloodstream infection by 11% in NICU 2.

The fact that the number of registered nurse hours was not associated with bloodstream infection in NICU 1 (HR, 1.53; 95% CI, 0.39-6.07) may have several explanations. When compared with the infants in NICU 2, those in NICU 1 were significantly smaller and more acutely ill, with more invasive devices, which could outweigh the effect of registered nurse staffing. In addition, the infants in NICU 1 had consistently fewer registered nurse hours of care per day than those in NICU 2. This lack of variation in registered nurse hours in NICU 1 may have made it more difficult to detect an association between registered nurse hours and bloodstream infection in these infants. Surprisingly, we found that when nursing acuity increased, registered nurse hours remained the same in NICU 1 and decreased in NICU 2. This unrecognized increase in nursing acuity could have increased the risk of bloodstream infection in both NICUs. It has been reported that scores on acuity measures are associated with the risk of healthcare-associated infection in infants. Gray and colleagues[41] report in a study of low-birth-weight infants that assessing illness severity with the Score for Neonatal Acute Physiology provides information on the risk of bloodstream infection beyond that provided by birth weight alone. Griffin and Moorman[42] reported that Score for Neonatal Acute Physiology values rise 24 hours before bloodstream infection. It has also been reported that the Clinical Risk Index for Babies is predictive of bloodstream infection in low-birth-weight infants.[43] Hospital staffing decisions are typically determined by the number of patients in a unit; however, the foregoing findings suggest that hospitals should consider implementing a patient classification system that is acuity driven to determine nurse staffing need.

This study had several limitations. First, it was conducted in 2 NICUs with high-risk infants, which limits generalizability to other hospital units and patient populations. Second, although the level of nurse education has been associated with adverse patient outcomes,[44] the educational level of nurses was unmeasured in this study. Third, the 2 study NICUs were environmentally different in a number of ways (NICU 2 was newly renovated and more spacious than NICU 1).

In conclusion, our findings suggest that registered nurse staffing is associated with the risk of bloodstream infection among infants in the NICU. We hypothesize that inadequate nurse staffing and increased nurse workload in a critical care environment results in poor hand hygiene compliance, breaks in aseptic technique, or compromises in practice that might increase the risk of transmitting infection. Further research is warranted that examines the association between registered nurse staffing and healthcare-associated infection to improve the quality of care and the outcomes of infants in the NICU.



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