Effects of High Patient to Nurse Ratios on Neonatal Catheter-Related Sepsis

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Abstract

Objectives

To evaluate understudied risk factors related to catheter-related sepsis (CRS) in patients in neonatal intensive care units (NICUs), specifically those related to nurse work overload.

Design

Single-center, prospective, analytical, observational study of a cohort of newborns with indwelling central lines.

Setting and Patients

Newborn patients, born between 24 to 40 weeks, admitted to the NICU of Hospital General of Castellón were studied between May 2011 to March 2013 with central lines inserted at the unit lasting for more than 5 days.

Measurements and Main Results

Demographic, clinical, and catheter variables (insertion and maintenance) were recorded. Patient to nurse ratios on day five and during total dwell time were recorded. A total of 103 neonates were recruited and 156 catheters were examined. Fifteen episodes of CRS were confirmed, accounting for an incidence density of 9.6/1000 total catheter days (TCD). A high patient/nurse ratio on day 5 of catheter use was found to be a significant risk factor for CRSI with an OR of 5.3 (95% CI [1.3-22.8]) in both multivariate and bivariate analyses.

Conclusion

Adequate nurse staffing organization is an important factor to consider in quality improvement aimed at reducing CRS incidence in the NICU and to improve the quality of patient care.

Precis

Nurse staffing ratios in NICUs are an important factor in the prevention and development of CRS to improve the quality of patient care.

This study addresses the problem of CRS in a Spanish NICU and its relationship with patient/nurse ratio.
A high patient/nurse ratio is a significant factor in the development of CRS in the NICU.
The results have major implications in improving CRS outcomes in neonates in terms of by reducing the patient/nurse ratio.

Introduction

Catheter-related sepsis (CRS) is a very common problem in neonatal patients all over the world, affecting those admitted to NICUs with a great impact on morbidity, mortality, and medical expenses. Factors related to increased CRS risk in the neonatal population include low birth weight, Total Parenteral Nutrition (TPN) and Total Catheter Dwell Time (TDT) [1,2,3,4].

The incidence of CRS in many NICUs has decreased in response to multidisciplinary prevention strategies in developed countries [5,6,7]. The success of these strategies depends on collaborative work between a multidisciplinary team with and adequate registered nurse (RN) staffing. There is strong evidence supporting a causal relationship between higher nursing staffing levels and decreased inpatient mortality in neonates [8,9]. There is strong evidence supporting a causal relationship between higher nursing staffing levels and decreased neonatal mortality.

Studies show a relationship between understaffing and septic outbreaks in neonatal units [10, 11]. Few data exist about the relationship between CRS and nursing workload in the Spanish NICU environment. We conducted a prospective study to evaluate the relationship between patient/nurse ratio (PNR) and incidence of CRS as a main variable. We hypothesized that a high nurse work overload defined as a high patient/nurse ratio was a risk factor for CRS in neonates admitted to a Spanish NICU.

Methods

This study was approved by the International Review Board and conducted as a single-center, prospective longitudinal analytic observational study of a cohort of neonates (defined as aged between 24-40 weeks of gestation) admitted to the Hospital General de Castellón NICU from May 2011-March 2013 whose indwelling central lines were inserted in our unit. Neonates were excluded if their central lines were inserted out of the unit (operating room or another hospital); if the central line was inserted for less than 5 days; or if they were transferred to another unit or hospital. Every catheter and patient were monitored after central venous line (CVL) insertion. Mean patient to nurse ratio on day 5 of catheter (PNR5) and during total dwell time (TDT) of every CVL (PNRt) were the main variables indicating nurse workload.

These variables were recorded in our database every eight hours, which was the duration of nurse shifts studied. Other variables included demographic data (gestational age (GA), birth weight, weight on insertion, Apgar score, clinical risk index for babies (CRIB), and antenatal steroids), clinical data (need for and duration of mechanical ventilation, number of blood transfusions, TPN days, antibiotics on admission, antibiotic-free days, NICU length of stay, and neonatal death and cause), CVL insertion data (professional category, type of CVL, number of lumens, length, tip placement, area of placement, duration of insertion procedure and number of attempts, modification of position, sepsis at insertion), and CVL management data (internal handling of CVL defined as disconnection from the hubs for parenteral or drug

administration and blood sampling, drugs administrated, and TPN with lipids being administered through one or two lumens). TDT for every CVL was recorded.

The main response variable was the occurrence of a CRS episode. We defined central line-associated bloodstream infections (BSI) using the Centers for Disease Control and Prevention criteria [8], which require either a single positive blood culture for a recognized pathogen not related to infection at another site or two positive cultures for a common skin contaminant like coagulase-negative staphylococcus species drawn at separate occasions plus clinical signs for infection, such as fever (> 38°C rectal temperature), hypothermia (< 36°C rectal temperature), apnea, or bradycardia.

Statistical Analyses

Descriptions of sample frequencies, means, and medians were performed. Possible relationship between variables and the dependent variable (incidence of CRS) was evaluated through univariate analyses. Chi-square tests were performed for qualitative variables and Student's t-tests were performed for quantitative variables. A Kaplan-Meier survival curve analysis was performed to investigate the variable CRS incidence. We observed that the incidence of CRS was not regular along the dwell time and there was a non-linear relationship after analyzing catheter survival function. A non-linear incidence of the response variable (CRS incidence) was noted once the survival curve was analyzed with evidence of episodes until day 9 of crude death rate (CDR) but was not observed thereafter.

We used the Fractionated Polynomials of Royston (FPR) [9] in order to better understand the relationship between different variables with a different occurrence of main variable along TDT time. The FPR are an extended family of curves, whose power terms are restricted to a small predefined set of integer and non-integer values, have considerable flexibility, and fit nonlinear variables in a straightforward fashion. Cox regression was then applied to assess the risk factors influencing CRS and OR was calculated. Subsequently, Poisson regression was applied in order to check results. Confidence intervals of 95% ($p < 0.05$) were applied to statistical analyses. All statistical analyses were conducted through SPSS ver. 19.

Results

A total of 103 neonates with 156 catheters were recruited and followed.
Median gestational age (GA) was 30 SG (IR 30.2-31.2). GA was 30 weeks, (CI 95% [30.2-31.2]), weight 1280 g (CI 95% [1285,1440]) and weight on insertion (CI 95% [1295,1460]).

Clinical Variables	
Complete Antenatal Steroids Course	66.50%
Total Parenteral Nutrition days	6 (CI 95% [3.2,14.3])
Days of Mechanical Ventilation	2 (CI 95% [0.3,6])
Mean Hospital Stay	18.5 days (CI 95% [12.5,25.5])
In-hospital Death	5.50%

Table 1: Clinical Variables of the Cohort

Of the 156 catheters, 98 were peripherally-inserted central catheters (PICCs), 45 were umbilical, and 12 were femoral. Sixty-seven percent of all neonates required a central access while 32.3 % of them required more than one CVC upon admission. Single lumens comprised 55.8% of all central lines while the remaining 44.2 % were double lumen. Forty-five percent of them were inserted in the flexure of both arms and 32% were inserted in the epicraneal area. The average inserted length was 11.6 cm (95% CI [10.8,12.8]). The average distance from the tip to the confluence of superior or inferior vena cava to right atrium position was 2.3 cm (CI 95% [1.6,2.9]). Median duration of CVL insertion procedure was 15 min (3-120 min). The median number of attempts needed to achieve successful insertion was 1 (1-10) but 52% required a modification of the tip position after insertion.

CRS Incidence

Fifteen episodes of CRS were confirmed among 156 analyzed CVL using transcranial doppler (TCD) of 1547. Therefore, 9 % of CVL originated from CRS, accounting for an incidence density of 9.6/1000 TCD.
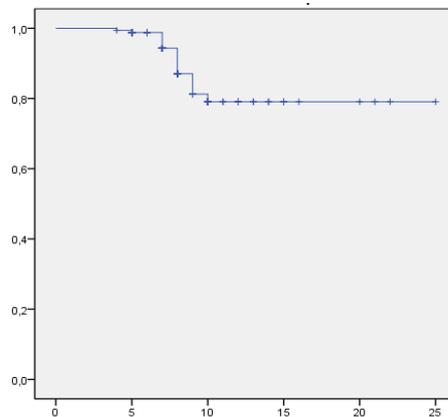

Figure 1: Survival Curve of CVL During TDT

CRS incidence was observed until day 9 of CDR but was not observed thereafter. Mortality in patients without CRS was 3% and 6.7% in those with CRS, but this was not statistically significant. Length of hospital stay for both CRS and not CRS patients was not statistically significant.

Microbiological agent	Percentage
S. Coagulase negative	66%
Acinetobacter	13%
E. Coli	6,6%
Pseudomonas	6,6%
Candida	6,6%

Table 2: Distribution of Microbiological Agents

Analysis of Risk Factors

None of the demographic variables yielded statistically significant results after both univariate and multivariate analyses. Clinical variables including sepsis at insertion, TPN days and antibiotics on admission, TDT, point of insertion, number of lumens, length of the CVL, length of the portion of CVL inserted and distance from the tip to the ideal location were not statistically significant as well. Despite an increased risk of CRS proportional to number of attempts (mean of 2.6 attempts in CRS patients compared to 2.1 in non-CRS), insertion technique was not statistically significant. The duration of the procedure was not associated with CRS or the professional category of the inserter (resident, nurse, fellow, or consultant).

Relation to Nurse Workload

We found a significant increased risk of CRS ($p = 0.032$) with mean PNR5 of 1.32 in non-CRS patients and 1.55 in those who developed CRS (OR 5.49,95% CI 1.4,13.8), as shown in Figure 2. However, no significant relationship was found after analyzing PRNt.
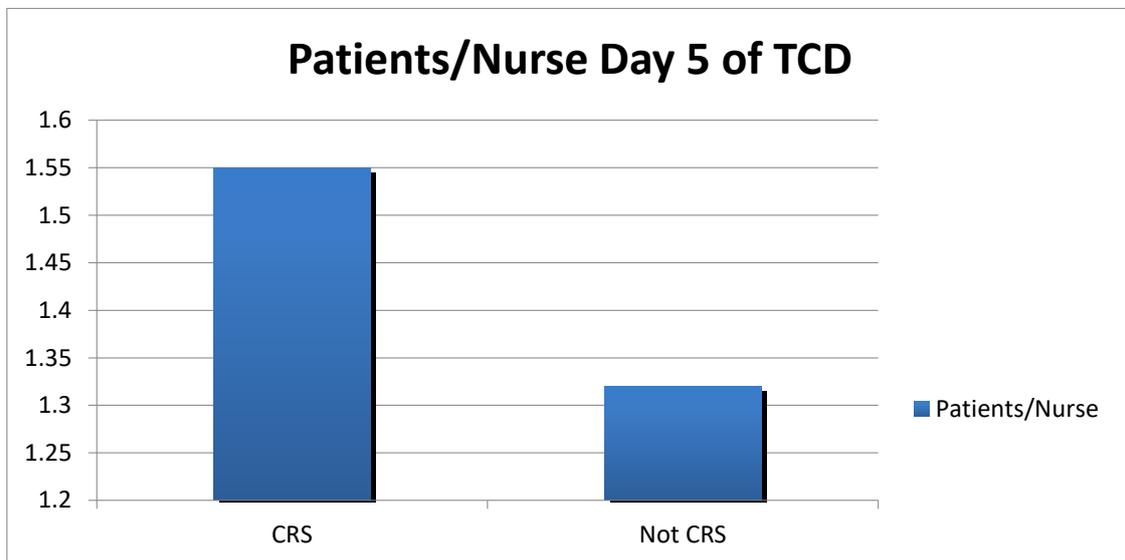

Figure 2: Media of Patient to Nurse Ratios on Day 5 of TCD (PNR5).

A statistically significant difference ($p = 0.019$) was found when examining the number of catheters inserted consecutively in the same patient during admission (OR 3.29, 95% CI [1.8-9.8]), indicating a higher risk of CRS at higher number of CVLs in the same patient.

	Univariate		Multivariate	
	OR (CI 95%)	p	OR (CI 95%)	P
GA at insertion	NS	NS		NS
Antenatal steroids	NS	0,08		
Number of antibiotics	NS	NS		NS
TPN through different lumens	NS	0,09		
> 1 lumen CVL	NS	0,058		NS
Consecutive CVL (>1) in same patient	4,4 (1,4-13,8)	0,008	3,3 (1,10-9,8)	0, 032
PNR5	NS	0,07 NS	5,4 (1,3-22,8)	0, 019

Table 3: Summary of statistically significant variables in both bivariate and multivariate analysis in relation to the incidence of CRS

Discussion

Our results show that PNR5 is a significant risk factor for CRS with an OR of 5.49 (CI 95% [1.3,22.8]), indicating a fivefold increment in the risk of CRS for every additional patient cared for by every nurse, at least until day 5 of admission. There is firm evidence in literature of the association between nurse work overload and poor patient outcomes. In a prospective study of risk-adjusted mortality in infants admitted to neonatal units, Hamilton et al. (2007) found that risk-adjusted mortality was inversely related to the provision of nurses with specialist neonatal qualifications and that increasing the ratio of nurses with neonatal qualifications to 1:1 was associated with a decrease in risk-adjusted mortality of 48% (OR: 0.52, 95% CI [0.33, 0.83]). Conversely, in a population-based analysis of operational clinical data from 43 tertiary-level neonatal units observed from 2008 to December 2012, [9] found that a 10% point decrease in the proportion of intensive care days on which one-to-one nursing was provided was associated with an increase in the in-hospital mortality rate of 0.6 (95% CI [1.2,0.0]; $p < 0.05$).

The reason for the association between understaffing and mortality rates remains unclear. However, a high patient/nurse ratio has also been associated to low weight gain in preterm infants [12] and with adverse events like unplanned extubations [13] pediatric and neonatal patients.

There is also evidence on literature of a relationship between understaffing and the increased incidence of nosocomial infections, especially outbreaks. In a retrospective cohort study from data collected by web survey of staff nurses, [12] concluded that understaffing was associated with an increased risk for very low birth weight (VLBW) nosocomial infection with an OR of 1.40 (95% CI [1.19-1.65]; $p < 0.001$). Andersen et al. (2002) found that work overload and a disproportionate number of specialized neonatal nurses as significant risk factors for a MRSA outbreak in the NICU.

After analyzing an *E. Cloacae* outbreak in a NICU, [13] found that cross-transmission was facilitated by understaffing and overcrowding (up to 25 neonates in a unit designed for 15), with an increased risk of *E. cloacae* carriage during the outbreak compared to periods without understaffing (RR 5.97; CI 95% [2.2,16.4]). Concurrent observation of handwashing practices of healthcare workers indicated poor compliance. The outbreak was terminated after workload decrease, hand antisepsis increase, and reinforcement of single-dose medication.

Finally [14], performed a systematic review of 76 studies analyzing outbreaks of extended spectrum beta-lactamase-producing organisms (ESBL) in NICUs. Understaffing was found as the most prevalent predisposing factor. However, an increase in staffing rates was one of the least frequently reported interventions [13]. found that the origin of the outbreak was unidentified in most studies, although suboptimal hand hygiene practices with horizontal dissemination of organisms was postulated as the most frequent cause. The underlying reason is hypothesized to be a lower adherence to hygiene/care bundles and check-lists in high workload situations. However, our study was not designed to analyze nurse compliance with different prevention bundles, which were recently established in our unit, or to examine the proportion of experienced nurses attending our patients. Therefore, a causal relationship cannot be established.

In 2014, the BMA perinatal medicine Framework of Practice recommended a nurse to patient ratio of 1:1. Compared to voluminous workload, nurse work overload has a more significant effect on CRS. In a multicentric prospective study carried out in 18 NICUs in USA Schulman et al. (2011) found that those units with a high number of admissions (> 700 patients/month) experienced lower incidence of CRS than units with low patient volume (<700 patients/month) with an OR of 0.49 (CI 95% [0.27-0.90]; $p = 0.02$). A disproportionate number of well-trained RNs is a more significant factor compared to voluminous work that contributes to increased CRS risk.

The direct effects of work overload are probable factors for a reduction in the optimal standards of nurse delivery of care. In a multisite cross-sectional survey [15]. Observed that 40% of nurses exhibited burnout syndrome. Moreover, multivariate results show that nurse reports of low-quality care were three times as likely in hospitals with low levels of staffing compared to the increased support for nurses in hospitals with high levels of staffing. In a more recent study [16], observed that an increase of one patient cared for by the same nurse caused a 23% in burnout syndrome and a 7% in hospital mortality.

Our study has several limitations. The most significant is a small sample size accompanied by a small number of catheters inserted. The abnormal distribution along dwell times of those events that required the application of Royston fractional polynomial also is a limitation. The Cox hazard model was chosen as an analytical method to evaluate the relationship between end points and risk factors. The Poisson regression model may be a better choice. One of the difficulties encountered during initial analysis is that measurements focused on related, rather than discrete, events. As such, a single patient can have more than one CRBSI and more than one central venous line inserted during the admission). In order to exclude this possibility, we applied a binomial Poisson regression model and obtained similar results in both significant variables, resulting in an increased RR in PNR5. However, PNRT did not reach statistical significance after both univariate and multivariate analyses. The statistically insignificant result can be explained by the special behavior of the main variable along dwell time, with all episodes of CRS occurring between days 5 to 9 of CDR only.

A new risk factor that was unidentified in among the literature review is the placement of consecutive CVLs (>1) in same patient. Although it is not unusual to replace an umbilical venous catheter (UVC) with a PICC line at the 4th or 5th day of life, preterm infants may require the insertion of more than one CVL during the same admission period. In addition, lumen thromboses may necessitate another CVL insertion. Malfunctioning CVLs may be related to an increased CRS risk [17]. showed a positive correlation between the use of alteplase

for malfunctioning central venous catheters and the development of a CRS and its likely association with intraluminal thrombi.

Our results indicate that nurse work overload is a risk factor for CRS. Adequate nurse staffing and organizational/managerial support for nurses are crucial factors in improving the quality of patient care. Adequate nurse staffing levels also diminishes job dissatisfaction and burnout, which ultimately reduces the incidence of CRS in NICUs.

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