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Patient-to-Nurse Ratios and Outcomes of Moderately Preterm Infants

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Abstract

OBJECTIVE—Moderately preterm infants (30–34 6/7 weeks' gestational age) represent the largest population of NICU residents. Whether their clinical outcomes are associated with differences in NICU nurse-staffing arrangements has not been assessed. The objective of this study was to test the influence of patient-to-nurse ratios (PNRs) on outcomes of care provided to moderately preterm infants.

PATIENTS AND METHODS—Using data from a prospective, multicenter, observational cohort study of 850 moderately preterm infants from 10 NICUs in California and Massachusetts, we tested for associations between PNR and several important clinical outcomes by using multivariate random-effects models. To correct for the influence of NICU size, we dichotomized the sample into those with an average daily census of <20 or ≥20 infants.

RESULTS—Overall, we found few clinically significant associations between PNR and clinical outcomes of care. Mean PNRs were higher in large compared with small NICUs (2.7 vs 2.1; $P < .001$). In bivariate analyses, an increase in PNR was associated with a slightly higher daily weight gain (5 g/day), greater gestational age at discharge, any intraventricular hemorrhage, and severe retinopathy of prematurity. After controlling for case mix, NICU size, and site of care, an additional patient per nurse was associated with a decrease in daily weight gain by 24%. Other variables were no longer independently associated with PNR.

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CONCLUSIONS—In this population of moderately preterm infants, the PNR was associated with a decrease in daily weight gain, but was not associated with other measures of quality. In contrast with findings in the adult intensive care literature, measured clinical outcomes were similar across the range of nurse-staffing arrangements among participating NICUs. We conclude that the PNR is not useful for profiling hospitals' quality of care delivery to moderately preterm infants.

Keywords

infant; newborn; health services research; nurse-staffing; outcomes

The quality of health care delivery is determined by the physical composition of the health-delivery system (care structure), the quality of the patient-provider interactions (care processes), and the results of care provision (care outcomes).¹ Measures of care structure, such as quantitative measures of physician and nurse-staffing, are relatively easy to ascertain. However, their validity as predictors of patient outcomes may be difficult to determine because many variables may confound this relationship. Nevertheless, previous staffing studies in the adult intensive care setting have demonstrated strong associations with patient outcomes.²⁻⁴ However, few authors have examined the effect of quantitative measures of nurse-staffing, such as the patient-to-nurse ratio (PNR), on outcomes of preterm infants. Few studies have examined the effect of patient-to-nurse ratios (PNRs) on clinical outcomes in the NICU setting and results have been inconclusive.⁵⁻⁸

Moderately preterm infants with a gestational age at birth between 30 and 34 6/7 weeks make up nearly half of NICU residents^{9,10} and experience considerable morbidity and mortality.^{11,12} Nearly half of these infants receive assisted ventilation, and >10% require readmission within 3 months of discharge.¹¹ To date, the influence of PNRs on clinical outcomes in this population is unknown. We aimed to add to the current body of literature by determining the association of nurse-staffing with clinical outcomes in moderately preterm infants.

PATIENTS AND METHODS

Sample

The Moderately Premature Infant Project is a multicenter cohort study of infants with a gestational age of 30 to 34 6/7 weeks. Details of this study are described elsewhere.¹¹ In brief, eligibility for this study included birth between September 2001 and January 2003 and to survival to discharge from 1 of 10 NICUs in California (5 level III nurseries in the Kaiser Permanente Medical Care Plan, including 1 fee-for-service hospital with some Kaiser Permanente Medical Care Plan presence) and Massachusetts (2 level III and 3 level II nurseries affiliated with the Division of Newborn Medicine of the Department of Pediatrics, Harvard Medical School). We excluded infants transferred and discharged from nonparticipating facilities. Infants with major anomalies or chromosomal disorders were excluded, and gestational age was determined by using the best obstetrician-defined estimate. Initial recruitment targets were 100 infants from each site. At 3 high-volume sites, patients were randomly selected by using sampling algorithms to ensure that the final sample size of 100 was evenly distributed over the enrollment period. Four sites with slower-than-expected enrollment had enrollment capped at 60 to 65 infants so that data were collected at all sites through the same period. A total of 850 infants were enrolled in the study. Of these, 677 (78%) participated in a 3-month postdischarge survey designed to capture outcomes beyond the initial hospitalization. Patients transferred between participating NICUs were included in this analysis.

Measures

We abstracted data from patient medical records and hospitals' administrative records according to a previously validated protocol, the Neonatal Minimum Data Set.¹³

The PNR was calculated as the average of 3 daily nurse shifts beginning with the morning shift. NICU census was obtained at midnight on the preceding day. All but 1 NICU used 8-hour shift staffing. One NICU used 2 8-hour shifts and 2 4-hour shifts. We did account for nurses working partial shifts when recording staffing patterns (ie, 4.5 was recorded when 4 nurses worked a full 8-hour shift and 1 nurse worked only 4 hours). Only registered nurses were included in this tally. We did not have information on the skill-mix among nurses.

The following outcome measures were assessed for association with the PNR: gestational age at discharge; nosocomial infection; chronic lung disease (oxygen requirement at 36 weeks); days on assisted ventilation; days on oxygen; any intraventricular hemorrhage; severe retinopathy of prematurity (>stage 2); average daily weight gain (based on a daily average derived from the difference between birth weight and discharge weight over length of stay); any breast milk at discharge; emergency department visit within 3 months of discharge; and rehospitalization within 3 months of discharge. We chose any intraventricular hemorrhage rather than severe intraventricular hemorrhage (>grade 2) because only 2 patients in our sample had a diagnosis of the latter.

We investigated the effect of covariates on the relationship between the dependent variables and the PNR at 2 levels. At the patient level, we controlled for gestational age at birth, birth weight, gender, race/ethnicity (non-Hispanic white or other), and severity of illness as measured by the Score for Neonatal Acute Physiology II (SNAP-II).¹⁴ SNAP-II scores of <9 are considered low, and scores of >20 are considered high. At the hospital level, we used average daily census as a proxy for NICU size and divided the hospitals into 2 groups. Seven NICUs with an average daily census of fewer than 20 patients were designated as "small," and the remaining 3 NICUs were considered "large" for the purposes of our analyses.

Main Analysis

We conducted descriptive analyses and compared the characteristics of infants from small and large NICUs by using the Fisher's exact test for categorical variables and the *t* test for continuous variables. We then tested bivariate associations between PNRs and our outcomes of interest by using linear and logistic regression. To account for possible confounding, we used multivariable linear and logistic regression models including the patient level variables listed above and site of care added as a random effect. Outcome variables with a nonnormal distribution, including daily weight gain, days on assisted ventilation, and days on oxygen, were log transformed for random-effects modeling. We considered an association between the outcome variable and the PNR with a 2-tailed *P* value of <.05 statistically significant.

Sensitivity Analyses

Transfers between NICUs may bias results toward the null, because patients are exposed to varying PNRs among facilities. To assess potential transfer bias we restricted the analyses to patients who were inborn or transferred before 3 days of age. Patients transferred after 3 days of age were excluded.

The generally good health of moderately preterm infants may limit the detection of a subtle association between PNRs and adverse outcomes of care. We conducted sensitivity analyses in which we restricted the patient population to those in the top quartile of SNAP-II scores.

We used SAS 9.1 (SAS Institute, Inc, Cary, NC) for all statistical analyses. The 8 institutional review boards with jurisdiction over the 10 sites approved this study. With the exception of 1 site, which required written consent for all parts of the study, collection of medical chart data were approved for all eligible infants, and parental permission for the interview was required. The institutional review board at Baylor College of Medicine determined the analyses to be exempt from review.

RESULTS

Summary Statistics

As shown in Table 1, the 7 small and 3 large NICUs differed with respect to several clinical variables. Large NICUs had significantly greater average PNRs than small NICUs. Their patients also achieved significantly higher daily weight gains (6 g/day) but had longer lengths of stay, higher gestational ages at discharge, more days on assisted ventilation and oxygen, and lower rates of any breast milk at discharge, despite a comparable case mix among their moderately preterm infant population. Overall, illness severity was low in both groups. A significant proportion of infants required return visits to the emergency department or rehospitalization within 3 months after they were discharged from the hospital. Because none of the infants had severe retinopathy, this variable was excluded from subsequent analyses.

Association of PNR With Outcome Variables

Table 2 shows the associations between PNR and outcome variables in bivariate and multivariate analyses. PNR is associated with an increase in a given variable. A negative effect size means that an increase in PNR is associated with a decrease in a given variable. In bivariate analyses, an increase in PNR was associated with greater average daily weight gain, later gestational age at discharge, and higher risk of intraventricular hemorrhage. Of note, although the associations for these variables were highly significant, the parameter estimates were quite small (eg, 5 g/day weight gain for each additional patient per nurse), and the clinical significance of these findings may be limited.

After controlling for case mix, NICU size, and site of care, an additional patient per nurse was associated with a decrease in average daily weight gain by 24% (weight gain is reduced by a factor of $\exp(-0.28) = 0.76$, or a 24% reduction). The change in weight gain is multiplicative rather than linear because of the log transformation. To investigate which confounder resulted in the change of direction in the association between average daily weight gain and PNR from bivariate to multivariate analyses, we performed manual backward stepwise regression. After removing variables from the multivariate model in order of increasing statistical significance, we discovered that the site indicator was responsible for changing the direction of the association, suggesting that site-specific care processes or patient characteristics are confounding this relationship.

In the multivariate model, changes in the PNR were no longer independently associated with gestational age at discharge and any intraventricular hemorrhage, indicating that the apparent relation between these variables in bivariate analyses was due to confounding.

Sensitivity Analyses

Transfer Bias—Restriction of the study sample to an inborn and early transfer population did not significantly influence the results (Table 3).

High Illness Severity Subset—We restricted the study sample to a population with higher clinical risk, those in the top quartile of SNAP-II ($n = 227$, SNAP-II score ≥ 9), to

detect a signal of PNR on clinical outcomes. In multivariate analyses none of the clinical outcomes remained independently associated with higher PNR (Table 4).

DISCUSSION

We examined the association of PNRs on outcomes of moderately preterm infants. The main result from this study is that PNRs alone were not reliably associated with outcomes of care in this population. Despite exhaustive efforts, we were unable to reliably discriminate quality of care delivery among participating NICUs. Our finding of more generous nurse-staffing in small NICUs should, therefore, not be understood to mean that lower staffing ratios do not affect quality of care. Our interpretation is rather, that other measures need to be developed to more reliably discriminate quality of care in this relatively healthy population.

The greater nursing resource use in small NICUs does not necessarily reflect excess staffing capacity but rather the need for flexibility in staffing, because patient-census fluctuations per staff are proportionally larger in small NICUs. In addition, nurses in small NICUs may be performing a variety of duties that are the responsibility of dedicated ancillary staff in large NICUs. However, despite the higher salaries that nurses typically command when compared with ancillary staff, and despite the similar outcomes between small and large NICUs, the greater nursing resource use in small NICUs may not necessarily constitute an efficiency problem from the perspective of society. Although large NICUs may achieve efficiencies of scale with regard to the use of resources, they may be less able to offer other benefits parents value, such as reduced travel time and improved opportunities to spend time with their children or return to work.

The relation between nurse-staffing and adverse outcomes might follow a curve in which outcomes do not change perceptibly across a range of PNRs until they reach an inflection point at which nurses are unable to account for increasing workload. For the measures analyzed in this study, it seems that nurse-staffing in the participating NICUs operates on the flat part of the curve. It is important to emphasize that this study is hypothesis generating and cannot determine causality. Thus, whether lowering the PNRs would lead to fewer or more adverse outcomes is unknown but clearly warrants empiric examination in the context of the chronic nursing shortage. Differences in nurses' job profile between small and large NICUs, the extent to which responsibilities are adjusted to patient acuity, and nursing quality need to be examined, among other questions.

In addition to the relative health of our study population, several reasons might have prevented us from finding a significant relation between PNRs and clinical outcomes. Our measurement unit for this study (daily PNRs) may not be sensitive enough to detect the kind of staffing adjustments NICUs are able (or unable) to make in response to a sudden rise in patient severity, census, or both. For example, in the Kaiser Permanente Medical Care Program, it is extremely uncommon to have more than a 2-hour lag in obtaining an additional nurse when one is needed. Thus, changes in staffing levels are occurring in a time frame that is much narrower than that measured in our study.

Traditional measures of care outcomes, such as chronic lung disease or nosocomial infections, occur infrequently in moderately preterm infants. In contrast, average daily weight gain is attributable to all patients and may, therefore, be a more sensitive change indicator. Indeed, we found that an additional patient per nurse resulted in a 24% decrease in average daily weight gain. Explanations for this finding require additional exploration. We speculate that accumulation of small defects in care (less time for feedings and for

developmental care, more untimely patient interruptions, less rapid weaning from a ventilator or from parenteral nutrition, etc) may have resulted in reduced weight gain.

It is possible that PNRs influenced quality of care and outcomes of more premature infants in the same NICUs. Because illness severity is higher in these infants, it is conceivable they would be more vulnerable to the consequences of higher workload.

In other areas of medicine an increased nursing workload has been associated with an increased risk of morbidity and mortality. For example, Pronovost et al² found a nearly twofold increase in the risk for postoperative complications after abdominal surgery in patients who received care in ICUs with high PNRs (3–4:1). Tarnow-Mordi et al⁴ similarly found that the adjusted mortality rate was more than doubled in patients exposed to high versus low ICU workloads, defined by average nursing requirement per occupied bed and peak occupancy. Other authors have substantiated these results.^{15,16}

In neonatology, the evidence for an association between nurse-staffing and patient outcomes has been contradictory. In a previous study, we found a significant correlation between a different quantitative measure of workload (NICU census) and the decision to discharge preterm infants.¹⁷ Low NICU census resulted in discharge of fewer-than-expected infants and vice versa. Most neonatal staffing-related research has focused on the effects on very low birth weight infants. These studies have yielded inconclusive results, and those conducted abroad may not easily translate to the United States because of differences in nurse training and staffing arrangements. Findings from the United Kingdom Neonatal Staffing Study of >13 000 infants at 54 NICUs showed a strong correlation between NICU occupancy and mortality. Although the authors of that study did not find a relation between absolute PNR and mortality for the whole cohort, the ranked percentiles of PNR in every NICU showed an increase in mortality rate with an increase in the PNR.⁷ Hamilton et al⁶ studied patients from 7 Scottish and 2 Australian neonatal units and found that the odds of risk-adjusted mortality increased by nearly 80% with assignment of >1.7 infants per nurse per shift. Conversely, the authors of a single-center Australian study reported that the adjusted odds of mortality improved by 82% with the PNR above the highest tercile for this NICU, suggesting improved survival with the highest PNR.⁸ Contradictory results might be related to differences in study design and national models of care provision, yet these findings certainly warrant cautious interpretation and additional study.

The results of our study must be viewed within the context of the study design. One limitation of this study is the potential for transfer bias, which may be introduced around the time of birth or later in the course of an infant when transfer occurs for convalescent, chronic, or acute care. However, sensitivity analyses demonstrated no significant influence on study conclusions. Sampling bias because of enrollment at discharge and exclusion of infants transferred to a nonparticipating center may have affected our findings. However, given that 7 of 10 facilities were level III NICUs, and given that our previous work with this study population demonstrated an association between higher NICU census and greater number of discharges,¹⁷ we think our sample was relatively enriched with sicker infants. In this case, bias favors finding clinically significant associations of staffing ratios with clinical outcomes.

Observational studies are subject to confounding from unmeasured variables across NICUs, such as differences in patient mix, patient-care practices, staffing, and organizational make-up. For example, the PNR is merely a quantitative measure of nurse-staffing. We had no information regarding the quality of nursing, which might vary among NICUs and might influence patient outcomes.¹⁸ However, this study is strengthened by several efforts to control bias and confounding, including the use of sampling strategies intended to correct

for sitespecific differences in recruitment, adjustment for clinical risk by using previously validated tools, and correction for hospital-level effects.

CONCLUSIONS

To date, we know little regarding the measurement of quality of care delivery to the most common NICU residents, moderately preterm infants. In this population of moderately preterm infants, nurse-staffing was associated with a decrease in daily weight gain, but was not associated with other measures of quality. The association of PNR with a decrease in daily weight gain is of questionable clinical significance. Future research should focus on developing valid and reliable measures of quality of care for this less acutely ill population. Such measures might need to focus more on processes of care that enhance family satisfaction, reduce family anxiety, and are associated with a seamless transition to the home environment. Healthpolicy implications from this study include that the PNR is not useful for profiling hospitals' quality of care delivery to moderately preterm infants.

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ABBREVIATIONS

PNR	patient-to-nurse ratio
SNAP-II	Score for Neonatal Acute Physiology II

WHAT'S KNOWN ON THIS SUBJECT

In many areas of medicine, increased PNRs have been associated with better patient outcomes. However, in the NICU setting, studies have yielded contradictory results. The effect of nurse-staffing on outcomes of moderately preterm infants has not been examined.

WHAT THIS STUDY ADDS

In this population of moderately preterm infants, increased nurse-staffing was associated with a decrease in daily weight gain but was not associated with other measures of quality. Nurse-staffing should not be used for profiling hospitals' quality of care delivery to moderately preterm infants.

TABLE 1

Infant and Hospital Characteristics

Variables	Small NICUs		Large NICUs		P
	n	%	n	%	
No. of hospitals	7	—	3	—	—
No. of patients	550	—	300	—	—
Boys	277	50	152	51	.94
Maternal race, white	267	60	138	60	.87
Nosocomial infection ^a	18	3.3	11	3.7	.84
Assisted ventilation	143	26	82	27	.68
Chronic lung disease ^b	14	2.6	11	3.7	.40
Any intraventricular hemorrhage	21	3.8	22	7.4	.02
Retinopathy of prematurity (greater than stage 2)	0	0	0	0	NA
Any breast milk at discharge	424	78	199	67	<.001
Emergency room visit ^c	75	17	46	20	.37
Rehospitalization ^c	45	10	29	13	.63
	Mean	SD	Mean	SD	
Average daily PNR	2.1	0.4	2.7	0.4	<.001
Average daily weight gain	7.5	19.1	13.7	15.7	<.001
Gestational age at discharge, wk	35.9	1.2	36.5	1.5	<.001
Average daily census	11.2	4.2	43.9	10.1	<.001
Length of stay, median, interquartile range, d	18.7	12.0	23.8	14.4	<.001
Birth weight, g	1969	441	1908	424	.05
Gestational age at birth, wk	33.2	1.3	33.1	1.4	.28
SNAP-II	5.9	8.5	5.6	7.2	.68
Days on assisted ventilation	1.3	3.8	1.6	4.9	.29
Days on oxygen	2.6	7.3	3.5	8.7	.15

“Small” and “large” NICUs are defined as those with an average daily census of <20 or ≥20, respectively. NA indicates not applicable.

^a Bacterial, fungal, and viral.

^b Oxygen requirement at 36 weeks' gestational age.

Within 3 months after discharge.

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TABLE 2

Associations of PNR and Outcome Variables Among All Patients

Variables	Bivariable Associations			Multivariable Associations ^a		
	Parameter Estimate	SE	P	Parameter Estimate	SE	P
Daily weight gain, g	5.22	1.29	<.001	-0.28	0.12	.02
Gestational age at discharge, wk	0.48	0.09	<.001	0.01	0.004	.15
Days on assisted ventilation	-0.23	0.31	.46	0.10	0.21	.63
Days on oxygen	-0.21	0.58	.72	-0.09	0.27	.74
Assisted ventilation	0.05	0.16	.77	0.03	0.21	.87
Any intraventricular hemorrhage	0.75	0.33	.02	0.60	0.62	.36
Chronic lung disease ^b	-0.37	0.44	.39	-0.55	0.61	.39
Any breast milk at discharge	-0.22	0.16	.19	0.05	0.35	.90
Nosocomial infection ^c	0.08	0.39	.83	-0.25	0.52	.64
Emergency room visit ^d	-0.13	0.40	.53	-0.08	0.22	.72
Rehospitalization ^d	0.16	0.26	.54	0.40	0.26	.16

N = 850. Adjustments are made for birth weight, gender, race, SNAP-II score, NICU size, and site of care in a random effects model.

^aFor multivariate analyses, daily weight gain, gestational age at discharge, days on assisted ventilation, and days on oxygen were log transformed.^bOxygen requirement at 36 weeks' gestational age.^cBacterial, fungal, and viral.^dWithin 3 months after discharge.

TABLE 3

Associations of PNR and Outcome Variables Excluding Transferred Patients

Variables	Bivariable Associations			Multivariable Associations ^a		
	Parameter Estimate	SE	P	Parameter Estimate	SE	P
Daily weight gain, g	5.06	1.47	<.001	-0.45	0.16	.006
Gestational age at discharge, wk	0.46	0.10	<.001	0.01	0.01	.08
Days on assisted ventilation	-0.46	0.30	.13	0.08	0.27	.78
Days on oxygen	-0.46	0.59	.44	-0.01	0.26	.97
Assisted ventilation	0.11	0.19	.57	0.10	0.31	.75
Any intraventricular hemorrhage	0.63	0.39	.10	0.57	0.47	.25
Chronic lung disease ^b	-0.67	0.56	.23	-0.03	0.77	.97
Any breast milk at discharge	-0.33	0.18	.07	-0.32	0.38	.42
Nosocomial infection ^c	-0.11	0.49	.83	-0.48	0.93	.62
Emergency room visit ^d	0.04	0.23	.86	0.08	0.23	.73
Rehospitalization ^d	0.20	0.28	.47	0.22	0.30	.48

N = 695, excluding patients transferred in after 3 days of age. Adjustments are made for birth weight, gender, race, SNAP-II score, NICU size, and site of care in a random effects model.

^aFor multivariate analyses, daily weight gain, gestational age at discharge, days on assisted ventilation, and days on oxygen were log transformed.

^bOxygen requirement at 36 weeks' gestational age.

^cBacterial, fungal, and viral.

^dWithin 3 months after discharge.

TABLE 4
Associations of PNR and Outcome Variables Among Patients in the Top Quartile of SNAP-II

Variables	Bivariable Associations			Multivariable Associations ^a		
	Parameter Estimate	SE	P	Parameter Estimate	SE	P
Daily weight gain, g	4.51	2.35	.06	0.03	0.13	.80
Gestational age at discharge, wk	0.44	0.20	.03	0.01	0.01	.30
Days on assisted ventilation	-0.76	0.97	.44	-0.23	0.22	.29
Days on oxygen	0.17	10.68	.92	-0.14	0.43	.75
Assisted ventilation	-0.25	0.28	.37	0.07	0.35	.84
Any intraventricular hemorrhage	1.22	0.55	.03	0.91	0.57	.15
Chronic lung disease ^b	0.07	0.55	.91	-0.28	0.75	.71
Any breast milk at discharge	-0.03	0.32	.91	0.18	0.38	.64
Nosocomial infection ^c	0.38	0.61	.54	-0.44	0.83	.61
Emergency room visit ^d	0.21	0.37	.57	0.32	0.50	.53
Rehospitalization ^d	0.65	0.46	.16	0.64	0.52	.25

N = 227, patients with SNAP-II score ≥ 9 . Adjustments are made for birth weight, gender, race, SNAP-II score, NICU size, and site of care in a random effects model.

^aFor multivariate analyses, daily weight gain, gestational age at discharge, days on assisted ventilation, and days on oxygen were log transformed.

^bOxygen requirement at 36 weeks' gestational age.

^cBacterial, fungal, and viral.

^dWithin 3 months after discharge.