Neonatal intensive care unit occupancy rate and probability of discharge of very preterm infants

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Abstract

Objective

To assess the association of NICU occupancy with probability of discharge and length of stay (LOS) among infants born < 33 weeks gestational age (GA).

Study design:

Retrospective study of 3388 infants born 23–32 weeks GA, admitted to five Level 3/4 NICUs (2014–2018) and discharged alive. Standardized ratios of observed-to-expected number of discharges were calculated for each quintile of unit occupancy. Multivariable linear regression models were used to assess the association between LOS and occupancy.

Results

At the lowest unit occupancy quintiles (Q1 and Q2), infants were 12% and 11% less likely to be discharged compared to the expected number. At the highest unit occupancy quintile (Q5), infants were 20% more likely to be discharged. Highest occupancy (Q5) was also associated with a 4.7-day (95% CI 1.7, 7.7) reduction in LOS compared Q1.

Conclusion

NICU occupancy was associated with likelihood of discharge and LOS among infants born < 33 weeks GA.

Key Points

High unit occupancy was associated with higher probability of transfer/discharge and shorter length of stay in Level 3/4 NICUs

These results suggest that providers integrate organizational variables in their clinical decision-making for discharge planning

Introduction

Preterm infants born < 33 weeks gestational age (GA) are at high risk of neonatal complications and need to be admitted in specialized neonatal intensive care units (NICUs) for longer periods of time compared to term infants.[1, 2] Recent studies have shown significant variations in length of stay (LOS) between NICUs and countries.[3, 4, 5] Factors that may contribute to variations in NICU LOS include ability to transfer to step down units, family teaching and organization of post-discharge follow-up.[6,7] External factors such as NICU occupancy may contribute to the planning of discharge of neonates. In a multicenter study in the United States, infants born between 30 and 34 weeks GA were more likely to be discharged home on days of higher occupancy, suggesting that providers consider NICU demand in their decision to discharge.[8] However, it remains unclear whether these finding apply to more premature infants born < 29 weeks who may have more complex discharge planning, and whether these findings are generalizable to NICUs in highly regionalized health systems that transfer high proportions of infants 29–32 weeks to stepdown units.

Canada has a publicly funded healthcare system with fixed resources and individual provinces are responsible for planning and allocating most publicly insured health services. Within each province, regionalization of perinatal care has led to centralization of specialized maternity units and NICUs. In such a system with a limited number of beds, it is unclear whether bed occupancy influences timing of discharge from Level 3/4 NICUs among preterm infants born < 33 weeks. Therefore, we aimed to assess the association of NICU occupancy with probability of discharge and LOS in Level 3/4 NICUs among infants born < 33 weeks GA.

Methods

Setting and study design

The province of Quebec (Canada) has a territory of 1.5 million km^2 and a population of 8 million. Neonatal health services are divided into four health networks with oversight and management of services being led by the province. There are four Level 4 (all pediatric surgical and medical specialties available), two Level 3 (select pediatric specialties available and no surgical consultants) and 12 Level 2 NICUs in the province (based on American Academy of Pediatrics definitions of Levels of Care).[9] Admissions are distributed among NICUs based on proximity to the patient's home as well as availability of beds and resources. This study included five participating NICUs (four Level 4 and one Level 3 NICU), all located within a 240 km radius, and three within the same metropolitan area. Median Level 3/4 NICU size is 34 beds (range 20–65) and median number of admissions (all GAs included) per NICU is 600 (range 400–990) per year. General criteria for admission to Level 2 NICUs are harmonized in the province and include GA ≥ 32 weeks, weight ≥ 1500 grams and no need for invasive mechanical ventilation.[10] Criteria for return transfer from Level 3/4 to Level 2 are similar but include additional stability criteria at time of return transfer: full enteral feeds, no central line and maximum respiratory support of CPAP at 5 cm H_2O with FiO2 21% or low flow oxygen. During the study period, the five participating Level 3/4 NICUs admitted approximately 93% of infants born < 29 weeks in the province and 85% of infants born 29–32 weeks.[11] Overall, this regionalization model of care is similar to the other provinces in Canada and comparable to several high-income countries that have universal and publicly funded healthcare systems.[5]

This was a multicenter retrospective cohort study including infants born between 23^0 and 32^6 weeks GA, admitted to five Level 3/4 NICUs in the province of Quebec (Canada) between January 2014 and December 2018. The study time frame and subsequent sample size was based on convenience. We excluded infants that were moribund on admission or admitted for palliative care, had a major congenital anomaly, died before NICU discharge (since our study focused on probability of transfer/discharge) or had missing discharge date. Approval for this project was obtained from the institutional Research and Ethics Board of each participating site.

Patient characteristics and outcomes

Patient data for the five participating units was obtained from the Canadian Neonatal Network database. At each NICU, trained abstractors follow a standard protocol[12] to enter patient information into a data-entry program with built-in error checking that has high reliability and internal consistency.[13] Patient characteristics included GA at birth, birth weight, sex, small for GA status (birth weight < 10th percentile for GA and sex based on Canadian growth charts),[14] multiple births, mode of delivery, 5-minute Apgar score < 7 and Score for Neonatal Acute Physiology version II (SNAP-II) > 20.[15] NICU discharge was defined as live discharge from the NICU, regardless of destination (home, community hospital or different unit within the hospital). Length of stay was defined as total calendar days spent in any Level 3/4 NICU. Readmission to Level 3/4 NICU included readmissions from home, community hospital or different unit within the hospital. Readmission data did not include information on emergency department visits (without NICU admission) or admission in other departments in the hospital. Patient data was linked to unit-level exposure variables by date of discharge.

Exposure variables definitions

Unit occupancy rate was defined as the total number of infants in the NICU (note that all infants physically in the NICU were included in the census [all GAs and all medical conditions]) at each shift, divided by the total number of funded beds. Unit occupancy data was recorded at the beginning of each nursing shift (8:00 a.m., 4:00 p.m. and 12:00 a.m.) in a provincial administrative database (SiteNeo). The primary exposure was unit occupancy before discharge of each patient and was calculated as mean unit occupancy of the two days prior to and the morning of discharge (mean occupancy of 7 shifts). This allowed for statistical smoothing of the exposure variable and for integration of discharge planning time, which typically occurs in the days prior.

Nurse-to-patient ratios [16] may also affect probability of patient discharge,[16] as it reflects workload in the NICU and has been variably associated with LOS in previous studies.[8, 17, 18] NPRs were not included in the primary analysis as nursing data was only available for 4 of the participating NICUs, including one with data limited to 2015–2018. However, we performed secondary analyses for NPRs with the available data using a similar approach as for occupancy (mean NPR in the NICU of the 2 days prior to and morning of discharge). The NPRs were calculated at the beginning of each shift as the total number of nursing hours worked by bedside nurses divided by the total number of required hours of care based on patient dependency categories (all patients in NICU included). Number of nursing hours worked each shift was obtained from each hospital's administrative payroll system (Logibec©), whereas number of patients per dependency category at each shift was obtained from the provincial administrative database (SiteNeo). Patient dependency categories and corresponding required hours of care (number of nurses required multiplied by 8-hour shifts) are based on provincial guidelines: unstable (1 nurse per patient), intensive care (0.7 nurses per patient), intermediate care (0.3 nurses per patient) and continuing care (0.25 nurses per patient).[19]

Statistical analyses

Quintiles of daily occupancy (using the mean occupancy two days prior to and the morning of each study day) were created for each unit, with Q1 being the lowest occupancy and Q5 being the highest. Infants were grouped into the quintile corresponding to their day of discharge. Should occupancy not be associated with discharge probability, we would expect the number of discharged infants to be evenly distributed across the quintiles (20% in each). We used Spearman's rank correlation coefficient to assess the trend between NICU occupancy and discharge. Standardized ratios (SR) and corresponding 95% confidence intervals (CI) of observed-to-expected number of discharges were calculated for each occupancy quintile. An SR with corresponding 95% CI including the null value of 1.0 indicates that discharges occurred within expected proportions. Additional SR analyses were conducted among GA subgroups (< 29 weeks and 29–32 weeks), for infants based on discharge destination (home and other unit), as well as for individual NICUs to assess for potential biases attributable to variations in site practices. Secondary analyses assessing NPR and likelihood of discharge followed a similar approach as for occupancy, and only included the 4 sites with available nursing data.

To evaluate the association of occupancy with LOS, infant and discharge characteristics were descriptively compared across occupancy quintiles. Unadjusted comparisons were made using the Chi-square test for categorical variables and the Kruskal-Wallis test for continuous variables. Different statistical models were considered to evaluate the association between occupancy quintile and LOS (using Q1 as reference) within the complete cohort as well as within GA subgroups (< 29 weeks and 29–32 weeks). Since our study population excluded infants that died, the right-skewed distribution of the LOS caused fewer challenges for modeling than in studies that included infants that died.[20] Similar to previous studies comparing LOS among NICU survivors, multivariable linear regression models had normally distributed residuals and were used for this analysis.[5] Adjustment variables were selected based on their know association with LOS in neonates[6]: GA in weeks, sex, small for GA status and multiple births. Negative binomial generalized linear models also showed adequate fit and were used as sensitivity analysis using the same adjustment variables. We did not adjust for multiple comparisons. All analyses were performed using R version 3.6.0 (R Foundation for Statistical Computing, Vienna, Austria). A two-sided P value < 0.05 was considered statistically significant.

Results

A total of 3820 infants born 23–32 weeks GA were admitted to the 5 participating NICUs during the study period **(Supplementary Fig. 1)**. Of those, 432 infants were excluded: 42 were moribund on admission or admitted for palliative care, 93 had major congenital anomalies, 286 died before discharge and 11 had missing discharge date. The final study population included 3388 infants.

Among included infants, 1245 (37%) were born < 29 weeks GA, 337 (10%) were small for GA and 960 (28%) were multiple births (Table 1). Median length of stay was 51 days [IQR 28–86] and median corrected GA at discharge was 37 weeks [IQR 35–40]. Median NICU occupancy prior to infant discharge was 90% [IQR 84–95]. Among all infants born < 33 weeks, 1883 (56%) were discharged home and 1504 (44%) to other units (either a Level 2 NICU or another unit within the hospital). A higher proportion of infants born < 29 weeks GA were discharged home compared to those born 29–32 weeks (70% vs. 45%). There were 122 infants (4.0%) readmitted to a Level 3 NICU after initial discharge/transfer (23 were readmitted from home and 101 were readmitted from another unit). Infants discharged home from the NICU had lower GA at birth and longer LOS than infants transferred to another unit **(Supplementary Table 1)**

Table 1
Characteristics of the study population (n = 3388)

Variables	Value
Infant characteristics	
Gestational age, weeks	30 [27–31]
Gestational age group	
23–25 weeks	391 (12)
26–28 weeks	854 (25)
29–30 weeks	823 (24)
31–32 weeks	1320 (39)
Birth weight, grams	1340 [980–1680]
Male sex	1809 (53)
Small for gestational age	337 (10)
Multiple births	960 (28)
Caesarean birth	2258 (67)
Apgar score at 5 min < 7	968 (29)
SNAP-II score > 20	400 (12)
Discharge characteristics	
Length of stay, days	51 [28–86]
Corrected gestational age at discharge, weeks	37 [35–40]
Discharge destination	
Home	1883 (56)
Other unit (within hospital or Level 2 site)	1504 (44)
Discharge home from Level 3 NICU in subgroups	
Subgroup of infants born < 29 weeks	875/1245 (70)
Subgroup of infants born 29–32 weeks	1008/2143 (45)
Readmitted to a Level 3 NICU	122 (4)

Data presented as n (%) for categorical variables and median [IQR] for continuous variables

Abbreviations: NICU, neonatal intensive care unit; SNAP-II, Score for Neonatal Acute Physiology version II

Variables	Value
From home	23 (1)
From other unit (within hospital or Level 2 site)	101 (3)
Readmitted to a Level 3 NICU in subgroups	
Subgroup of infants born < 29 weeks	52/1245 (4)
Subgroup of infants born 29–32 weeks	70/2143 (3)
Data presented as n (%) for categorical variables and median [IQR] for continuous variables	
Abbreviations: NICU, neonatal intensive care unit; SNAP-II, Score for Neonatal Acute Physiology version II	

Unit occupancy quintiles correlated with probability of discharge (Spearman's rank correlation coefficient = 0.69, $p < 0.01$). When unit occupancy was in the lowest quintiles (Q1 and Q2) infants were, respectively, 12% and 11% less likely to be discharged than expected (Fig. 1). When unit occupancy was highest (Q5), infants were 20% more likely to be discharged. Subgroup analysis by GA group showed similar results for infants born 29–32 weeks GA, but discharges occurred within expected rates for all occupancy quintiles among infants born < 29 weeks. In the subgroup of infants discharged to another unit, occupancy in the highest quintile (Q5) was associated with a higher probability of discharge, with comparable effect directions among infants discharged home (Fig. 2). Analyses stratified by individual NICUs showed similar results **(Supplementary Table 2).** Among infants admitted to the 4 NICUs with NPR data (n = 2325), median NPR prior to discharge was 1.03 [IQR 0.89–1.22]. Discharges occurred within expected rates for all NPR quintiles, suggesting no association between NPR and probability of discharge **(Supplementary Table 3**).

Infant characteristics were statistically similar across quintiles of NICU occupancy prior to discharge (Table 2). Total LOS and corrected GA at discharge were lower for infants in the highest occupancy quintile (Q5). Discharge destination did not vary significantly between occupancy quintiles among infants < 29 weeks. Among infants born 29–32 weeks GA, more infants were discharged to another unit in Q5 than in lower quintiles of occupancy. There was no statistically significant difference in readmission rates among occupancy quintiles. Multivariable analysis of all infants born < 33 weeks GA showed that higher occupancy prior to discharge (Q5) was associated with a 4.7-day (95% CI 1.7–7.7) reduction in LOS compared Q1 (Table 3). Subgroup analyses showed similar results only among infants born 29–32 weeks GA. Analysis of LOS using negative binomial generalized linear models also showed similar results **(Supplementary Table 4).**

Table 2

Infant characteristics according to quintile of occupancy prior to discharge

Variables	Quintile 1 (lowest)	Quintile 2	Quintile 3	Quintile 4	Quintile 5 (highest)	P-value
	N=593	N=604	N=675	N=704	N=812	
Infant characteristics						
Gestational age, weeks	29 [27-31]	30 [27-31]	30 [27-31]	30 [27-31]	30 [28-31]	**0.03**
Gestational age group						**0.03**
<29 weeks	234 (39)	237 (39)	258 (38)	253 (36)	263 (32)	
29-32 weeks	359 (61)	367 (61)	417 (62)	451 (64)	549 (68)	
Birth weight, grams	1300 [950-1685]	1300 [950-1650]	1330 [980-1650]	1350 [1000-1700]	1390 [1020-1690]	0.12
Male sex	309 (52)	307 (51)	373 (55)	378 (54)	442 (54)	0.51
Small for gestational age	57 (10)	73 (12)	58 (9)	70 (10)	79 (10)	0.34
Multiple births	155 (26)	168 (28)	207 (31)	201 (29)	229 (28)	0.51
Caesarean birth	401 (68)	407 (68)	473 (70)	446 (64)	531 (66)	0.11
Apgar at 5 min <7	177 (31)	187 (31)	186 (28)	204 (29)	214 (27)	0.26
SNAP-II score >20	74 (12)	84 (14)	81 (12)	76 (11)	85 (11)	0.30
Discharge characteristics						
Length of stay, days	56 [31-89]	59 [29-89]	53 [29-86]	51 [30-86]	44 [23-80]	**<0.01**
Corrected gestational age at discharge, weeks	37 [35-40]	37 [35-40]	37 [35-40]	37 [35-40]	36 [34-39]	**<0.01**
Discharge destination among all infants <33 weeks						**0.03**
Home	340 (57)	351 (58)	381 (56)	399 (57)	412 (51)	

Other unit	253 (43)	252 (42)	294 (44)	305 (43)	400 (49)	
Discharge destination among subgroup of infants <29 weeks						0.71
Home	164 (70)	173 (73)	184 (71)	170 (67)	184 (70)	
Other unit	70 (30)	64 (27)	74 (29)	83 (33)	79 (30)	
Discharge destination among subgroup of infants 29-32 weeks						**0.04**
Home	176 (49)	178 (49)	197 (47)	229 (51)	228 (42)	
Other unit	183 (51)	188 (51)	220 (53)	222 (49)	321 (58)	
Readmitted to a Level 3 NICU	24 (4)	26 (4)	27 (4)	22 (3)	23 (3)	0.50

Data presented as n (%) for categorical variables and median [IQR] for continuous variables

Abbreviations: NICU, neonatal intensive care unit; SNAP-II, Score for Neonatal Acute Physiology version II

P-values derived from the Chi-square test for categorical variables and Kruskal-Wallis test for continuous variables

Table 3
Multivariable linear regression analysis for association of length of stay and NICU occupancy quintile among infants born < 33 weeks and among gestational age subgroups

Variables	**Coefficient, days (95% CI)**		
	All infants born < 33 weeks	**Subgroup of infants** **born < 29 weeks**	**Subgroup of infants** **born 29–32 weeks**
Gestational age (1 week increase)	**-13.3 (-13.7, -12.8)**	**-14.4 (-16.1, -12.8)**	**-11.2 (-12.2, -10.2)**
Male sex	-0.8 (-2.8, 1.1)	0.8 (-3.3, 4.8)	-1.8 (-3.8, 0.2)
Small for gestational age	**18.9 (15.3, 22.5)**	**25.1 (17.6, 32.6)**	**16.1 (12.1, 20.0)**
Multiplicity	**2.7 (0.8, 4.6)**	**7.1 (3.3, 11.0)**	0.3 (-1.8, 2.4)
Occupancy quintiles			
Quintile 1 (lowest)	Reference	Reference	Reference
Quintile 2	0.6 (-3.0, 4.2)	-0.3 (-7.2, 6.5)	0.7 (-3.2, 4.7)
Quintile 3	-1.7 (-4.6, 1.3)	-2.9 (-8.2, 2.5)	-1.2 (-4.6, 2.1)
Quintile 4	-1.0 (-4.0, 2.0)	-2.4 (-7.9, 3.2)	-0.6 (-4.1, 2.8)
Quintile 5 (highest)	**-4.7 (-7.7, -1.7)**	-3.1 (-9.3, 3.0)	**-5.8 (-9.0, -2.5)**
Model variables included: gestational age (weeks), sex, small for gestational age status and multiple births, occupancy quintile			

Discussion

In this multicenter center study of 3388 infants admitted in a regionalized healthcare system, we found that higher NICU occupancy is associated with a higher probability of discharge and shorter LOS in Level 3/4 NICUs among preterm infants born < 33 weeks GA. When unit occupancy was in the lowest quintiles, preterm infants were 11–12% less likely to be discharged than expected. These results were mainly attributed to differences in discharge practices among infants 29–32 weeks.

The increase in discharge probability at higher NICU occupancy correlated with a higher proportion of infants being transferred to other units. This suggests that in a centrally coordinated, regionalized neonatal healthcare system, Level 3/4 NICUs increase transfers to Level 2 NICUs or other units in periods of high occupancy in order to reduce NICU strain and maintain capacity for new admissions. This is consistent with previous reports showing higher probability of discharge of infants born 30 to 34 weeks GA in periods of high occupancy in the United States.[8] We did not find an association between NICU occupancy and discharge for premature infants born < 29 weeks. This may be attributable to small sample size for this subgroup. It is also possible that since a majority of infants born < 29 weeks are discharged directly home from Level 3/4 NICUs, the discharge planning is less influenced by NICU occupancy and may rather be dependent on family education and patient clinical status. Indeed, previous studies have shown that differences in available resources for home follow-up care and type of home care resources provided (gavage, oxygen, etc.) likely contribute to variations in length of stay among preterm infants born < 29 weeks.[5, 21, 22]

Overall, we observed that NICUs in the province operated at high occupancy (median occupancy per shift 90%, IQR 84–95), similar to other NICUs in Canada.[23] The analyses stratified by NICU also showed similar associations between higher probability of discharge at the highest occupancy quintile, suggesting similar practices in discharge and transfer criteria between the NICUs included in this study. Specifically, this may be explained by the presence of pre-defined admission criteria for Level 2 NICUs across the province and harmonized publicly managed home care resources.

In the secondary analyses using available nursing data from 4 sites, we did not observe a significant association between NPRs prior to discharge and probability of discharge. Nursing ratios have previously been associated with several patient outcomes like mortality, nosocomial infection and medical incidents in the NICU,[24, 25, 26] but there have been conflicting reports on its association with discharge or length of stay. Some studies have shown that lower NPRs may increase NICU strain and prompt earlier discharge,[8] whereas others have suggested that higher NPRs may lead to earlier discharges by improving discharge preparation and allowing more patient education.[17, 18].

The association of unit occupancy with probability of discharge highlights how organizational factors, such as unit occupancy, may influence clinicians' behavior on discharge or transfer planning. This is suggested by previous NICU and adult ICU studies which found that higher unit occupancy was associated with higher discharge rates and higher numbers of premature discharges.[8, 27, 28] Contrary to recovering adult patients whose discharge from the ICU to wards is linked to high risk of readmission,[29] preterm infants transferred to a Level 2 NICU in Quebec are generally at lower risk of clinical deterioration due to required stability criteria for transfer as highlighted by the low readmission rate after discharge from Level 3 NICU in our cohort. The variations in discharge and LOS based on occupancy also suggests that there may be a possibility to improve the efficiency of discharge planning. Considering the persistent challenge of finite resources in healthcare, there is a vital need to identify interventions that reduce LOS and standardize discharge planning.

Strengths and limitations

This study included a large and contemporary cohort of infants, with patient data obtained from a validated dataset. Further, occupancy was calculated as the mean over 7 shifts (2 days prior to and the morning of discharge) and not only one daily assessment, which allowed to better account for shift-by-shift fluctuations in occupancy. Our results were consistent using two different statistical approaches (SR for discharge probability and multivariable linear regression for LOS). Nevertheless, this study is subject to limitations. First, we did not have complete NPR data for all sites or information on nursing level of experience, which may contribute to discharge planning and NICU strain. Second, we did not have data on occupancy in Level 2 NICUs and geographic distances between hospitals and family homes, which can affect patient transfers between hospitals. Third, this was an observational study, which prevents inference of causation without more details on the decision-making process for discharge planning. Fourth, we did not have data on emergency department visits without readmission to Level 3 NICU and on parent satisfaction and stress prior to discharge.

Conclusions

In conclusion, higher NICU occupancy was associated with higher probability of discharge from Level 3/4 NICUs of very preterm infants born < 33 weeks in a regionalized healthcare system, suggesting that providers integrate organizational variables in their clinical decision-making for discharge planning. This association was mainly attributable to the subgroup of infants born 29–32 weeks. More research is required to identify strategies to harmonize discharge planning and reduce length of stay in the NICU.

Abbreviations And Acronyms

CI Confidence interval

GA Gestational age

LOS Length of stay

NICU Neonatal intensive care unit

NPR Nurse-to-patient ratio

Q Quartile

SNAP-II Score for Neonatal Acute Physiology version II

SR Standardized ratio

Declarations

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Conflicts of Interest

The authors have no conflicts of interest relevant to this article to disclose.

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Figures

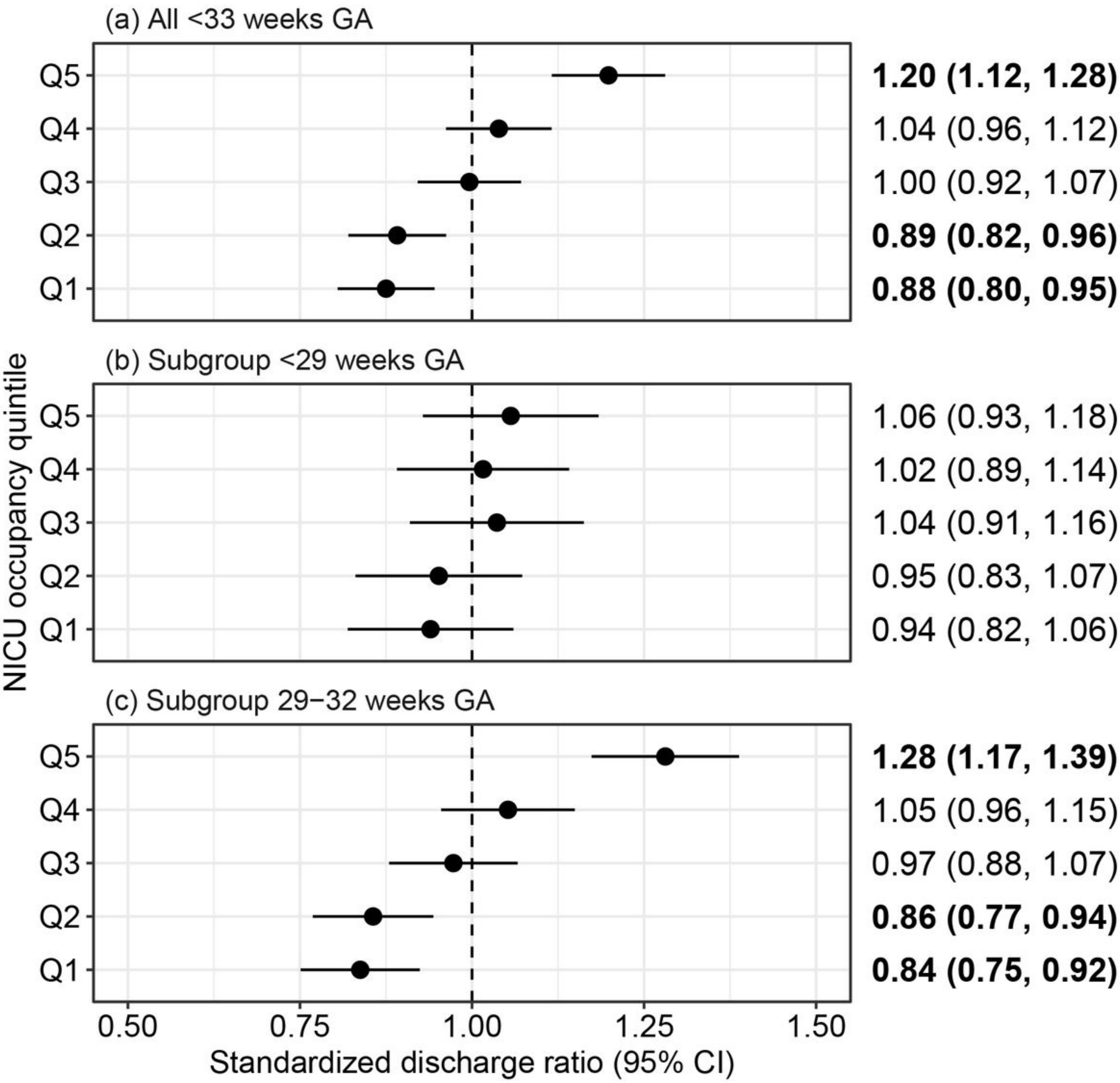

Figure 1

Standardized ratios for probability of discharge according to NICU occupancy quintiles

Legend: Among (a) all infants born <33 weeks, (b) subgroup of infants born <29 weeks and (c) subgroup of infants born 29-32 weeks. Occupancy quintiles from lowest (Q1) to highest (Q5).

Abbreviations: CI, confidence interval; GA, gestational age

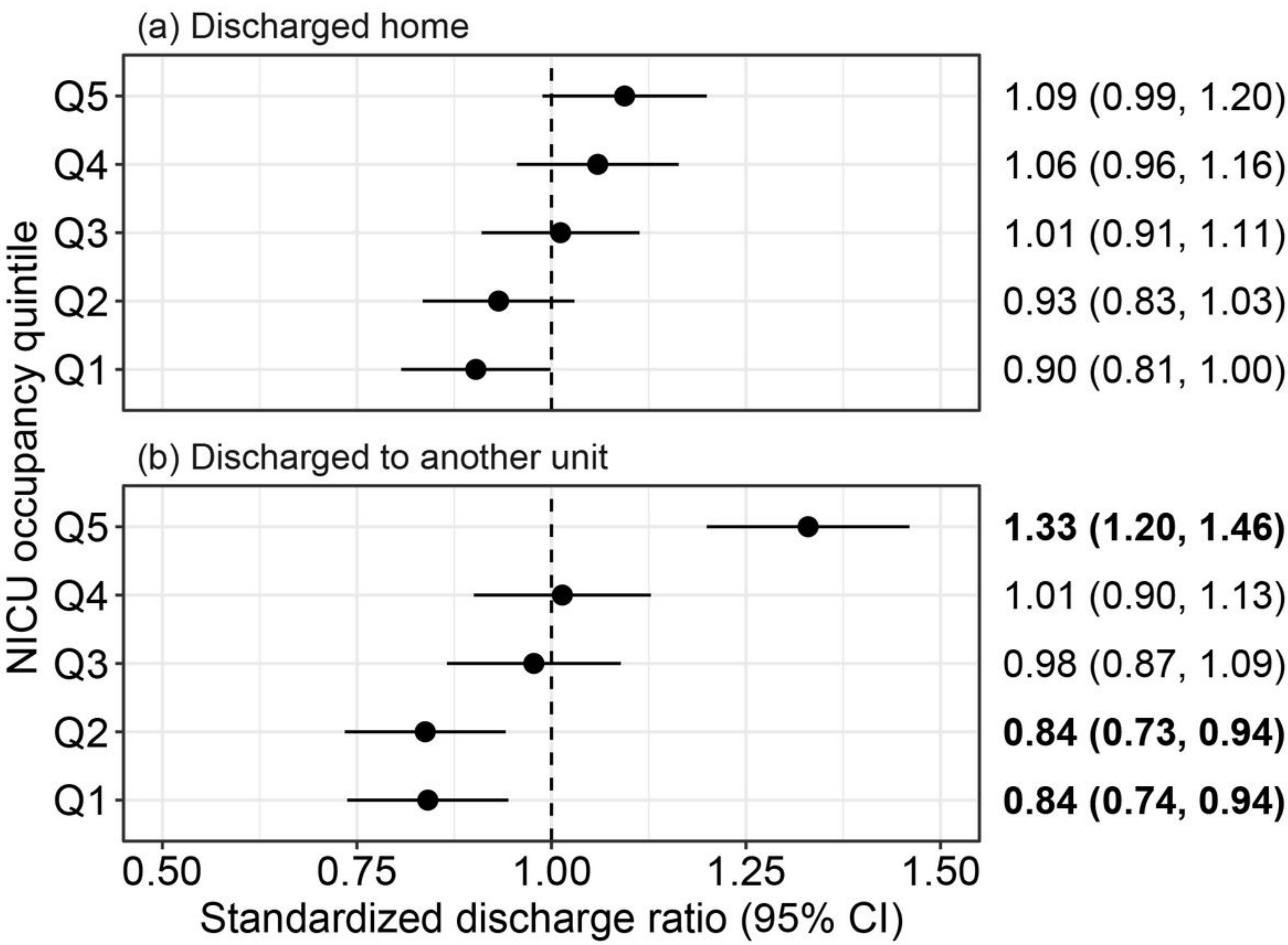

Figure 2

Standardized ratios for probability of discharge by NICU occupancy quintile stratified according to discharge destination

Legend: Among (a) infants born discharged home from Level 3/4 NICU (b) infants discharged to other unit from Level 3/4 NICU. Occupancy quintiles from lowest (Q1) to highest (Q5).

Abbreviations: CI, confidence interval; GA, gestational age

Supplementary Files

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