Regional Variation in Neonatal Intensive Care Admissions and the Relationship to Bed Supply

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Objective To characterize geographic variation in neonatal intensive care unit (NICU) admission rates across the entire birth cohort and evaluate the relationship between regional bed supply and NICU admission rates.

Study design This was a population-based, cross-sectional study. 2013 US birth certificate and 2012 American Hospital Association data were used to assign newborns and NICU beds to neonatal intensive care regions. Descriptive statistics of admission rates were calculated across neonatal intensive care regions. Multilevel logistic regression was used to examine the relationship between bed supply and individual odds of admission, with adjustment for maternal and newborn characteristics.

Results Among 3 304 364 study newborns, the NICU admission rate was 7.2 per 100 births and varied across regions for all birth weight categories. IQRs in admission rates were 84.5–93.2 per 100 births for 500-1499 g, 35.3–46.1 for 1500-2499 g, and 3.5–5.5 for ≥2500 g. Adjusted odds of admission for newborns of very low birth weight were unrelated to regional bed supply; however, newborns ≥2500 g in regions with the highest NICU bed supply were significantly more likely to be admitted to a NICU than those in regions with the lowest (aOR 1.20 [1.03-1.40]).

Conclusions There is persistent underuse of NICU care for newborns of very low birth weight that is not associated with regional bed supply. Among larger newborns, we find evidence of supply-sensitive care, raising concerns about the potential overuse of expensive and unnecessary care. Rather than improving access to needed care, NICU expansion may instead further deregionalize neonatal care, exacerbating underuse. *(J Pediatr 2017;■■:■■-■■).*

The highly specialized care provided in neonatal intensive care units (NICUs) is largely responsible for a >4-fold reduction in the neonatal mortality rate since the first NICU opened in 1960.[1,2] With continued advancement in technology and care processes, even infants born extremely premature, as young as 24 weeks' gestation, now routinely survive.[3] This reduction in mortality also has been accompanied by the reduction in some common morbidities.[4] Such care is expensive, however, with average payments of >$3000 for each day in the NICU.[5] Other adverse consequences to patients and families include the potential for iatrogenic injury, psychological distress, and altered parental roles.[6-8]

A study tracking the use of neonatal intensive care for infants with low birth weight (LBW) from 1950 to 1990 demonstrated that it was among the most cost-effective interventions in medicine as the result of the large magnitude of benefit realized over the course of a lifetime.[9] Although the necessity of neonatal intensive care for very ill newborns is well understood, larger newborns, who are on average less sick, inherently have less potential to benefit from such care yet are still exposed to many of the same risks. With expansion in the use of NICUs during the past 50 years, today the most common admission to a unit is a newborn of normal birth weight.[10] Compared with newborns of very low birth weight (VLBW), less is known about the care received by larger newborns and newborns born at term in NICUs, as well as what factors have contributed to the changing demographics of NICU admissions.

There has been only one national population-based study of neonatal intensive care use across the entire birth cohort,[10] and none that examines regional differences in admission rates. This study examines geographic variation in NICU admission rates for nearly the entire US birth cohort and the relationship with regional bed supply adjusted for patient characteristics. It specifically tests the hypotheses that greater variation exists among larger and more mature newborns and that greater bed supply is associated with increased likelihood of admission to a NICU after adjustment for maternal and newborn characteristics.

LBW	Low birth weight
NICR	Neonatal intensive care region
NICU	Neonatal intensive care unit
VLBW	Very low birth weight

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Methods

The study population and data are derived from the National Center for Health Statistics *Natality File*, which contains records for the entire US live birth cohort from January 1 to December 31, 2013.[11] Newborns were assigned to NICRs by county of maternal residence. NICRs represent empirically defined markets for neonatal intensive care services based on travel patterns of mothers with infants who are of LBW (<2500 g). The methods used to identify these 246 regions are described elsewhere.[12] Because NICR boundaries were defined with 1995 birth data, we assessed their current suitability using 2013 birth data. This analysis demonstrated the continued accuracy of these regions in describing perinatal care patterns with essentially unchanged median (IQR) birth localization for infants of VLBW from 0.89 (0.79-0.94) in 1995 to 0.90 (0.83-0.95) in 2003 (**Table I**; available at www.jpeds.com).

There were 3 940 764 births recorded in the US in 2013. Infants weighing <500 g were excluded (n = 5948) from analysis because they are not always considered viable and are recorded inconsistently as live births. Consistent with reporting from the Centers for Disease Control and Prevention, we also excluded births to nonresident mothers (residents include citizens, legal residents, and undocumented residents) (n = 8580). To examine the relationship between bed supply and the likelihood of admission to a NICU, births recorded with the 1989 US Standard Certificate of Live Birth (n = 374 582) were excluded, as the NICU admission variable was not added to the form until the most recent revision (2003 certificate), which had been adopted by 44 states and the District of Columbia in 2013. We also excluded births assigned to NICRs in which <80% of births were recorded with the 2003 certificate (n = 38 849; 29 NICRs), NICRs with <2000 births in 2013 (n = 12 258; 7 NICRs), and NICRs with low localization indices (n = 8271; 2 NICRs). The latter exclusion applied to NICRs in which <55% of newborns admitted to a NICU were born in the same region as maternal residence (**Appendix 1**; available at www.jpeds.com). These exclusions reduced the risk of bias due to inaccurate or systematically skewed reporting and from regions with poor market integrity. Multiple gestations (n = 120 637) and newborns with a recorded birthweight >7000 g (n = 46) also were not included in our primary analysis. Finally, records with missing data from variables used in our adjustment model were excluded (n = 67 399). Our final study population included 3 304 364 live births assigned to 208 NICRs representing 83.8% of 2013 US births. When calculating per-capita bed supply, and in ecological analysis of regional bed supply vs need, only infants <500 g and those to nonresident mothers were excluded, with analysis restricted to the same 208 NICRs with adequate reporting (n = 3 904 731).

The American Academy of Pediatrics identifies 4 levels of neonatal care.[13] Level I nurseries provide care for stable infants born at term. Level II nurseries, or intermediate care units, are capable of providing comprehensive care for moderately ill or infants born preterm, initial supportive care for high-risk infants before transfer to a higher-level unit, or convalescent care after time spent at a higher level unit. These units may "provide mechanical ventilation for brief duration (<24 hours) or continuous positive airway pressure or both."[13] Level III NICUs are capable of providing comprehensive care for high-risk and critically ill newborns including "a full range of respiratory support."[13] Level IV NICUs have the added availability of pediatric surgical subspecialists. We identified level III and IV NICU beds using the *2012 American Hospital Association Annual Survey of Hospitals*, assigning these to NICRs based on hospital location.[14] In ecological analyses of bed supply vs patient need, per-capita regional bed supply was calculated as the ratio of total NICU beds to total live births by maternal residence per NICR. In the primary analysis of NICU admission, the ratio of total NICU beds to total infants of VLBW was used to calculate a need-adjusted measure of regional bed supply. NICRs were categorized into quintiles of approximately equal numbers of births from very low to very high supply.

Our primary outcome was admission to a NICU. For birth certificate reporting, the Centers for Disease Control and Prevention defines this as "admission into a facility or unit staffed and equipped to provide *continuous* mechanical ventilator support for the newborn,"[15] approximating the American Academy of Pediatrics designation of a level III or IV NICU. Newborns who were transferred additionally were classified as a NICU admission (N = 13 396).

Statistical Analyses

Analyses were run for the overall cohort and stratified by birth weight: 500-1499 g (VLBW), 1500-2499 g (LBW), and ≥2500 g (normal birth weight). Variation in admission rates across NICRs are described with the use of descriptive statistics of median, range, IQR, and 5% to 95% range. When constructing maps to examine regional variation visually in admission rates, we used normalized rates, which represent the ratio of a region's birth weight–specific rate to the national birth weight–specific rate, showing the absolute variation in context of the underlying rate. Simple logistic regression was used to examine the crude relationship between bed supply—by quintile expressed as indicator variables—and likelihood of admission. Multilevel logistic regression with newborns nested within regions was used to adjust for maternal and newborn characteristics related to the need for neonatal intensive care, adapting a model from 2 previously published studies of neonatal intensive care.[10,16] Individual level covariates included birth weight, gestational age, sex, delivery mode (vaginal or cesarean), and maternal marital status (married or unmarried), race/ethnicity (Hispanic, non-Hispanic white, non-Hispanic black, or non-Hispanic other), age (≤19, 20-24, 25-29, 30-34, 35-39, or ≥40 years), and educational attainment (<12, 12, 13-15, or ≥16 years). Birth weight and gestational age were included as continuous linear and polynomial terms to best approximate the relationship between these variables and the likelihood of admission.[10] Bed supply quintile was included as a fixed effect explanatory variable at the NICR level using the lowest supply quintile as the reference group, as our hypothesis was that admission rates varied directly in relation to bed supply.

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