# Neighborhood Inequality and Emergency Department Use in Neonatal Intensive Care Unit Graduates

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Neonatal intensive care unit graduates residing in high-risk neighborhoods were at increased risk of emergency department use and had higher rates of social/environmental risk factors. Distances to primary care provider and emergency department did not contribute to emergency department use. Knowledge of neighborhood risk is important for preventative service reform. *(J Pediatr 2020;226:294-8).*

Prematurity rates have been increasing nationwide, increasing the rates of emergency department (ED) visits by infants.[1-3] Neonatal intensive care unit (NICU) graduates use the ED at a higher rates than well-born infants owing to increased caretaker anxiety and vulnerability.[4,5] Within the first 30 days after NICU discharge, 14% of moderately preterm infants and 17% of late preterm infants visit the ED.[1] Up to 60% of ED visits in the first 3 months of life are nonurgent and 24% of infants have >1 visit.[6,7] Increased and preventable ED use inflates costs, creates undue family stress, and suggests a weakness in primary care and discharge education and support.[4,8-11] Infant risk factors (gestational age, birth weight, specific medical morbidities, Medicaid insurance) and maternal risk factors (age, race, gravida, primary language, education, income, mental health history) have been associated with NICU graduate ED use.[1,2,6-8,12-16] High-risk neighborhoods have been associated with inadequate primary care access, inadequate mental health resources, increased rates of low birthweight, increased nonurgent ED use, increased pediatric critical care use, and increased childhood injury, rehospitalization, abuse, and mortality.[8,14-22] Patients whose home is closer to the ED or further away from their primary care provider (PCP) have been found to use the ED at a higher frequency as well.[23,24] However, it is not known whether neighborhood risk and distance also impact infant ED use after discharge from the NICU.

The study objective was to examine how neighborhood risk, distance to provider, and individual infant and maternal characteristics contributed to NICU infant ED use during the first 90 days after discharge. It was hypothesized that infant ED use would be higher for infants who live in high-risk neighborhoods and live closer to the ED relative to their PCP, compared with low-risk neighborhood infants. It was also hypothesized that established infant and maternal risk factors would be significantly associated with neighborhood risk.

| | |
|---|---|
| ED | Emergency department |
| NICU | Neonatal intensive care unit |
| PCP | Primary care provider |

## Methods

### Study Design and Population

This is a secondary analysis of a prospective cohort study consisting of 1391 preterm and full-term infants from Rhode Island and Southeastern Massachusetts hospitalized for >5 days in an 80-bed, single room, level 3-4 NICU.[13] Each infant was enrolled in a Transition Home Program, which provided enhanced transition services from the NICU through 3 months after discharge, as previously described.[13,25] This study expands on prior findings to explore the impact of neighborhood risk on infant ED visits. Institutional Review Board approval and informed consent were obtained.

### Geocoding

Family addresses were geocoded using ArcGIS v.10.4.1 (Esri, Redlands, California) and a manual review was performed to geocode unmatched addresses. If the address could not be geocoded, the infant was removed from the sample. Distances from the family address to the closest ED and family PCP were geocoded and calculated as well. Once geocoding was complete, the geocoded family addresses were assigned to Census block groups. Block group information was

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obtained from the 2010-2014 American Community Survey and 2010 US Census. The block group is the smallest geographic unit for which socioeconomic data and other neighborhood poverty markers are released.[26]

### Neighborhood Risk Index

For each block group, a neighborhood risk index was constructed using 8 highly correlated measures obtained from the 2010-2014 American Community Survey and the 2010 US Census: percent adults without high school education, percent single-parent households, percent household crowding (>1 person per room), percent renter-occupied housing units, percent vacant homes (excluding vacation homes), percent families below the federal poverty limit, percent non-white, and percent housing units built before 1950.[27] Quintiles were computed for each of the 8 measures and summed, resulting in a scale ranging from 8 to 40, with higher scores indicating greater neighborhood risk. The neighborhood risk index was categorized into high-risk (≥75th percentile) and low-risk (<75th percentile) neighborhoods.[27]

### Study Variables and Statistical Analyses

The independent variable of interest was high neighborhood risk. Additional independent variables included maternal age, race/ethnicity, non-English-speaking, gravida >1, marital status, number of people in the household, education level, child protective services involvement, domestic violence, and mental health conditions. Infant variables included birth weight, gestational age, multiple births, bronchopulmonary dysplasia, necrotizing enterocolitis, intraventricular hemorrhage grade 3-4, sepsis, days in the NICU, and health insurance status. The dependent variable was ED use in the first 90 days. Reason for ED visit and ED visits resulting in readmission were examined as well.

Infant ED use was treated as a dichotomous variable (≥1 vs none). PCP:ED distance ratio was divided into three groups: families with >2:1 PCP:ED distance ratio (ie, the PCP was located over twice as far from the family relative to the ED), families with >1:1 to 2:1 PCP:ED distance ratio (ie, the PCP was at a slightly greater distance to twice as far from the family relative to the ED), and those families with ≤1:1 PCP:ED distance ratio (ie, the PCP was the same distance or closer to the family relative to the ED). Analyses were conducted using Stata v14 (Stata, College Station, Texas). Bivariate analyses examined the association of (1) neighborhood risk with infant, maternal, and ED visit characteristics and (2) ED and PCP distance with infant ED use in the first 90 days after discharge and neighborhood risk. A $\chi^2$ test with a $P$ value of ≤.05 was defined as statistically significant. ORs, with a 95% CI, were also calculated. Continuous variables (birth weight, NICU stay duration, ED distance, and PCP distance) were assessed using a $t$ test. Multivariate logistic regressions, using gestational age, non-English speaking, maternal mental health condition, ED distance, and neighborhood risk as adjustment variables, were conducted to identify the predictive factors for infant ED use in the first 90 days after discharge. Some previously important maternal and infant risk factors for ED use were not incorporated into the multivariate model because they were included in the neighborhood risk compilation (ie, race/ethnicity), collinear with a variable included in the neighborhood risk compilation (ie, maternal education level and history of domestic abuse), collinear with one of the variables already included in the multivariate model (ie, gestational age and birth weight), and/or found to be not significant when placed into the multivariate model. ED distance was retained, given the initial hypothesis, and maternal mental health was included because past literature suggested its importance.[5,25,28]

Owing to the high proportion of multiple births (313; 24% of infants), it was necessary to adjust for clustering. This was accomplished using Stata v14 survey commands, necessitating standard error, rather than standard deviation, measurements.

## Results

Eighty-eight addresses could not be geocoded, leaving 1303 infants in the analyses. Record and location of the PCP's office could be geocoded for 1243 infants (95%). Nine women had 2 pregnancies during the study period. Of the 1303 infants, 344 (26.4%) lived in high-risk neighborhoods and 959 (73.6%) resided in low-risk neighborhoods; 243 (18.6%) used the ED ≥1 time in the first 90 days, with 43 (3.3%) using it ≥2 times. In bivariate analyses, maternal and infant characteristics significantly associated with high neighborhood risk were age <20 years old, non-white race/ethnicity, non-English speaking, gravida >1, not married, total in home >4, high school education or less, child protective services involvement, a history of domestic violence, birth weight, early preterm gestational age (<32 weeks), sepsis, days in the NICU, and Medicaid insurance (**Table I**).

High neighborhood risk was significantly associated with ED use in the first 30 and 90 days after discharge. In the first 30 days, 13.7% of infants in high-risk neighborhoods used the ED vs 7.4% in low-risk neighborhoods, and by 90 days, 26.2% of high-risk neighborhood infants used the ED vs 15.9% in low-risk neighborhoods. Infants in high-risk neighborhoods were more likely to visit the ED ≥2 times in the first 90 days (6.7% vs 2.1%) (**Table I**).

In **Table II** (available at www.jpeds.com), ED distance overall ($P$ = .01) and infants residing closer to the ED (<50th percentile) significantly predicted ED use (22.6% vs 14.7%; $P$ < .001), whereas distance from PCP and PCP:ED distance ratio were not significant. Infants residing closer to the ED were much more likely to be living in a high-risk neighborhood (47.9% vs 4.9%; $P$ < .001) and PCP:ED distance ratio was significantly associated with neighborhood risk. Reason for infant ED visit and ED visit resulting in readmission were not associated with neighborhood risk, even when ED visit reason was isolated to respiratory illness (**Table III**; available at www.jpeds.com).

**Table I. Maternal and infant characteristics associated with neighborhood risk**

| Characteristics | No. (%) (n = 1134*) | Neighborhood risk: High-risk ≥75 percentile (%) n = 306 (27.0%) | Neighborhood risk: Low-risk <75 percentile (%) n = 828 (73.0%) | OR (95% CI) | *P* value |
|---|---|---|---|---|---|
| Maternal | | | | | |
| Age <20 years | 80 (7%) | 37 (11.9%) | 43 (5.2%) | 2.5 (1.6-4.0) | <.001 |
| Race/ethnicity | | | | | |
| White | 660 (58.2%) | 65 (21.2%) | 595 (71.9%) | (ref) | (ref) |
| Hispanic | 249 (22.0%) | 155 (50.7%) | 94 (11.3%) | 15.1 (10.5-21.7) | <.001 |
| Black | 114 (10.1%) | 57 (18.6%) | 57 (6.9%) | 9.2 (5.8-14.3) | <.001 |
| Other† | 111 (9.8%) | 29 (9.5%) | 82 (9.9%) | 3.2 (2.0-5.3) | <.001 |
| Non-English speaking | 210 (18.5%) | 121 (39.5%) | 89 (10.8%) | 5.4 (3.9-7.5) | <.001 |
| Gravida >1 | 778 (68.0%) | 228 (73.6%) | 550 (66.0%) | 1.4 (1.1-1.9) | .02 |
| Not married | 583 (52.2%) | 220 (73.8%) | 363 (44.3%) | 3.5 (2.6-4.8) | .001 |
| Total in home >4 | 396 (34.9%) | 131 (42.8%) | 265 (32.0%) | 1.6 (1.2-2.1) | .001 |
| High school education or less | 462 (42.7%) | 197 (68.4%) | 265 (33.4%) | 4.3 (3.2-5.8) | <.001 |
| Child protective services | 117 (10.4%) | 47 (15.5%) | 70 (8.5%) | 2.0 (1.3-2.9) | .001 |
| Domestic violence | 87 (7.8%) | 33 (10.9%) | 54 (6.6%) | 1.7 (1.1-2.7) | .02 |
| Mental health condition | 427 (37.3%) | 106 (35.0%) | 321 (39.1%) | 0.8 (0.6-1.1) | .21 |
| Infant | n = 1303 | n = 344 (26.4%) | n = 959 (73.6%) | | *P* value |
| Birth weight (g) (mean ± SE) | 2132.7 ± 24 | 2047.6 ± 49 | 2195.4 ± 28 | 1.0 (1.0-1.0) | .009 |
| Early preterm (<32 weeks) | 306 (23.5%) | 97 (28.2%) | 209 (21.8%) | 1.4 (1.0-1.9) | .03 |
| Bronchopulmonary dysplasia | 94 (7.2%) | 28 (8.1%) | 66 (6.9%) | 1.2 (0.7-1.9) | .46 |
| Necrotizing enterocolitis | 22 (1.7%) | 9 (2.6%) | 13 (1.4%) | 2.0 (0.8-4.9) | .14 |
| Intraventricular hemorrhage 3-4 | 17 (1.3%) | 7 (2.0%) | 10 (1.0%) | 2.0 (0.7-5.6) | .20 |
| Sepsis | 27 (2.1%) | 13 (3.8%) | 14 (1.5%) | 2.7 (1.2-5.7) | .009 |
| Days in NICU (mean ± SE) | 31.2 ± 1.0 | 34.7 ± 2.2 | 28.6 ± 1.1 | 1.0 (1.0-1.0) | .01 |
| Medicaid insurance | 680 (52.2%) | 292 (84.9%) | 388 (40.5%) | 8.3 (5.7-12.0) | <.001 |
| Infant ED use after discharge | | | | | |
| ≥1 ED visit in ≤7 days | 36 (2.8%) | 13 (3.8%) | 23 (2.4%) | 1.6 (0.8-3.3) | .20 |
| ≥1 ED visit in ≤30 days | 118 (9.1%) | 47 (13.7%) | 71 (7.4%) | 2.0 (1.3-2.9) | .001 |
| ≥1 ED visit in ≤90 days | 243 (18.6%) | 90 (26.2%) | 153 (15.9%) | 1.9 (1.4-2.5) | <.001 |
| ≥2 ED visits in ≤90 days | 43 (3.3%) | 23 (6.7%) | 20 (2.1%) | 3.4 (1.8-6.4) | <.001 |

Substance misuse, lack of prenatal care, multiple births, home oxygen therapy at discharge, and feeding method at discharge (breast feeding vs formula vs both, with breast feeding as the reference value) were examined, but were found to be not significantly associated with neighborhood risk.
*A total of 1143 if every pregnancy is included (9 mothers had >1 pregnancy in the study duration).
†Includes American Indian/Alaskan Native, Asian/Pacific Islander, Mixed, and Other.

In the multivariable model (Table IV), variables predictive of infant ED use in the first 90 days were high neighborhood risk, non-English speaking, maternal mental health history, and early preterm gestational age. ED distance was not significant.

## Discussion

This study demonstrated that NICU graduates residing in high-risk neighborhoods had higher rates of ED use after discharge; high-risk neighborhoods were associated with increased rates of social and environmental risk factors; and ED use was significantly predicted by early preterm gestational age (<32 weeks), maternal mental health history, and non-English-speaking status, in addition to high neighborhood risk.

Although neighborhood risk significantly influenced ED use 30 and 90 days after discharge, it did not within the first 7 days. This finding may be due to the Transition Home Program or simply because the majority of infants visit their primary provider within the first week of discharge.[13] The disparity in ED use may have increased at 90 days because

**Table IV. Multivariate logistic regression model of infant ED use in the first 90 days after discharge**

| Characteristics | No. (%) | Unadjusted OR | 95% CI | *P* value | aOR | 95% CI | *P* value |
|---|---|---|---|---|---|---|---|
| Neighborhood characteristics | | | | | | | |
| High risk (≥75th percentile) | 344 (26.4%) | 1.87 | 1.37-2.54 | <.001 | 1.46 | 1.02-2.10 | .040 |
| ED distance (m) | N/A | 1.00 | 1.00-1.00* | .03 | 1.00 | 1.00-1.00* | .672 |
| Maternal characteristics | | | | | | | |
| Non-English speaking | 237 (17.1%) | 2.22 | 1.60-3.07 | <.001 | 2.18 | 1.49-3.20 | <.001 |
| Mental health condition | 427 (37.3%) | 1.45 | 1.09-1.92 | .010 | 1.62 | 1.19-2.21 | .002 |
| Infant characteristics | | | | | | | |
| Gestational age (<32 weeks) | 306 (24.7%) | 1.67 | 1.23-2.26 | .001 | 1.65 | 1.19-2.29 | .003 |

*N/A*, not applicable.
*Without rounding to the nearest hundredths decimal place, the unadjusted 95% CI is 0.999925-0.9999959 and the adjusted 95% CI is 0.9999543-1.00003.

of structural inequities that characterize the experience of families in high-risk neighborhoods, such as housing instability, adverse housing conditions, limited nutrition/food access, pollution, poverty, prejudice, and decreased access to, quality in, or trust in primary care.[8,14,15,17,22,29-31]

A strong association between high neighborhood risk and social and environmental risk factors was also demonstrated. Socioeconomic disparities can contribute to high levels of toxic stress and can manifest as a multitude of negative health outcomes.[29-33] This finding was reflected in the characteristics of our cohort in which mothers in high-risk neighborhoods were at greater odds to have an early preterm infant, be a teen mom, be non-English speaking, be unmarried, have a high school education or less, have child protective services involvement, and have experienced domestic violence. These findings further reiterate the structural inequalities between neighborhoods.[29-31,33,34]

Although early preterm birth is more likely in high-risk neighborhoods, the vulnerability of these infants extends beyond the social etiologies of ill health and neighborhood. In both high- and low-risk neighborhoods, an infant of low gestational age is more prone to neurodevelopmental, behavioral, respiratory, and cardiovascular sequelae, placing them at greater risk for future health care use.[35,36] A history of maternal mental health diagnoses has been associated with increased infant health care use, and ED use, regardless of neighborhood risk.[5,28,37,38] Language barriers have been shown to be associated with decreased quality of care and difficulty accessing primary care, leaving non-English-speaking families with access only to the ED when medical concerns arise.[8,34,39,40] Because race/ethnicity was included in the neighborhood risk index compilation, it was not included in the multivariate model. For this reason, it is difficult to determine its role in NICU graduate ED use in our study; however, prior studies support that race is an important indicator of structural inequity.[29-31,41]

Living closer to the ED was associated with both high neighborhood risk and ED use in the bivariate analyses; however, because high-risk neighborhoods closely cluster around the hospital systems in Rhode Island, this factor likely conflated the relationship between distance to the ED and ED use, making it not statistically significant, as our multivariate model suggests.

The strengths of this work include a longitudinal study of NICU graduates using geocoding to examine the impact of neighborhood risk on ED use, analyses that adjusted for environmental, psychosocial, and medical risk factors, and findings that justify using neighborhood risk to impact policy and protocols to improve outcomes for high-risk infants. We acknowledge that living in a high-risk neighborhood in Rhode Island and Southeastern Massachusetts may differ with living in a high-risk neighborhood in other parts of the country; however, given what is measured with the index (high prevalence of sociodemographic and housing characteristics known to be associated with poor health outcomes), we would expect the overall findings to be generalizable to other areas of the country.[8,14-22,27]

Limitations include the characteristics of our cohort; 100% of the families received enhanced transition home services which may have led to an underestimate of neighborhood impact and ED use rates. Second, patients were not queried directly about their use of the ED, and only the data accessed in this study are available for understanding motivation. Patients may provide information about specific issues that could be targeted in a cost-efficient manner (ie, office hours, lack of phone services, lack of (in-person] interpreting services, etc) or more systemic issues (ie, lack of health insurance). In higher income neighborhoods, parents may use urgent care centers rather than the ED if these are readily available, also potentially contributing to these findings. Third, although maternal mental health history was found to predict ED use, our data did not include specific diagnoses or illness severity. Fourth, we studied ED visits resulting in readmission, rather than ED visit urgency. Further study between NICU graduate ED visit urgency and neighborhood risk is recommended.

Increased neighborhood risk was independently associated with NICU graduate ED use, in addition to early preterm birth (<32 weeks), maternal mental health history, and non-English-speaking parents. Distances to PCP and ED did not contribute to ED use. These data provide a framework for the investigation of modifiable characteristics of neighborhoods that contribute to adverse outcomes and can potentially guide public health policy and preventative service reform. ■

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**Table II. Distance to ED and PCP associated with infant ED use and neighborhood risk**

| Neighborhood characteristics | No. (%) | ED use 90 days after discharge from NICU | | *P* value |
|---|---|---|---|---|
| | | Yes | No | |
| Total infants | 1303 | 243 (18.6%) | 1060 (81.4%) | N/A |
| Neighborhood index | | | | <.001 |
| High risk (≥75th percentile) | 344 (26.4%) | 90 (26.2%) | 254 (73.8%) | |
| Low risk (<75th percentile) | 959 (73.6%) | 153 (15.9%) | 806 (84.1%) | |
| ED distance (m) (mean ± SE) | 5560.0 ± 156 | 4870.8 ± 297 | 5718.0 ± 177 | .01 |
| Total infants | 1243* | 230 (18.5%) | 1013 (81.5%) | N/A |
| PCP distance (m) (mean ± SE) | 10 125.8 ± 312 | 9201.8 ± 562 | 10 335.6 ± 356 | .08 |
| PCP:ED distance ratio | | | | .49 |
| >2:1 | 496 (39.9%) | 99 (20.0%) | 397 (80.0%) | |
| >1:1 to 2:1 | 393 (31.6%) | 72 (18.3%) | 321 (81.7%) | |
| ≤1:1 | 354 (28.5%) | 59 (16.7%) | 295 (83.3%) | |

| Distance | No. (%) | Neighborhood risk | | *P* value |
|---|---|---|---|---|
| | | High-Risk ≥75 Percentile (%) | Low-Risk <75 Percentile (%) | |
| Total infants | 1303 | 344 (26.4%) | 959 (73.6%) | N/A |
| ED distance (m) (mean ± SE) | 5560.0 ± 156 | 2400.3 ± 79 | 6693 ± 194 | <.001 |
| Total infants | 1243* | 329 (26.5) | 914 (73.5%) | N/A |
| PCP distance (m) (mean ± SE) | 10 125.8 ± 312 | 6711.2 ± 456 | 11 354.9 ± 383 | <.001 |
| PCP:ED distance ratio | | | | .001 |
| >2:1 | 496 (39.9%) | 167 (33.7%) | 329 (66.3%) | |
| >1:1 to 2:1 | 393 (31.6%) | 81 (20.6%) | 312 (79.4%) | |
| ≤1:1 | 354 (28.5%) | 81 (22.9%) | 273 (77.1%) | |

*N/A*, not applicable.
*Record and location of the PCPs office could only be geocoded for 1243 infants (95%).

**Table III. Infant ED visit reason and/or readmission associated with neighborhood risk**

| Infant ED visit characteristics | No. (%) | Neighborhood risk | | *P* value |
|---|---|---|---|---|
| | | High risk ≥75 percentile (%) | Low risk <75 percentile (%) | |
| Total ED visits* | 306 | 128 | 178 | N/A |
| Infant ED visit reason* | | | | .079 |
| Respiratory | 118 (38.6%) | 56 (43.8%) | 62 (34.8%) | |
| Gastrointestinal | 68 (22.2%) | 28 (21.9%) | 40 (22.5%) | |
| Infection/fever | 40 (13.1%) | 13 (10.2%) | 27 (15.2%) | |
| Other | 17 (5.6%) | 4 (3.1%) | 13 (7.3%) | |
| Neurologic | 16 (5.2%) | 12 (9.4%) | 4 (2.3%) | |
| Skin/rash | 12 (3.9%) | 4 (3.1%) | 8 (4.5%) | |
| Accidents | 10 (3.3%) | 2 (1.6%) | 8 (4.5%) | |
| Crying | 9 (2.9%) | 5 (3.9%) | 4 (2.3%) | |
| Injury/child abuse | 6 (2.0%) | 2 (1.6%) | 4 (2.3%) | |
| Parent concern | 6 (2.0%) | 1 (0.8%) | 5 (2.8%) | |
| Surgery | 3 (1.0%) | 1 (0.8%) | 2 (1.1%) | |
| Cardiac issues | 1 (0.3%) | 0 (0.0%) | 1 (0.6%) | |
| ED visit resulting in readmission* | | | | .269 |
| Yes | 118 (38.6%) | 54 (42.2%) | 64 (36.0%) | |
| No | 188 (61.4%) | 74 (57.8%) | 114 (64.0%) | |
| ED visit reason resulting in readmission*,† | | | | .298 |
| Respiratory | 66 (55.9%) | 33 (61.1%) | 33 (51.6%) | |

*ED visit-level data, as opposed to infant-level data. For this reason some of the infants have multiple entries because they had multiple ED visits and/or inpatient readmissions during the study period.
†Respiratory diagnoses were examined separately given they were the most frequent reason for readmission.