

# Hospital Admission and Emergency Department Utilization in an Infant Medicaid Population

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## ABSTRACT

**BACKGROUND AND OBJECTIVE:** In the first year of life, the rate of rehospitalization for infants has been shown to be between 4.4% and 9.5%. Reducing avoidable health care utilization is a population health priority. The goal of this study was to identify maternal and infant factors associated with rehospitalization and emergency department (ED) utilization in a cohort of newborn Medicaid recipients.

**METHODS:** A longitudinal database was created by linking mother–infant dyads giving birth at a regional perinatal referral center with Delaware state Medicaid data. Multivariable logistic regression and negative binomial regression were used to examine inpatient hospitalization and ED utilization within 6 months after birth.

**RESULTS:** The study cohort included 4112 infants; 452 (11.0%) were rehospitalized, and 1680 (41%) used the ED within 6 months of birth. Variables independently associated with inpatient rehospitalization included NICU admission (odds ratio [OR]: 1.7 [95% confidence interval (CI): 1.3–2.3]), maternal bipolar diagnosis (OR: 1.5 [95% CI: 1.1–2.2]), count of maternal prenatal hospital admissions (OR: 1.3 [95% CI: 1.1–1.5]), and count of maternal ED visits (OR: 1.08 [95% CI: 1.04–1.1]). Black race (incident rate ratio [IRR]: 1.2 [95% CI: 1.1–1.3]), fall birth (IRR: 1.2 [95% CI: 1.01–1.3]), count of maternal ED visits (IRR: 1.1 [95% CI: 1.09–1.12]), number of maternal medications (IRR: 1.02 [95% CI: 1.01–1.03]), and maternal age (IRR: 0.97 [95% CI: 0.96–0.98]) were associated with ED utilization.

**CONCLUSIONS:** In this newborn Medicaid population, multiple maternal factors (including age, race, and mental health diagnoses) were associated with health care utilization in the 6 months after initial hospital discharge. Our data provide potential risk factors for targeted intervention and suggest that maternal factors should be considered in identifying a population at risk for rehospitalization and ED utilization.

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To date, many studies on rehospitalization of the newborn have investigated utilization occurring in the 30 days after initial hospital discharge.<sup>1-3</sup> Limiting analysis of hospitalization and emergency department (ED) visits to 30 days will not capture potentially important episodes of infant health care utilization that occur after this time period. During the first year of life, 4.4% to 9.5% of term infants are rehospitalized, with Medicaid patients being at increased risk compared with those with private insurance.<sup>4,5</sup> Rehospitalization and ED visits are stressful to the family and costly to the payer. Common conditions leading to early newborn rehospitalization identified in previous studies include jaundice, feeding issues, and infection.<sup>1,6,7</sup> Risk factors associated with newborn rehospitalization vary and include low gestational age, NICU stay,<sup>8</sup> and bronchopulmonary dysplasia.<sup>9</sup> The causes of newborn rehospitalization may be contextual based on discharge policies, systems of care, and social determinants.<sup>10</sup> Many studies of newborn rehospitalization have focused on specific populations, including infants receiving NICU care,<sup>9</sup> surgery for congenital heart disease,<sup>11</sup> and late preterm<sup>2</sup> or early term<sup>12</sup> infants. Most studies have not comprehensively evaluated important maternal factors, including mental health, medication use, and maternal ED use, which may contribute to infant admission or ED utilization. As payment models are changing away from fee-for-service and toward quality and risk-based payments,<sup>13,14</sup> the factors associated with infant admission and ED utilization beyond the newborn period are important to explore. Recognition of these risk factors in the perinatal period would potentially allow health care systems and/or insurance providers to develop strategies to prevent rehospitalization and ED utilization during the first 6 months of life.

We hypothesized that maternal factors, in addition to infant-level factors, would play a key role in infant rehospitalization and ED utilization at 30 days and 6 months after initial hospital discharge. Thus, the goal of the present study was to identify both maternal and infant factors that have predictive association with rehospitalization

and ED utilization in a cohort of newborn Medicaid recipients after initial hospital discharge. We also aimed to determine the diagnoses leading to hospitalization and ED utilization in the 6 months after initial hospital discharge.

## METHODS

### Setting

This study is a retrospective observational cohort analysis of infants born between January 1, 2009, and December 31, 2012, at Christiana Care Health System, a regional perinatal referral center within Delaware. Medicaid was the sole payer for mothers and infants at the time of birth in the study sample. This study was approved by the institutional review boards for both the state of Delaware and the health system involved.

### Data Collection

A database was created matching multiple-level hospital record data with Medicaid claims data from Delaware. A longitudinal patient record containing mother and infant pairs ("dyads") was created by integrating records from the hospital setting with administrative claims data from Medicaid. The data derived from electronic hospital records include clinical information concerning the course of labor and delivery, pregnancy, and nursery or NICU. Administrative claims data were provided by the Delaware Department of Medicaid and Medical Assistance. These data included fully adjudicated medical and pharmacy claims and member benefit eligibility information.

Data from both sources were integrated by using several available data elements in an iterative manner and quality checked after each step to ensure the accuracy of the matching process. Infants and mothers were first identified and their data provided by Christiana Care Health System to the research team for integration with the claims data. Matches were made with Medicaid data by using member and plan identification numbers, name elements, birth dates, and the Delaware Client Information System case numbers, which were used to confirm familial relationship between the mother and infant in the claims

data. The vast majority of dyads (>90%) were successfully integrated by using the full birth date, name elements, and case number information. For the remaining dyads (<10%), a combination of partial name elements along with phonetic algorithms were used. A manual database review of these integrated dyads was performed to ensure accuracy of matching.

For mother and infant dyads to be included in the study sample, their data had to be successfully integrated between both data sources, and the mother had to have at least 9 months of health plan eligibility before the infant's date of birth so that her baseline characteristics and utilization patterns could be assessed. Mothers and infants who were transferred from another facility or were out-of-state residents were excluded from the analysis. In addition, undocumented noncitizens with emergency labor and delivery benefits were excluded because no data outside of the birth event itself were available in either data source.

The primary outcomes for the present study were as follows: (1) inpatient rehospitalization; or (2) visits to the ED within 6 months of initial discharge from the infant birth event. Each study outcome was assessed separately. Infants who were seen in the ED, then admitted to the inpatient setting, were classified as being rehospitalized. The 6-month time period was chosen by the research team to provide a more longitudinal assessment of health care utilization than what is presently in the literature.

Administrative claims data provided by the Delaware Department of Medicaid and Medical Assistance were used to assess prenatal comorbidities and utilization patterns for the mother during each trimester. Comorbidities and complications were identified from the claims data by using *International Classification of Diseases, Ninth Revision*, codes. Prenatal health care utilization factors collected from the claims data for each trimester included measures such as: counts of inpatient and ED visits, number of unique prescriptions filled, use of controlled substances (specifically, opioid narcotics), and the Kotelchuck Index to assess adequacy of

prenatal care.<sup>15</sup> For the purposes of this study, we categorized intermediate, adequate, and intensive levels of prenatal care in the Kotelchuck Index as 1 category contrasted with inadequate care.

The electronic hospital records were abstracted from the data warehouse to identify clinical information collected during the birth event that is not routinely contained within claims data. These clinical measures included, among others, items such as gestational age, birth weight, 5-minute Apgar scores, length of hospital stay, admission to the NICU, and mother's marital status.

### Data Analysis

We sought to understand the association between infant- and maternal-level characteristics with inpatient rehospitalization for infants, tested for statistical significance ( $P \leq .05$ ), based on a logistic regression model. Exponentiated estimates were expressed as odds ratios (ORs), and 95% confidence intervals (CIs) were calculated. The Hosmer-Lemeshow test was used to assess model fit, and C-statistics were used to assess discrimination. Because it was common for infants to have  $>1$  ED visit, the statistical significance ( $P \leq .05$ ) between infant- and maternal-level characteristics and the number of ED visits occurring within 6 months of initial discharge was examined by using negative binomial regression models. The models' exponentiated estimates were expressed as the incident rate ratio (IRR), and 95% CIs were calculated. The Akaike information criterion and log-likelihood were used to assess model fit. All analyses were conducted by using SAS version 9.4 (SAS Institute, Inc, Cary, NC).

Independent variables were included in the models if the unadjusted analysis demonstrated a statistically significant relationship between the variable and the outcome of interest ( $P < .05$ ) or were known to be associated with the dependent variable. We incrementally incorporated variables from different periods of the care continuum, resulting in the creation of several statistical models (base model with infant characteristics, base plus maternal

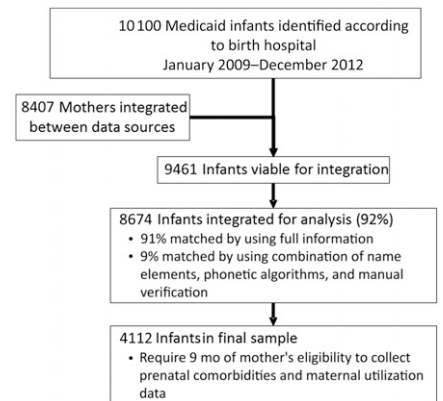
prenatal variables, and final model adding in delivery period variables). Only the final models that use the full range of available information from both infants and mothers are reported here, with a focus on hospital admissions and ED utilization occurring within 6 months from birth discharge. Secondary analyses were conducted by using the full model specification but focusing on inpatient rehospitalization or ED visits that occurred within 30 days from birth discharge.

### RESULTS

The study sample of 4112 infants was derived from a total of 10 100 infants (Fig 1). There were no differences in the included and excluded group in the proportion of premature births, very low birth weight births, infant sex, season of birth, Apgar scores, or mode of delivery (data not shown). Excluded infants were more likely to be of black race (54% vs 31%;  $P < .0001$ ) and Hispanic ethnicity (37% vs 13%;  $P < .0001$ ) compared with the included group.

The median time to rehospitalization in the 6-month study period was 52 days (interquartile range: 22–101 days; range: 2–185 days), whereas the median time to first ED visit was 70 days (interquartile range: 32–120 days; range: 2–185 days). Among the study sample, rehospitalization occurred in 178 infants (4%) by 30 days and 452 infants (11%) by 6 months. After the initial discharge, 460 (11%) infants were seen in the ED by 30 days, and 1680 infants (41%) used the ED in the 6-month study period. The diagnoses related to rehospitalization and ED visits in the 6-month study period are presented in Table 1. Regardless of setting, respiratory-related conditions were the most frequently occurring primary diagnoses.

Infants rehospitalized were of lower gestational age and birth weight and were more likely to be premature compared with infants who were not rehospitalized (Table 2). Rehospitalized infants were more likely to have a 5-minute Apgar score  $\leq 5$  and less likely to be female compared with infants not rehospitalized. Those infants who visited the ED within 6 months of initial hospital discharge were less likely to have a 5-minute Apgar score  $\leq 5$  and



**FIGURE 1** Selection criteria and sample attrition. [small]

more likely to be of black or other race/ethnicity compared with infants who did not use the ED. No other demographic differences were noted between infants who had ED visits and those who did not. Cesarean deliveries performed during the index birth event were more common in both groups of infants who were rehospitalized or who visited the ED.

After birth, infants who were rehospitalized and those who were seen in the ED had longer lengths of hospital stay before initial discharge compared with those infants not rehospitalized or seen in the ED (Table 2). Similarly, those infants who were rehospitalized were more likely to have had a NICU admission compared with those infants not rehospitalized. Infants rehospitalized were more likely to be diagnosed with jaundice, sepsis, bronchopulmonary dysplasia, or apnea before initial discharge; they were also more likely to have received mechanical ventilation and had a cord prolapse during the initial hospital visit compared with infants who were not rehospitalized. Those infants who used the ED were more likely to have received mechanical ventilation compared with those infants who did not use the ED. All other infant-related comorbidities or complications were similar and not statistically significant between the study groups.

For infants who were rehospitalized or had an ED visit, their mothers had greater mental health–related comorbidities compared with those not readmitted or

**TABLE 1** Top Reasons for Readmission and ED Visits in the 6-Month Study

| % of Readmitted   | % of Total Infants | Description  |
|-------------------|--------------------|--|
| Inpatient setting |                    |  |
| 37.6              | 4.1                | Symptoms involving respiratory system and other chest symptoms (ICD-9: 786)                            |
| 31.9              | 3.5                | Acute bronchitis and bronchiolitis (ICD-9: 466)  |
| 25.4              | 2.8                | General symptoms (ICD-9: 780)  |
| 16.8              | 1.8                | Other diseases of the lung (ICD-9: 518)  |
| 8.0               | 0.9                | Acute upper respiratory infections of multiple or unspecified sites (ICD-9: 465)                       |
| 7.1               | 0.8                | Other ill-defined and unknown causes of morbidity and mortality (ICD-9: 799)                           |
| 6.2               | 0.7                | Symptoms involving digestive system (ICD-9: 787)   |
| 5.8               | 0.6                | Other perinatal jaundice (ICD-9: 774)  |
| 5.5               | 0.6                | Viral and chlamydial infection in conditions classified elsewhere and of unspecified site (ICD-9: 079) |
| 5.5               | 0.6                | Conditions involving the integument and temperature regulation of fetus and newborn (ICD-9: 778)       |
| ED                |                    |  |
| 24.5              | 10.0               | Acute upper respiratory infections of multiple or unspecified sites (ICD-9: 465)                       |
| 22.7              | 9.3                | Symptoms involving respiratory system and other chest symptoms (ICD-9: 786)                            |
| 22.4              | 9.2                | General symptoms (ICD-9: 780)  |
| 15.2              | 6.2                | Acute bronchitis and bronchiolitis (ICD-9: 466)  |
| 12.5              | 5.1                | Symptoms involving digestive system (ICD-9: 787)   |
| 10.1              | 4.1                | Suppurative and unspecified otitis media (ICD-9: 382)  |
| 9.2               | 3.7                | Viral and chlamydial infection in conditions classified elsewhere and of unspecified site (ICD-9: 079) |
| 5.1               | 2.1                | Diseases of esophagus (ICD-9: 530)   |
| 4.9               | 2.0                | Observation and evaluation for suspected conditions not found (ICD-9: V71)                             |
| 4.5               | 1.8                | Functional digestive disorders not elsewhere classified (ICD-9: 564)                                   |

ICD-9, International Classification of Diseases, Ninth Revision.

rehospitalization, other mental health conditions, maternal prenatal inpatient admissions, and prenatal ED visits were all independently associated with increased odds of rehospitalization of the newborn. Maternal depression was associated with decreased odds of rehospitalization.

## DISCUSSION

The main findings of the present study are that numerous maternal conditions and utilization patterns, in addition to infant-level factors, are associated with subsequent health care utilization in an infant Medicaid population. Respiratory-related diagnoses were the predominant reason for both ED utilization and rehospitalization in the 6 months after hospital discharge. This study highlights the relationship that maternal factors and prenatal utilization patterns can have on rehospitalization and ED visits which occur early in an infant's life. Our study advances the literature on infant health care utilization by investigating detailed maternal-level factors, often not available in large administrative databases, in addition to robust infant-level factors.

Our study investigated rehospitalization and ED use from the perspective of a Medicaid provider and health care system discharging infants after birth. Many studies of newborn rehospitalization have focused on subgroups of infants, including term,<sup>7</sup> early term,<sup>12</sup> late preterm,<sup>1</sup> and those with congenital heart disease<sup>11</sup> or hyperbilirubinemia.<sup>3</sup> To broadly study population-level health care utilization, this study included all gestations and reasons for admission, and expanded the time of rehospitalization and ED utilization to 6 months. Our findings have important implications as health care models shift toward services that are preventative and population health based.<sup>16,17</sup> Because infant rehospitalization and ED visits were associated with maternal utilization of similar services, our results may reflect, to a degree, the pattern of families seeking care in the ED. Increased use of the ED has previously been observed in the Medicaid population.<sup>18–20</sup> Although this study was not designed to compare Medicaid versus private insurance, our results confirm that

having an ED visit (Table 3). Mothers of infants rehospitalized or seen in the ED also had higher prenatal inpatient and ED utilization and received more unique prescription fills during the prenatal period compared with infants who were not rehospitalized or those with no ED visits. No other differences in maternal characteristics or health care utilization were noted between groups.

After controlling for potential confounding variables, factors independently associated with lower ED utilization include older gestational age, white race, 5-minute Apgar score  $\leq 5$ , older maternal age, and being part of a multiple gestation birth. Fall births (compared with winter births), other

race/ethnicity (compared with white race), maternal prenatal ED visits, and number of maternal prenatal prescription fills were associated with increased ED utilization (Table 4). For the secondary analysis of 30-day ED visits, use of mechanical ventilation, maternal prenatal ED visits, and number of unique prenatal prescription fills remained positively associated with ED visits, whereas increased maternal age was associated with a reduction in ED visits.

The following variables were independently associated with rehospitalization: NICU admission, maternal bipolar diagnosis, and maternal prenatal inpatient admission (Table 4). In the secondary analysis of 30-day

**TABLE 2** Infant Demographic Characteristics and Clinical Conditions

| Variable                             | Inpatient                |                               | ED                            |                     | Total Sample<br>(N = 4112) |
|--------------------------------------|--------------------------|-------------------------------|-------------------------------|---------------------|----------------------------|
|                                      | Rehospitalized (n = 452) |                               | Not Rehospitalized (n = 3660) |                     |                            |
|                                      | Rehospitalized (n = 452) | Not Rehospitalized (n = 3660) | Visit (n = 1680)              | No Visit (n = 2432) |                            |
| Gestational age, wk                  | 37.4 ± 3.3               | 38.4 ± 2.5*                   | 38.2 ± 2.5                    | 38.3 ± 2.7          | 38.3 ± 2.6                 |
| Preterm (<37 wk)                     | 102 (22.6)               | 409 (11.2)*                   | 220 (13.1)                    | 291 (12.0)          | 511 (12.4)                 |
| Birth weight, g                      | 2956 ± 794               | 3158 ± 640*                   | 3131 ± 644                    | 3140 ± 673          | 3136 ± 661                 |
| Birth weight group                   |                          |                               |                               |                     |                            |
| >4000 g                              | 22 (4.9)                 | 210 (5.7)                     | 89 (5.3)                      | 143 (5.9)           | 232 (5.6)                  |
| <2500 g                              | 94 (20.8)                | 399 (10.9)*                   | 214 (12.7)                    | 279 (11.5)          | 493 (12.0)                 |
| <1500 g                              | 30 (6.6)                 | 103 (2.8)*                    | 52 (3.1)                      | 81 (3.3)            | 133 (3.2)                  |
| 5-min Apgar score ≤5                 | 15 (3.3)                 | 61 (1.7)*                     | 18 (1.1)                      | 58 (2.4)*           | 76 (1.8)                   |
| Sex (% female)                       | 201 (44.5)               | 1821 (49.8)*                  | 786 (46.8)                    | 1236 (50.8)         | 2022 (49.2)                |
| Race/ethnicity                       |                          |                               |                               |                     |                            |
| black                                | 231 (51.1)               | 1990 (54.4)                   | 949 (56.5)                    | 1272 (52.3)*        | 2221 (54)                  |
| White                                | 156 (34.5)               | 1108 (30.3)                   | 457 (27.2)                    | 807 (33.2)*         | 1264 (30.7)                |
| Other <sup>a</sup>                   | 65 (14.3)                | 562 (15.3)                    | 274 (16.3)                    | 353 (14.5)*         | 627 (15.2)                 |
| Birth season                         |                          |                               |                               |                     |                            |
| Winter                               | 102 (22.6)               | 939 (25.7)                    | 422 (25.1)                    | 619 (25.5)          | 1041 (25.3)                |
| Spring                               | 96 (21.2)                | 840 (23.0)                    | 337 (20.1)                    | 599 (24.6)          | 936 (22.8)                 |
| Summer                               | 124 (27.4)               | 960 (26.2)                    | 455 (27.1)                    | 629 (25.9)          | 1084 (26.4)                |
| Fall                                 | 130 (28.8)               | 912 (25.2)                    | 466 (27.7)                    | 585 (24.1)          | 1051 (25.6)                |
| Cesarean delivery                    | 172 (38.1)               | 1186 (32.4)*                  | 599 (35.7)                    | 759 (31.2)*         | 1358 (33.0)                |
| Initial hospital LOS (days, mean/SD) | 5.9 ± 15.92              | 2.1 ± 8.46*                   | 3.0 ± 11.3                    | 2.2 ± 8.3*          | 2.5 ± 9.6                  |
| NICU admission                       | 153 (33.8)               | 663 (18.1)*                   | 341 (20.3)                    | 475 (19.5)          | 816 (19.8)                 |
| Jaundice                             | 102 (22.6)               | 660 (18.0)*                   | 313 (18.6)                    | 449 (18.5)          | 762 (18.5)                 |
| Mechanical ventilation               | 70 (15.5)                | 276 (7.5)*                    | 159 (9.5)                     | 187 (7.7)*          | 346 (8.4)                  |
| Sepsis                               | 32 (7.1)                 | 88 (2.4)*                     | 55 (3.3)                      | 65 (2.7)            | 120 (2.9)                  |
| Bronchopulmonary dysplasia           | 17 (3.8)                 | 52 (1.4)*                     | 32 (1.9)                      | 37 (1.5)            | 69 (1.7)                   |
| Apnea                                | 35 (7.7)                 | 70 (1.9)*                     | 50 (3.0)                      | 55 (2.3)            | 105 (2.6)                  |
| Neonatal abstinence syndrome         | 16 (3.5)                 | 142 (3.9)                     | 65 (3.9)                      | 93 (3.8)            | 158 (3.8)                  |
| Cord prolapse                        | 25 (5.5)                 | 120 (3.3)*                    | 64 (3.8)                      | 81 (3.3)            | 145 (3.5)                  |
| Meconium-stained fluid               | 54 (11.9)                | 470 (12.8)                    | 200 (11.9)                    | 324 (13.3)          | 524 (12.7)                 |
| Nuchal cord                          | 108 (23.9)               | 847 (23.1)                    | 410 (24.4)                    | 545 (22.4)          | 955 (23.2)                 |
| Oligohydramnios                      | 8 (1.8)                  | 35 (1.0)                      | 17 (1.0)                      | 26 (1.1)            | 43 (1.0)                   |

Data are presented as mean ± SD or n (%). LOS, length of stay.

<sup>a</sup> Includes Hispanic ethnicity, Asian, Pacific Islander, and Native American.

\*  $P < .05$ .

**TABLE 3** Maternal Demographic Characteristics and Conditions

| Variable  | Inpatient                           |   | ED                          |                                | Total Sample<br>( <i>N</i> = 4112) |
|---|-------------------------------------|---|-----------------------------|--------------------------------|------------------------------------|
|   | Rehospitalized<br>( <i>n</i> = 452) | Not Rephospitalized<br>( <i>n</i> = 3660) | Visit<br>( <i>n</i> = 1680) | No Visit<br>( <i>n</i> = 2432) |                                    |
| Age on delivery date, y                                 | 25.1 ± 5.59                         | 25.4 ± 5.71                               | 24.6 ± 5.53                 | 25.9 ± 5.74                    | 25.4 ± 5.69                        |
| Married   | 80 (17.7)                           | 707 (19.3)                                | 278 (16.5)                  | 509 (20.9)*                    | 787 (19.1)                         |
| Drug or alcohol abuse                                   | 58 (12.8)                           | 397 (10.9)                                | 186 (11.1)                  | 269 (11.1)                     | 455 (11.1)                         |
| Prior Cesarean delivery                                 | 91 (20.1)                           | 732 (20.0)                                | 341 (20.3)                  | 482 (19.8)                     | 823 (20.0)                         |
| Kotelchuck Index (other versus inadequate) <sup>a</sup> | 376 (83.2)                          | 2893 (79.0)*                              | 1390 (82.7)                 | 1879 (77.3)                    | 3269 (79.5)                        |
| Prenatal visit, first trimester                         | 327 (72.4)                          | 2444 (66.8)*                              | 1190 (70.8)                 | 1581 (65.0)                    | 2771 (67.4)                        |
| Bipolar disorder  | 49 (10.8)                           | 198 (5.4)*                                | 130 (7.7)                   | 117 (4.8)*                     | 247 (6.0)                          |
| Depression disorders                                    | 72 (15.9)                           | 495 (13.5)                                | 264 (15.7)                  | 303 (12.5)*                    | 567 (13.8)                         |
| Other mental health diagnosis                           | 182 (40.3)                          | 1090 (29.8)*                              | 578 (34.4)                  | 694 (28.5)*                    | 1272 (30.9)                        |
| Prenatal inpatient (count)                              | 1.3 ± 0.74                          | 1.1 ± 0.47*                               | 1.2 ± 0.56                  | 1.1 ± 0.46*                    | 1.2 ± 0.51                         |
| Prenatal ED (count)                                     | 3.7 ± 4.06                          | 2.6 ± 2.72*                               | 3.5 ± 3.38                  | 2.2 ± 2.4*                     | 2.7 ± 2.91                         |
| Maternal unique medications (count)                     | 8.0 ± 6.22                          | 6.8 ± 5.49*                               | 7.8 ± 6.13                  | 6.4 ± 5.10*                    | 6.9 ± 5.59                         |

Data are presented as mean ± SD or *n* (%).

<sup>a</sup> Kotelchuck index was transformed into a binary variable in which “other” represents intermediate, adequate, and intensive levels of prenatal care.

\* *P* < .05.

the ED is frequently used by the Medicaid population.

Our data show that antenatal maternal utilization patterns (including the number of unique medications and ED visits, along with race and age) were associated with newborn ED utilization. Maternal factors such as bipolar diagnosis and inpatient admission during pregnancy were associated with infant rehospitalization. Three results were observed from our analyses that require further analysis. Five minute Apgar scores ≤5 and multiple gestation births were associated with decreased odds of ED utilization, whereas a diagnosis of maternal depression was associated with a decrease in 30-day rehospitalization. Because perinatal asphyxia or other conditions associated with delivery room resuscitation may have a role in later health care utilization, we chose to include the 5-minute Apgar score in our analysis as a proxy for delivery room stability. It is possible that the 5-minute Apgar score and multiple births were associated with an increase in utilization of outpatient resources, including home health or scheduled primary care visits that reduced ED utilization. The role of depression and its relation with other existing mental health conditions requires further deliberation, as the presence of

other prenatal mental health conditions was associated with increased utilization.

Although varied in nature, many of the clinical diagnoses associated with rehospitalization and ED utilization in the present study sample were related to respiratory conditions. Our study supports the recent finding that respiratory-related conditions are a frequent cause of hospital admission.<sup>5</sup> Recent studies have suggested infection, gastrointestinal illnesses, and hyperbilirubinemia as major causes for newborn rehospitalization in the first month of life.<sup>3,16</sup> Interventions to reduce rehospitalizations have concentrated on breastfeeding and hyperbilirubinemia, which drive readmissions soon after birth.<sup>21,22</sup> Our study results, in addition to the findings of Ray and Lorch,<sup>5</sup> highlight the importance of considering the length of follow-up period in designing programs to prevent hospital admission and show that preventing hospitalization and ED utilization up to 6 months will likely require a different focus compared with the first month of life.

The present study has important implications for health care systems and insurers, and it illustrates that preventing unnecessary utilization may prove challenging during the first 6 months of life. The data suggest that risk factors for 6-month rehospitalization and ED utilization

can be identified during the birth hospitalization, but that many factors, including NICU admission, race, age, and previous maternal utilization, are not modifiable. Based on our findings, trials of early case management of high-risk dyads are warranted to reduce hospitalization and ED utilization. Case management may be able to be initiated during the birth hospitalization before the mother–infant dyad is potentially lost to follow-up. Preventing respiratory-related health care utilization will be difficult. Programs to increase hand hygiene, maternal and infant immunizations, and smoking cessation are potential interventions to reduce respiratory-related utilization.

Our study has a number of strengths. We were able to explore detailed maternal risk factors derived from hospital-level data and increase knowledge on rehospitalization and ED utilization beyond the first month of life. The importance of this approach is highlighted by the finding that the median time of rehospitalization and ED utilization occurred after the first month of life, suggesting that following up infants for a longer time period may be necessary to make a substantial impact on reducing costs. Studies including a single hospital system may underestimate rehospitalization.<sup>23</sup> By integrating clinical

**TABLE 4** Multivariable Models, ED Utilization, and Rehospitalization for the First 6 Months and 30 Days

| Variable                           | Rehospitalization |                   | ED Visits         |                   |
|------------------------------------|-------------------|-------------------|-------------------|-------------------|
|                                    | 6-mo OR (95% CI)  | 30-d OR (95% CI)  | 6-mo IRR (95% CI) | 30-d IRR (95% CI) |
| Gestational age, wk                | 0.97 (0.91–1.03)  | 0.93 (0.85–1.02)  | 0.96* (0.94–0.99) | 0.95 (0.90–1.00)  |
| Female                             | 0.84 (0.69–1.03)  | 0.79 (0.57–1.07)  | 0.88* (0.81–0.97) | 0.85 (0.71–1.01)  |
| Race: black (ref = white)          | 0.81 (0.64–1.02)  | 0.80 (0.56–1.14)  | 1.17* (1.05–1.31) | 1.09 (0.88–1.35)  |
| Race: other (ref = white)          | 0.92 (0.67–1.27)  | 1.15 (0.72–1.83)  | 1.29* (1.11–1.49) | 1.28 (0.96–1.69)  |
| 5-min Apgar score ≤ 5              | 1.09 (0.57–2.10)  | 0.63 (0.20–1.99)  | 0.52* (0.34–0.80) | 0.55 (0.24–1.23)  |
| Birth weight (per 100 g)           | 0.99 (0.97–1.02)  | 0.99 (0.95–1.03)  | 1.88 (0.63–5.62)  | 1.37 (0.16–11.63) |
| NICU admission                     | 1.70* (1.29–2.25) | 1.02 (0.64–1.62)  | 1.10 (0.95–1.27)  | 1.05 (0.80–1.39)  |
| Multiple gestation                 | 1.37 (0.88–2.13)  | 1.78 (0.98–3.22)  | 0.70* (0.53–0.91) | 0.82 (0.50–1.34)  |
| Jaundice                           | 0.99 (0.77–1.28)  | 0.96 (0.65–1.42)  | 0.93 (0.82–1.05)  | 0.98 (0.77–1.24)  |
| Mechanical ventilation             | 1.25 (0.87–1.79)  | 0.99 (0.55–1.78)  | 1.17 (0.97–1.40)  | 1.41* (1.01–1.97) |
| Chronic lung disease               | 1.08 (0.58–2.01)  | 0.51 (0.15–1.76)  | 1.02 (0.72–1.45)  | 0.82 (0.41–1.62)  |
| Spring (ref: winter)               | 1.05 (0.77–1.42)  | 0.92 (0.59–1.45)  | 0.90 (0.79–1.03)  | 0.99 (0.76–1.28)  |
| Summer (ref: winter)               | 1.21 (0.91–1.60)  | 1.04 (0.67–1.59)  | 1.10 (0.97–1.24)  | 1.01 (0.79–1.30)  |
| Fall (ref: winter)                 | 1.31 (0.99–1.74)  | 1.15 (0.75–1.75)  | 1.15* (1.01–1.30) | 1.00 (0.78–1.28)  |
| Mother age (y)                     | 0.99 (0.97–1.01)  | 0.99 (0.96–1.02)  | 0.97* (0.96–0.98) | 0.97* (0.95–0.99) |
| Mother married                     | 1.00 (0.75–1.31)  | 0.93 (0.61–1.44)  | 0.92 (0.81–1.04)  | 1.00 (0.78–1.29)  |
| Mother drug/alcohol condition      | 0.80 (0.58–1.12)  | 0.93 (0.57–1.50)  | 0.96 (0.82–1.13)  | 0.96 (0.71–1.31)  |
| Mother bipolar diagnosis           | 1.53* (1.04–2.23) | 1.42 (0.81–2.50)  | 1.06 (0.88–1.28)  | 0.83 (0.55–1.23)  |
| Mother depression diagnosis        | 0.79 (0.57–1.08)  | 0.54* (0.33–0.90) | 0.97 (0.83–1.12)  | 0.97 (0.72–1.30)  |
| Mother other mental health         | 1.24 (0.96–1.61)  | 1.49* (1.01–2.18) | 1.02 (0.90–1.15)  | 0.85 (0.67–1.08)  |
| Kotelchuck Index                   | 1.06 (0.74–1.51)  | 0.86 (0.50–1.49)  | 1.07 (0.91–1.25)  | 0.99 (0.73–1.35)  |
| Prenatal visit, first trimester    | 1.12 (0.83–1.51)  | 1.17 (0.73–1.89)  | 1.06 (0.93–1.20)  | 1.00 (0.77–1.31)  |
| Mother use of opioids              | 1.14 (0.89–1.47)  | 1.19 (0.81–1.73)  | 0.96 (0.86–1.08)  | 0.91 (0.72–1.14)  |
| Mother inpatient visits (count)    | 1.28* (1.09–1.51) | 1.44* (1.16–1.78) | 1.02 (0.94–1.11)  | 1.01 (0.87–1.17)  |
| Mother ED visits (count)           | 1.08* (1.04–1.12) | 1.07* (1.02–1.12) | 1.11* (1.09–1.12) | 1.07* (1.05–1.10) |
| Mother unique medications          | 1.00 (0.98–1.02)  | 1.00 (0.97–1.03)  | 1.02* (1.01–1.03) | 1.04* (1.03–1.06) |
| Model Akaike information criterion | —                 | —                 | 8897              | 3163              |
| Model C-Statistic                  | 0.67              | 0.66              | —                 | —                 |

\*  $P < .05$ .

information from a regional hospital with administrative claims data from a state Medicaid plan, we were able to capture postnatal utilization of infants regardless of location.

Our study is not without its limitations, however. It is likely that there are socioeconomic, paternal, and clinical factors responsible for unmeasured confounding that were unobtainable from the data sources. To assess antenatal maternal conditions, our final sample required the infant's mother to have 9 months of Medicaid eligibility. Although the included and excluded population differed only in race/ethnicity, it is likely that there were some additional unobserved

biases introduced into the study by exclusion of undocumented immigrants. The exclusion of some black and Hispanic dyads that did not have 9 months of consecutive Medicaid eligibility before birth may also have led to some selection bias in the formation of the final study group. Because we relied on administrative data, coding errors may be present that could affect the study results. No chart review was conducted specifically for this study; however, the state of Delaware works closely with their plan administrators for billing and payment purposes to routinely audit and monitor information that is submitted on medical and pharmacy claims. Although we could not account for planned

admissions, most of the diagnoses related to admission were associated with acute disease processes, and thus the influence of planned admissions was likely minimal. We did not analyze primary care utilization as a modifier of rehospitalization or ED use, as has been done in other studies.<sup>20</sup> These variables were not considered because we took the perspective of a health system discharging infants at the time of birth when use of subsequent primary care visits would not be known.

## CONCLUSIONS

Our study is unique in investigating a cohort of infants receiving Medicaid for 6 months after hospital discharge. Respiratory-related illnesses were the leading causes of both

admission and ED utilization. Importantly, we were able to include robust maternal factors in the models. Our study provides potential clinical targets for early case management to prevent rehospitalization of a high-risk population. We could not determine from the study the efficacy of any potential interventional strategies. Ongoing investigation will be required to determine the scope and types of intervention that would work to diminish unnecessary health care utilization in the infant Medicaid population.

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