Incidence, Risk Factors, and Reasons for 30-Day Hospital Readmission among Healthy Late Preterm Infants

Abstract

Objective: Late preterm infants have an increased risk of morbidity relative to term infants. We sought to determine the rate, temporal trend, risk factors, and reasons for 30-day readmission.

Study design: This is a retrospective cohort study of infants born at 34 to 42 weeks' gestation in California between January 1, 2011, and December 31, 2017. Birth certificates maintained by California Vital Statistics were linked to discharge records maintained by the California Office of Statewide Health Planning and Development. The readmission rate was calculated as the proportion of infants who were discharged and readmitted within 30 days. Multivariable logistic regression was used to identify risk factors and derive a predictive model.

Results: Of 172,902 late preterm infants, 10,238 (5.9%) were readmitted within 30 days. Compared with term infants, late preterm infants had greater odds of readmission (OR: 2.28 [95% CI: 2.23-2.33]). The temporal trend indicated increases in all-cause and jaundice-specific readmission among late preterm infants ($p<0.001$) from 2011 to 2017. The common diagnoses at readmission were jaundice (52%), infections (13%), and respiratory complications (4%). In the adjusted model, factors that were associated with greater odds of readmission included assisted vaginal birth, maternal age ≥34 years, diabetes, chorioamnionitis, and primiparity. The model had poor predictive ability (c-statistic 0.573 [95% CI: 0.567-0.579]).

Conclusion: The findings contribute important information on what factors increase or decrease the risk of readmission. Future research is needed to examine tailored predischarge and follow-up care practices that could reduce the rate of hospital readmission among late preterm infants.

Introduction

One in ten infants in the United States is born preterm (before 37 completed weeks of gestation). Late preterm infants (LPTs), born at 34 0/7 to 36 6/7 weeks' gestation, account for the majority (73%) of preterm births.[1] The recent increase in preterm birth in the United States (9.57% in 2014 to 10.23% in 2019) is mostly attributed to an increase in LPTs.[1,2] LPTs are physiologically and metabolically immature and are at increased risk of respiratory distress and other complications during birth hospitalization.[3,4] Moreover, compared to term infants, LPTs have a greater risk of neonatal death (<28 days) and infant mortality (<1 year) and a two- to three-fold increased rate of readmission in the neonatal period.[5,6] Indeed, an estimated 4-8% of LPTs are readmitted to the hospital within 28-30 days of birth.[7,8] Despite these data, much of the literature on prematurity is focused on very preterm (<34 weeks' gestation) and very low birthweight (<1500 gram) infants.[2] An American Academy of Pediatrics (AAP) report in 2019 underscored the need for more evidence to prevent morbidity and improve the outcomes of LPTs.[2]

Although reducing unplanned hospital readmissions soon after discharge is a marker for improved quality of care, its use is problematic in the case of neonatal inpatient care, as factors other than healthcare quality may influence readmissions. Concern that discharge of mothers and their newborns too early or at less than 48 hours after birth could be associated with early readmission led to enactment of the federal law, "Newborns' and Mothers' Health Protection Act," in 1996.[9] This mandated that insurers may not restrict hospital stays to less than 48 hours and 96 hours, respectively, for vaginal and cesarean childbirth. The enactment of this mandate and recommendations from AAP led to a sharp decline in early discharge (i.e., within 48 hours of vaginal birth) among term and late preterm infants.[10,11] However, studies conducted before

and after the mandate reported conflicting findings on the association between duration of birth hospitalization and readmission rate, with some reporting that a short length of stay was associated with increased risk of readmission and others finding no statistically significant association.[8,12,13] Efforts to minimize the risk of readmission due to hyperbilirubinemia through bilirubin measurement at birth admission have also been implemented with varied success.

As such, targeted assessment of LPT health before discharge may prove useful. The AAP recommends that the duration of birth hospitalization be tailored.[14,15] However, in the absence of complications, the majority of LPTs receive similar care as term infants during birth hospitalization.[7] Birth hospitalization discharge can be anticipated in the absence of comorbidity, feeding problems, apnea, or failure to maintain body temperature. Current AAP guidelines and readiness for discharge assessment do not provide tailored vulnerability rankings of LPTs. Universal recommendations such as prolonging the duration of birth hospitalization, based solely on gestational age, are neither desirable nor likely to change outcomes. Therefore, identifying other potentially modifiable factors or ways to differentiate at-risk LPTs might be useful. Few studies have investigated maternal and infant variables associated with readmission. The aims of this study were to compare the rate of 30-day readmission among LPT to term infants using the most recent data from California; evaluate temporal trends, determine precipitators, and identify maternal and infant characteristics associated with readmission; and test the performance of a predictive model. By including readily available maternal, infant, and socioeconomic variables in our study, we aim to determine new factors that might be associated with readmission. As hyperbilirubinemia has been identified as one of the primary reasons for readmission in previous studies,[8,15,16]our study, also examined the temporal trend of readmission due to jaundice.

Methods

Study design

This is a retrospective cohort study of infants born at 34 to 42 weeks' gestation between January 1, 2011, and December 31, 2017, in California. Birth certificates maintained by California Vital Statistics were linked to hospital discharge records maintained by the California Office of Statewide Health Planning and Development (OSHPD). The OSHPD database contains detailed information on maternal and infant characteristics as well as discharge diagnoses and procedures, and has previously been linked effectively with California Vital Statistics.[17] Hospital discharge files provided diagnosis and procedure codes based on the International Classification of Diseases, 9th and 10th Revisions, Clinical Modification (ICD-9-CM, ICD-10-CM), as reported to the California OSHPD by healthcare facilities.[18] The OSHPD database has been previously used for studies investigating the association between maternal and infant characteristics at birth and neonatal outcomes.[18,19] Neonates had to meet the following criteria to be eligible: born at 34 0/7 to 42 6/7 weeks' gestation; not admitted to a neonatal intensive care unit (NICU) during birth hospitalization; no major congenital anomalies; not transferred from another hospital at birth; and discharged alive from birth hospitalization. By excluding neonates who needed specialized care, we were able to restrict our sample to those who were presumed healthy at birth.

The primary outcome was hospital readmission within 30 days of birth. To avoid double counting of infants who had multiple readmissions in the neonatal period, only initial readmission data were extracted. Gestational age at birth was categorized as late preterm (34-36 weeks), early term (37-38 weeks), and term (39-42 weeks), in accordance with AAP guidelines.[2] Birthweight was categorized as very low (<1500 grams), low (1500-2499 grams), normal (2500-

3499 grams), and high (≥3500 grams). Hospital discharge records were the source of information for primary readmission diagnoses.

Socioeconomic, demographic, and maternal and infant characteristics were selected for inclusion in the modeling process based on our conceptual model that was informed by literature review, biological plausibility, and availability of data.[7,8,13,20,21,22] Candidate variables included duration of birth hospitalization, sex, birthweight, mode of delivery, adequacy of prenatal care, payer at the time of delivery, race/ethnicity, maternal educational level, maternal age, maternal diabetes (gestational and preexisting), maternal hypertension (gestational and preexisting), perinatal smoking, chorioamnionitis, and parity. Adequacy of prenatal care was assigned according to the Kotelchuck adequacy of prenatal care utilization index.[23] The Kotelchuck index uses time of prenatal care initiation and number of perinatal visits to categorize prenatal care into four levels: inadequate (<50% of expected visits), intermediate (50-59% of expected visits), adequate (80-109% of expected visits), and adequate plus (≥110% of expected visits).

Statistical analysis

Descriptive statistics were used to characterize the timing and precipitators of readmission. Demographic, maternal, and infant variables were summarized using means with standard deviations for continuous variables or frequencies for categorical variables. We applied the chi-square test to compare the risk of readmission. The Mann-Kendall trend test was used to assess the temporal direction of all-cause and jaundice-specific readmission by gestational age. Multivariable logistic regression was used to estimate adjusted odds ratios (aOR) with 95% confidence intervals (CI). All candidate variables were included in a complete multivariable

model for predicting 30-day readmission among late preterm infants. This model was simplified using reverse stepwise selection, with the least statistically significant variable eliminated at each step. Model performance was evaluated by estimating the c-statistic, which is equivalent to the area under the receiver operating characteristic curve. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC).

The study was approved by the Committee for the Protection of Human Subjects within the Health and Human Services Agency of the State of California.

Results

Cohort characteristics and rate of readmission

Among 2,960,753 infants in the study cohort, LPTs represented 5.8% (n=172,902). Our sample had a slightly higher proportion (53.2%) of male LPTs. Over half (60.6%) of LPTs had a normal birthweight (≥2500 grams) and 48.4% were born via cesarean section. The average duration of birth hospitalization was 5 days, with a slightly shorter duration among those who were readmitted. Most mothers (79.6%) of LPTs had adequate or adequate-plus prenatal care. The readmission rate varied by gestational age, with infants born at 35 weeks having the highest rate (6.5%), infants born at 34 or 36 weeks having the second highest rate (5.7%), and term infants having the lowest rate (≤2.8%). LPTs had increased odds of readmission compared with term infants (OR 2.28 [95% CI: 2.23-2.33]). Similarly, early-term infants had greater odds of being readmitted than term infants (OR 1.41 [95% CI: 1.39-1.44]) (Table 1).

Temporal trend

The trend in all-cause readmissions over time increased for LPTs (p-value <0.001), remained stable in early-term infants, and slightly decreased for term infants (p-value <0.001) (Figure 1a). A similar trend was observed among infants admitted for jaundice. The trend in the proportion of babies readmitted due to jaundice increased for LPTs, remained stable in early-term infants, and declined in term infants (p-value <0.001) (Figure 1b).

Timing and precipitators of readmission

Readmissions occurred mostly in the first 15 days of life for all neonates (77.5%), with the highest proportion on day 3 (15.6%), day 4 (16.0%), and day 5 (11.7%). The principal diagnosis of readmission was jaundice (70.2%) in the first week and jaundice (24.8%) or infection (26.0%) in the second week for all neonates. Mirroring the overall timing of readmission for all infants in the sample, most LPTs (61.6%) were readmitted in the first week of life. The primary precipitators of 30-day readmission among LPTs were jaundice (51.8%), infection (13.1%), temperature instability (4.8%), respiratory complications (4.1%), and gastrointestinal symptoms (3.4%) (Table S1).

Risk factors

Our multivariable logistic regression model for all-cause readmission of LPTs at 30 days of life was adjusted for all covariates in Table 3. There was no significant association between duration of birth hospitalization and readmission. Compared to babies whose mothers self-reported as White, Asians had a greater adjusted odds of being readmitted (aOR: 1.10 [95% CI: 1.03-1.18]), and non-Hispanic Blacks had a lower adjusted odds of being readmitted (aOR: 0.81 [95% CI: 0.74-0.90]). Birth hospitalizations that were paid using public payers/Medicaid had a greater risk

of readmission than those paid by private insurance (aOR: 1.35 [95% CI: 1.29-1.42]). Self-payment was protective (aOR: 0.72 [95% CI: 0.62-0.85]). There was no difference in the risk of readmission between babies whose mothers had less than a 12th grade education compared to those who had completed 12th grade. The adequacy of prenatal care, as defined by the Kotelchuck adequacy of prenatal care utilization index, was not found to be a significant contributor to readmission.

Maternal and delivery variables independently associated with 30-day readmission among LPTs included maternal age ≥34 years (aOR:1.07 [95% CI: 1.02-1.12]), primiparity (aOR:1.24 [95% CI: 1.17-1.31]), diabetes (aOR:1.14 [95% CI: 1.08-1.20]), chorioamnionitis (aOR:1.24 [95% CI: 1.08-1.43]), and assisted vaginal birth (aOR:1.26 [95% CI: 1.12-1.42]). Newborns of mothers with diabetes (gestational or preexisting) had greater odds of being readmitted due to infection compared to other causes of readmission (OR: 1.25 [95% CI: 1.09-1.42]). There was no significant difference in the precipitator of readmission (infection versus non-infection) among newborns of mothers who had chorioamnionitis (OR: 1.30 [95% CI: 0.90-1.88]).

Maternal hypertension (aOR: 1.02 [95% CI: 0.97-1.07]) and perinatal smoking (aOR: 0.98 [95% CI: 0.89-1.09]) were not associated with readmission. LPTs who were delivered via cesarean section (aOR: 0.78 [95% CI: 0.75-0.82]), were female (aOR: 0.88 [95% CI: 0.84-0.91]), or who had very low birthweight (aOR: 0.57 [95% CI: 0.40-0.82]) or low birthweight (aOR: 0.92 [95% CI: 0.88-0.96]) had a lower risk. The mean duration of birth hospitalization was higher among those born via cesarean section compared with the overall study sample (6.1 days versus 5.0 days). Similarly, LPTs with very low birthweight had a higher mean duration of birth

hospitalization than the overall study sample (20.3 days versus 5.0 days). The final model for predicting 30-day readmission included nine variables (birthweight, sex, mode of delivery, payment type, race/ethnicity, maternal age, diabetes, chorioamnionitis, parity) (Table S2) and had a c-statistic of 0.573 (95% CI: 0.567-0.579) (Figure S1). In a sensitivity analysis excluding LPTs who had a prolonged duration of birth hospitalization (>5 days) (Table S3), there was a slight improvement in model performance (c-statistic 0.604 [95% CI: 0.597-0.610]).

Discussion

Late preterm infants might appear outwardly mature but are often at increased risk of morbidity. In this retrospective cohort study in California, over a seven-year period, we found a 30-day readmission rate of 5.9% and an increasing temporal trend in readmission of LPTs. Most readmissions occurred in the first week of life and often had a principal diagnosis of jaundice. Infection, temperature instability, respiratory complications, and gastrointestinal symptoms were also found to be important causes of readmission.

Despite greater awareness of the vulnerability of LPTs, the readmission rate in our study was within the range of readmission rates [range: 3.5% to 8%] reported by other studies in the United States in the last decade.[7,8,21,22,24] Similarly, the increased odds of readmission among LPTs relative to term infants was consistent with earlier studies.[8,22,25] The unchanged risk of readmission among LPTs and the increasing temporal trend are of concern. It appears that changes in practices such as minimum hospital birth stay, predischarge screening for hyperbilirubinemia, increase in breastfeeding practices, and AAP recommendations regarding readiness for discharge criteria[14,26,27] might have fallen short in achieving population-level

impact. It is possible that interfacility variations in practice might have masked the progress that has been achieved by hospitals that adhered to AAP recommendations. Goyal and colleagues examined the duration of birth hospitalization and found that adherence to AAP discharge guidelines and the minimum stay mandate were not universally practiced and that adherence varied by hospital.[11] Understanding predischarge care practices at hospitals that have successfully reduced the risk of readmission is vital to inform future care practices.

The association between duration of birth hospitalization and readmission may be confounded by birthweight, mode of delivery, and unmeasured variables, such as infant comorbidities, parental readiness, and breastfeeding status. Strata-specific analysis of readmission by recommended length of stay, mode of delivery, and birthweight illustrated this complexity. However, the protective effect of cesarean birth and low birthweight observed in the multivariable model in this study might be mediated by the duration of birth hospitalization, as longer initial hospital stays allow for issues such as hyperbilirubinemia, temperature instability, and feeding problems to be resolved prior to discharge. Identifying infants who could benefit from longer birth hospitalization is an important actionable solution in reducing the rate of readmission.

Physiologically, bilirubin levels in LPT often peak between day 4 and day 7,[26] corresponding to the high 7-day readmission rate due to jaundice observed in our study. Studies have found associations between screening for hyperbilirubinemia and subthreshold phototherapy with lower odds of readmission due to jaundice.[29] Eggert et al demonstrated that the introduction of universal predischarge bilirubin screening for newborns was associated with a reduction in readmission for jaundice (0.55% to 0.43%).[30]A decrease in readmission for phototherapy

following subthreshold phototherapy during birth hospitalization was also reported by Wickremasinghe et al; however, the number needed to treat was large.[29] While Kuzniewicz et al did not find a similar reduction in readmission rate, they demonstrated that introduction of universal bilirubin screening among infants ≥34 weeks' gestation was associated with a reduction in the incidence of severe hyperbilirubinemia.[28] Tailored predischarge bilirubin screening and subthreshold phototherapy could contribute to minimizing the risk of early readmission.

Our findings support the emerging evidence from Shapiro-Mendoza,[7] Kuzniewicz,[8] and Escobar[22] that there are multiple risk factors for readmission among LPTs. Our study contributes new data regarding the association between readmission and maternal diabetes, chorioamnionitis, assisted vaginal delivery, maternal age ≥34 years, and primiparity. Similar to other studies,[7,16,22] our results show increased odds of readmission among infants whose mothers self-reported as Asian and lower odds among non-Hispanic Black mothers, compared with White mothers. While some studies have suggested that a lower rate of exclusive breastfeeding among Black mothers might contribute to a lower incidence of jaundice resulting in readmission,[7,31] we believe this pathway is more complicated. Socioeconomic status, payer at the time of birth hospitalization, and maternal education are intertwined with race and ethnicity. These complex relations may be confounded by unmeasured factors, including level of trust in the healthcare system, healthcare utilization practices, and access to resources. Further examination of this conceptual pathway is needed to better understand the relationship of socioeconomic status and race/ethnicity with readmission.

Our predictive model based on routinely collected data demonstrated poor discriminatory ability. Inclusion of rich predictive variables, such as infant clinical status (dehydration, breastfeeding, weight loss), parental perception of discharge readiness, and laboratory results (bilirubin level) might improve model performance in future studies. Disease-specific risk stratifications based on maternal and infant variables, such as early-onset neonatal sepsis,[32]have demonstrated good performance in identifying at-risk infants. Similarly, an approach based on the main causes of readmission among LPTs identified in this study might have better predictive ability.

This large population-based cohort enabled us to estimate the absolute risk of readmission, identify rare risk factors, and evaluate the most recent temporal trends. However, the study also had limitations, including possible errors in the administrative database that is missing ICD codes on discharge files. We lacked information on breastfeeding status, level of neonatal inpatient care, diagnostic tests, treatments received during birth hospitalization, and follow-up care provided after discharge. Data on inter-facility variations in care during birth hospitalization and discharge readiness were not available. Although we adjusted for confounding variables, we cannot exclude the possibility of unmeasured factors and possible interactions.

In summary, LPTs face the greatest risk of hospital readmission within the first week of life. There is emerging evidence that early detection and proactive management of jaundice could minimize the risk of readmission in this population. Our findings advance understanding of maternal and infant factors beyond length of stay that are associated with readmission. This information could eventually contribute to future risk classification matrices to differentiate LPTs who are at increased risk of readmission and could benefit from tailored predischarge care

during birth hospitalization, such as breastfeeding support, prevention of dehydration, screening for hyperbilirubinemia, thermal care at home, and early follow-up visits. Future studies are needed to examine hospital and follow-up care practices that could successfully reduce the rate of readmission in this vulnerable population.

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Figure legends

Figure 1. Percentage of infants readmitted within 30 days of life by gestational age group. Blue, late preterm infants born at 34-36 weeks GA; red, early-term infants born at 37-38 weeks GA; and green, term infants born at 39-42 weeks GA. The solid line is the temporal trend, and circles are the rate of readmission.

A. All-cause readmission stratified according to gestational age category

B. Jaundice readmission stratified according to gestational age category