Published in final edited form as:

J Pediatr. 2013 January ; 162(1): 28–34.e2. doi:10.1016/j.jpeds.2012.06.051.

Subtypes of Preterm Birth and the Risk of Postneonatal Death

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Abstract

Objective—To examine the differences in postneonatal death risk among 3 clinical subtypes of preterm birth: preterm premature rupture of membranes (PROM), indicated preterm birth, and spontaneous preterm labor.

Study design—We analyzed the 2001–2005 US linked birth/infant death (birth cohort) datasets. The preterm birth subtypes were classified using information on the birth certificate: reported PROM, induction of labor, cesarean section, and complications of pregnancy and labor. Cox proportional hazard models were used to estimate covariate-adjusted hazard ratios and 95% CIs for postneonatal death (from days 28 to 365). Estimation was given for preterm birth subtypes in a week-by-week analysis. Causes of death were analyzed by preterm birth subtype and then separately at 24–27, 28–31, and 32–36 weeks of gestation.

Results—For the total of 1 895 350 singleton preterm births who survived the neonatal period, the postneonatal mortality rate was 1.11% for preterm PROM, 0.78% for indicated preterm birth, and 0.53% for spontaneous preterm labor. Preterm PROM was associated with significantly higher risk of postneonatal death compared with spontaneous preterm labor in infants born at 27 weeks gestation or later. Similarly, indicated preterm birth was associated with a significantly higher risk of postneonatal death than spontaneous preterm labor in infants born at 25 weeks gestation or later. Preterm PROM and indicated preterm birth were associated with greater risk of death in the postneonatal period compared with spontaneous preterm labor, irrespective of the cause of death.

Conclusion—Subtypes of preterm birth carry different risks of postneonatal mortality. Prevention of preterm-related postneonatal death may require more research into the root causes of preterm birth subtypes.

Infant mortality in the US has remained unchanged over the last several years, reported at ~6.75 per 1000 live births in 2007.¹ Preterm birth is a leading cause of infant death in the US, accounting for ~36% of infant deaths in 2007.¹ Although neonatal mortality was unchanged between 2006 and 2007, the postneonatal mortality rate increased by 5% between 2006 and 2007, from 2.22 to 2.33 per 1000 live births, with infants at lower gestational ages and birth weights making the greatest contribution to this increased

mortality.¹ Other studies have indicated that preterm birth is also associated with higher mortality rates in early childhood (age 1–5 years) and young adulthood (age 18–36 years),² demonstrating that the sequelae of preterm birth extend beyond early infancy.

Initiatives for successful prevention strategies against preterm birth have been elusive, as evidenced by the rising prematurity rates over the past decade, measured at 12.3% in 2008.^{3–7} It is plausible that heterogeneity in the natural history of preterm birth may exist and preclude a one-size-fits-all prevention strategy.^{8,9} To identify underlying etiologic factors and effective prevention methods for preterm birth, we must better understand the differences between clinical subtypes of preterm birth and various risk factors that may affect mortality in each group. Preterm birth can be classified as preterm labor, preterm premature rupture of membranes (PROM), and indicated preterm birth, with the first 2 classes often grouped as spontaneous preterm birth.³ Differences among these preterm birth subtypes and subsequent neonatal and postneonatal mortality rates have not been fully explored. This information may provide insight into the causes of and possible prevention of preterm birth,^{10–12} as well as the future risk of mortality.

Chen et al¹³ found that at 28–36 weeks of gestation, infants whose mother had preterm PROM or indicated preterm birth were at greater risk for neonatal death compared with infants whose mother had idiopathic spontaneous preterm labor, suggesting that differences in neonatal survival are influenced by the clinical complication of pregnancy, resulting in the specific subtypes of preterm birth. This finding is similar to results of large Swedish and Latin American studies indicating greater risk of neonatal death in indicated preterm births,^{11,12} as well as other studies showing higher rates of antepartum and postpartum mortality in infants born to mothers with PROM compared with infants born to mothers without PROM.^{14,15}

Despite the known contribution of preterm birth to increased infant mortality rates, however, no published study has directly compared the risk of postneonatal death (occurring between 28 days of life and 1 year) by preterm birth subtype. Although vital statistics show that pregnancy and delivery complications, unspecified preterm birth and low birth weight, and birth defects explain most neonatal deaths (occurring before 28 days of age), postneonatal deaths are often attributed to more diverse causes, including sudden infant death syndrome, trauma, and infections.^{1,16} Whether the etiology of preterm birth also influences postneonatal death risk is not clear. Therefore, our aim in the present study was to examine the differences in postneonatal death risk by the clinical subtypes of preterm birth (preterm labor, preterm PROM, and indicated preterm birth) in all gestational weeks and within specific gestational age groups, in addition to comparing causes of postneonatal death by preterm birth subtype. If differences in postneonatal death risk are identified, further investigation into the underlying etiologies of subtypes of preterm birth also may contribute to greater understanding of the causes of postneonatal mortality.

Methods

We used 2001–2005 US linked birth/infant death (birth cohort) datasets from the National Center for Health Statistics (NCHS). These birth cohort datasets included birth certificate information for all US births during the years of study (2001–2005) and death certificate information for infants who died in the first year of life (in 2001–2006). From 2001 to 2004, we included states that used the 1989 version of the birth certificate, given that the majority of states continued to use this version (48 states in 2003 and 43 states in 2004). For the year 2005, we included the 38 states using the 1989 version of the birth certificate and 12 states using the 2003 version. Our goal was to use the birth certificate data with the most robust completion of variables required to define our preterm birth subtypes. States using the 2003

version of birth certificate in 2003 and 2004 were excluded, because information on PROM was not included in the released datasets. During our study period, <1% of infant deaths could not be linked to corresponding birth certificates and were excluded from current analysis. For the 2001–2005 analysis, we restricted the datasets to residents in the US 50 states and Washington, DC area, singleton live births between 24 and 36 gestational weeks, and infants with sufficient information to allow determination of preterm birth subtype. Given that improvements in perinatal care may have occurred since 2005, we also obtained linked birth and infant death certificate data from Ohio for the years 2007–2010 to validate our findings. The analysis was approved by the Ohio Department of Health's Institutional Review Board and exempted from review by the University of Cincinnati's Institutional Review Board.

Preterm Birth Subtypes

In the datasets, gestational age was determined by the best obstetrical estimate, with last menstrual period (LMP) data correlated with clinical estimate of gestational age by the obstetrical provider.^{17,18} In accordance with the NCHS algorithm, the clinical estimate of gestational age was used if LMP data were not available or if LMP-based gestational age was clearly inconsistent with birth weight, which occurred in approximately 5%–6% of births during 2001–2005.^{19,20} If the day of LMP was missing but month and year were valid, then gestational age was imputed by the NCHS before releasing the data.²¹

Preterm birth subtypes were not reported directly in the birth certificates. Instead, they were defined in this study according to established definitions from the literature and information available in the datasets.^{22–25} Preterm PROM was defined as a preterm birth with prelabor PROM (>12 hours), in accordance with what is recorded on the birth certificate. Indicated preterm birth was defined as a preterm birth with either induction of labor or cesarean section delivery but without the presence of labor (without evidence of tocolysis, cephalopelvic disproportion, or precipitated, prolonged, or dysfunctional labor noted on the birth certificate).²⁶ Finally, those preterm births not classified as preterm PROM or indicated preterm birth were considered idiopathic preterm labor. This approach to classifying preterm birth subtypes yielded rates of specific subtypes similar to those reported previously,^{8,22} although, admittedly, this made the indicated preterm birth group a heterogeneous group.

Postneonatal Death

Postneonatal death was defined as death between age 28 days and 365 days (ie, first birthday). Because infants who died in the neonatal period (birth to 27 days of life) were not at risk for postneonatal death, we defined postneonatal death risk as the number of postneonatal deaths divided by the number of infants who did not die during the neonatal period.

The underlying causes of postneonatal death were coded according to the International Statistical Classification of Diseases and Related Health Problems, 10th Revision on the death certificates and were reported in 130 causal categories in the linked datasets. These causes were classified into 7 groups: perinatal conditions, birth defects, infections, sudden infant death syndrome, respiratory conditions, trauma, and other. Perinatal conditions included maternal complications of pregnancy and disorders related to duration of gestation and fetal malnutrition, birth trauma, and birth asphyxia (codes P00–P21). Birth defects included congenital malformations, deformations, and chromosomal abnormalities (Q00–Q99). Infections included certain infectious and parasitic diseases (A00–B99), meningitis (G00, G03), acute respiratory infection (J00–J06), influenza and pneumonia (J10–J18), congenital pneumonia (P23), necrotizing enterocolitis (P77), and acute bronchitis and bronchiolitis (J20–J42). Respiratory conditions included asthma or pneumonitis due to solids

and liquids (J45-J69), other unspecified disease of the respiratory system (J70-J98), respiratory distress of newborn (P22), and other respiratory disorders originating in the perinatal period, including neonatal aspiration syndromes, interstitial emphysema, pulmonary hemorrhage, chronic respiratory disease, and atelectasis (P24-P28). Trauma included unintentional injuries and homicide (U01, V01-Y84).

Statistical Analyses

The main purpose of this study was to compare gestational age–specific postneonatal death risk by preterm birth subtype. We first compared demographic and socioeconomic characteristics and gestational age–specific postneonatal death risk by preterm birth subtype. We then examined the differences in postneonatal death risk among preterm birth subtypes for each week of gestation between 24 and 36 weeks, to account for the trend of greater postneonatal death risk at earlier gestational ages. Because these were birth cohorts and postneonatal death was the time-to-event endpoint, we used a Cox proportional hazards model to estimate hazard ratios (HRs) and 95% CIs for the 3 preterm birth subtypes, adjusting for important covariates including maternal age, race, educational level, marital status, and live birth order and infant birth year and sex. We used idiopathic spontaneous preterm labor as the reference group for statistical comparisons because of its presumed lower likelihood of association with maternal and fetal medical complications that might influence postneonatal death risk. Because California birth certificates do not contain data on maternal smoking, we only adjusted for smoking during pregnancy in a sensitivity analysis to confirm that HRs did not change markedly. We then analyzed cause-specific postneonatal death risk by preterm birth subtype to explore the differences among these subtypes on certain causes of postneonatal death. In this cause-specific analysis, we grouped gestational age into 3 categories—24–27 weeks, 28–31 weeks, and 32–36 weeks—because week-by-week analysis would not have sufficient numbers of postneonatal deaths in some cause categories. Finally, we used the latest Ohio birth and death certificate data from 2007–2010 to validate our findings and ensure that our results persisted in a more recent cohort. All statistical analyses were conducted using SAS 9.2 (SAS Institute, Cary, North Carolina).

Results

The study population comprised 1 923 522 preterm births occurring between 2001 and 2005, with 1 895 350 of these preterm infants surviving the neonatal period. The 28 172 neonatal deaths included 4113 (14.6%) with preterm PROM, 12 651 (44.9%) with indicated preterm birth, and 11 408 (40.5%) with birth after spontaneous preterm labor. The neonatal mortality rate during the study period was 1.5%. The risk of neonatal mortality rate was highest in preterm PROM births (2.8%) compared with indicated preterm births (1.7%) and spontaneous preterm births (1.1%). Of all preterm births between 24–36 weeks who then survived the neonatal period, 139 709 (7.4%) were births after preterm PROM, 738 630 (39.0%) were indicated preterm births, and 1 017 011 (53.6%) were births after spontaneous preterm labor.

Compared with mothers with spontaneous preterm labor, mothers who had preterm PROM were more likely to be white, college-educated, married, and have no previous live births (Table I; available at www.jpeds.com). Mothers with indicated preterm birth were similar to those with preterm PROM, but with a higher percentage of previous live births. Mean gestational age was approximately 1 week shorter in infants whose mother had preterm PROM compared with those whose mother had indicated preterm birth or preterm labor. Mean birth weight was also the lowest in infants whose mother had preterm PROM (Table I).

A total of 12 637 infants died during the postneonatal period, for a postneonatal mortality rate of 0.67% in the 1 895 350 preterm infants who survived the neonatal period. The postneonatal mortality rate risk was highest in the preterm PROM birth group (1.11%) compared with the indicated preterm birth (0.78%) and preterm labor (0.53%) groups (Table II; available at www.jpeds.com). The rate of postneonatal death was lowest at all gestational ages for the spontaneous preterm labor group (Figure 1). For infants born after preterm PROM, the higher risk of postneonatal death reached significance only at 27 weeks gestation and greater (Figure 2 and Table II). Similarly, infants born after indicated preterm birth had a higher risk of postneonatal death compared with those born after spontaneous preterm labor at all gestational ages, although the difference reached significance only at 25 weeks and greater (Figure 2 and Table II).

Evaluating the entire population of preterm infants, compared with the spontaneous preterm birth group, the preterm PROM group had a more than 2-fold greater postneonatal mortality rate (adjusted HR, 2.25; 95% CI, 2.12–2.38) and the indicated preterm birth group had an ~60% greater postneonatal mortality rate (adjusted HR, 1.61; 95% CI, 1.55–1.67) (Table II). In a year-by-year analysis, these higher risks of postneonatal death in the preterm PROM and indicated preterm birth groups persisted for the entire study period (data not shown).

We validated our findings using a more recent cohort using linked birth and death certificates from the State of Ohio for 2007–2010, comparing these data with the US data for 2001–2005 (Table III). Of note, it is possible that we did not capture all postneonatal deaths from infants born during the year 2010, because 2011 data are not yet available. Nevertheless, the overall neonatal and postneonatal mortality rates were similar. In addition, these results confirm our findings of a more than 2-fold greater risk of postneonatal death in infants born after preterm PROM compared with those born after spontaneous preterm labor.

In all preterm births, the risk of dying in the postneonatal period was higher in the preterm PROM group compared with the preterm labor group, irrespective of the cause of death (Table IV). The risk of death was greater in the indicated preterm birth group compared with the preterm labor group for all causes except other causes. For infants born at 24–27 weeks gestation, the risk of death from perinatal conditions and trauma was higher in the preterm PROM and indicated preterm birth groups than in the spontaneous preterm labor group. For infants born at 28–31 weeks gestation, the risk of death was greater in the preterm PROM and indicated preterm birth groups than in the preterm labor group in all cause of death categories except respiratory conditions and other causes. For infants born at 32–36 weeks gestation, compared with the spontaneous preterm birth group, the preterm PROM group had a higher risk of death from all causes except perinatal conditions, and the indicated preterm birth group had a higher risk of death from all causes except respiratory conditions and other causes.

Discussion

The risk of neonatal death by preterm birth subtype has been studied extensively, with several large population-based studies demonstrating that indicated preterm birth and preterm PROM are associated with higher mortality risk compared with spontaneous preterm labor.^{10–13,27,28} This report directly compares postneonatal death risk among preterm birth subtypes. A previous Swedish study reported a lower neonatal and infant death risk in spontaneous preterm births than in medically indicated preterm births (defined similarly but called “iatrogenic” in that study) at 34–36 weeks of gestation; however, some calculations based on the data presented in that study indicated a similar risk of postneonatal death at that gestational age.¹² In this large national dataset, the risk of postneonatal death was higher in the preterm PROM and indicated preterm birth groups compared with the

preterm labor group, particularly for infants born at 27 weeks gestation. At shorter gestational ages toward the threshold of viability, it is likely that the higher risk of neonatal mortality diminished the significance of the differences in postneonatal death rates among groups. Once a newborn at that extreme of viability has overcome the initial neonatal period, the root causes of the subtypes of preterm birth may play a greater role in the risk of postneonatal death. In addition, the increased risk of postneonatal death covered a wide range of causes of death, including perinatal conditions, birth defects, infections, and respiratory conditions.

Although this study only examined the increased risk of postneonatal death in preterm infants, other studies have shown that the increased risk may persist into early childhood and even adulthood.² Presumably, infants who died in the postneonatal period were not as gravely ill as those who died in early neonatal period. Nonetheless, our data suggest that downstream effects of shorter gestational length and pathophysiological changes associated with preterm PROM or indicated preterm birth can still be detected in the postneonatal period and result in mortality. As such, clinicians should be aware that the sequelae of prematurity may perpetuate well beyond the walls of the neonatal intensive care unit, and that root causes of prematurity may program survivors for such long-term morbidities as asthma, hypertension, diabetes, and others.^{29–31}

Gestational age at birth is more predictive of postneonatal death risk than preterm birth subtype. However, recent studies have shown that the heterogeneity of causality in preterm birth also plays an important role, and that both the causal processes leading to the birth and the level of fetal maturity achieved play roles in mortality.^{32,33} Recognizing this, comparing postneonatal death risk by preterm birth subtype has merit in research of preterm birth etiology and pathological consequences. Given the heterogeneity within these clinical subtypes of preterm birth, it is helpful to examine the subtypes separately in terms of etiology and management.^{34–36} Because indications and risk factors for each clinical subtype of preterm birth also differ,^{34,37} these underlying causes may actually determine the pathophysiology of labor or rupture of membranes, and even influence delivery outcomes. These underlying causes may influence the timing of delivery, which is sometimes based on little or insufficient evidence, compounding the effects of prematurity.³⁸ As such, we postulate that the differences in postneonatal survival among preterm birth subtypes have root causes (eg, chorioamnionitis, hypertension, preeclampsia, diabetes) in the antepartum period.^{39–42} In addition, these underlying causes may also combine with other postnatal factors to increase the risk of infant death. For example, infants whose mother had preterm PROM were born on average a week earlier and weighed an average of 542 g less than infants born after preterm labor, likely related to recommendations for delivery by 34 weeks gestation owing to an increased risk of chorioamnionitis.³⁸ Indeed, the greatest causative contributors to the preterm PROM subtype include anemia, genitourinary infections, and chorioamnionitis,³⁷ which also may have specific effects on the infant. Similarly, infants born as indicated preterm births had a slightly shorter average gestational age and a 146 g lower average birth weight than infants born after preterm labor, possibly reflecting other common causes of indicated preterm birth, such as intrauterine growth restriction and small for gestational age status, particularly in the late preterm population,⁴³ or other causes, such as chronic and gestational hypertensive disorders, diabetes, complications related to congenital malformations, and other medical comorbidities that may affect infant survival through mechanisms other than fetal growth restriction.^{39,40} For example, the presence of congenital anomalies may affect the timing or method of delivery, which certainly affects neonatal morbidity and mortality in addition to indications for delivery, although consistent recommendations for the ideal time of delivery of infants with certain anomalies do not always exist.^{44–47} Thus, the keys to preventing these excessive postneonatal deaths from preterm PROM and indicated preterm birth may lie in this critical prenatal period, and in

how these clinical subtypes are managed and how delivery is timed, although postnatal interventions, such as neonatal intensive care unit admission, breast-feeding, immunization, and supine sleeping position, and antibiotics for infection, cannot be dismissed.

As with many studies that use vital statistics data, this study has several limitations. First, as with any study using vital statistics records, gestational age could be estimated inaccurately in the vital statistics data used for this study, but is unlikely to be differentially classified among the preterm birth subtypes or to bias our results to any significant degree. Second, we derived the preterm birth subtypes from birth certificate data, so misclassification cannot be ruled out. Although the optimal approach is for attending physicians to determine preterm birth subtypes in clinical studies, this approach would preclude the very large samples needed for research on infant survival, and we feel that existing data are still valuable for studying the causes and consequences of different subtypes of preterm birth. In addition, given that the definition of PROM on both versions of the birth certificate is PROM >12 hours, the true incidence of PROM could have been underreported, potentially including some cases of PROM into the spontaneous preterm labor group, biasing our results toward the null. Third, although we found differences in postneonatal death risk by preterm birth subtypes within gestational age strata, gestational age is still a dominant determinant of infant survival, and thus emphasis should be placed on preventive or therapeutic procedures that can delay delivery if at all possible. Fourth, the ~1% of infant deaths that cannot be linked to the original birth certificate might have caused misclassification of infant survival status. Although it is unlikely that the misclassification is differential by preterm birth subtype, we considered an extreme situation in which all nonlinkable postneonatal deaths ($n = 127$ based on 12 637 linkable postneonatal deaths) were associated with preterm labor. In this scenario, the rate of postneonatal death in the preterm labor group is 0.54% for all gestational ages, only minimally different from the 0.53% rate reported in Table II. It is unlikely that the risk estimates of preterm birth subtypes would change if all infant deaths were linkable. Finally, even though our study is a large population-based study including 5 years of linked US birth and death data, with validation by data from Ohio, more research is needed on the consequences of preterm birth subtype. Outcomes beyond survival are also important, especially the long-term neurologic, cognitive, and behavioral consequences.⁴⁸

Given the differences in the risk of postneonatal death among preterm birth subtypes, understanding the underlying causes of preterm birth subtypes and the interventions to prevent or decrease preterm births should be a consideration in averting related postneonatal deaths, with an overall goal of decreasing infant mortality. Obstetricians have the unenviable task of carefully weighing the risks of continuing pregnancy to the mother and fetus versus prematurity in the newborn, and a balanced view of stillbirth risk, fetal distress, infection, and preterm birth sequelae should be available when determining the timing of delivery, to allow the safest clinical decisions for both mother and baby.

Acknowledgments

B.K.-R. is supported by a *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Award (K12HD051953).

Glossary

HR	Hazard ratio
LMP	Last menstrual period
NCHS	National Center for Health Statistics

PROM Premature rupture of membranes

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Figure 1. Gestational age-specific frequency of postneonatal death by preterm birth subtype. *PTB*, preterm birth.

Figure 2.

Gestational age-specific adjusted HRs and 95% CIs for postneonatal mortality risk by preterm birth subtype. HRs are adjusted for maternal age, race, education, marital status, and live birth order, and infant birth year and sex.

Table I

Maternal and infant characteristics by preterm birth subtypes, US data, 2001–2005

Variable	Preterm PROM (n = 139 709)	Indicated PTB (n = 738 630)	Preterm labor (n = 1 017 011)
Maternal age, years, mean $\pm$ SD	27.5 $\pm$ 6.5	27.9 $\pm$ 6.6	26.1 $\pm$ 6.4
Maternal race, %			
Non-Hispanic white	55.3	52.3	45.9
African American	21.8	20.7	21.7
Hispanic	16.5	21.5	25.6
Other	6.5	5.6	6.8
Maternal education, years, %			
<12	22.7	23.3	30.9
12	31.6	32.4	32.5
>12	45.7	44.3	36.6
Smoking during pregnancy, %			
Yes	16.0	12.5	12.8
No	75.8	77.2	74.9
Unknown	8.2	10.3	12.4
Married, %	57.7	60.8	53.1
Previous live birth delivery, %	50.5	61.3	59.6
Male infants, %	54.6	53.1	54.1
Gestational age, weeks, mean $\pm$ SD	33.2 $\pm$ 3.0	34.2 $\pm$ 2.6	34.3 $\pm$ 2.4
Birth weight, g, mean $\pm$ SD	2250 $\pm$ 714	2646 $\pm$ 811	2792 $\pm$ 668

PTB, preterm birth.

Table II
Postneonatal death risk and estimated HR by preterm birth subtype and completed weeks of gestation

Gestational age and preterm birth subtype	Total preterm infants, n	Postnatal deaths, n	Postneonatal mortality rate, %	Unadjusted HR (95% CI)	Adjusted HR (95% CI) *
Total					
Preterm PROM	139 709	1545	1.11	2.11 (1.99–2.23)	2.25 (2.12–2.38)
Indicated PTB	738 630	5739	0.78	1.48 (1.42–1.53)	1.61 (1.55–1.67)
Preterm labor	1 017 011	5353	0.53	Reference	Reference
24 weeks					
Preterm PROM	1860	184	9.89	1.06 (0.89–1.27)	1.07 (0.90–1.28)
Indicated PTB	3586	370	10.32	1.11 (0.97–1.28)	1.14 (0.99–1.31)
Preterm labor	4337	406	9.36	Reference	Reference
25 weeks					
Preterm PROM	2452	181	7.38	1.18 (0.98–1.40)	1.20 (1.00–1.44)
Indicated PTB	5454	412	7.55	1.21 (1.05–1.39)	1.24 (1.08–1.43)
Preterm labor	5829	368	6.31	Reference	Reference
26 weeks					
Preterm PROM	2935	147	5.01	1.15 (0.94–1.39)	1.16 (0.95–1.41)
Indicated PTB	7165	436	6.09	1.40 (1.21–1.62)	1.47 (1.26–1.70)
Preterm labor	7108	311	4.38	Reference	Reference
27 weeks					
Preterm PROM	3245	127	3.91	1.39 (1.12–1.73)	1.44 (1.16–1.80)
Indicated PTB	8556	367	4.29	1.53 (1.30–1.81)	1.62 (1.36–1.91)
Preterm labor	7968	225	2.82	Reference	Reference
28 weeks					
Preterm PROM	3745	88	2.35	1.27 (0.99–1.62)	1.32 (1.03–1.68)
Indicated PTB	12 262	340	2.77	1.50 (1.27–1.77)	1.59 (1.34–1.88)
Preterm labor	12 564	234	1.86	Reference	Reference
29 weeks					
Preterm PROM	4470	94	2.10	1.73 (1.35–2.21)	1.78 (1.39–2.28)
Indicated PTB	15 203	320	2.10	1.73 (1.44–2.07)	1.84 (1.53–2.21)
Preterm labor	15 439	188	1.22	Reference	Reference

Gestational age and preterm birth subtype	Total preterm infants, n	Postnatal deaths, n	Postneonatal mortality rate, %	Unadjusted HR (95% CI)	Adjusted HR (95% CI)*
30 weeks					
Preterm PROM	5771	101	1.75	1.75 (1.39–2.22)	1.84 (1.45–2.34)
Indicated PTB	20 730	296	1.43	1.43 (1.20–1.70)	1.57 (1.32–1.88)
Preterm labor	22 455	225	1.00	Reference	Reference
31 weeks					
Preterm PROM	7241	84	1.16	1.42 (1.11–1.82)	1.51 (1.17–1.93)
Indicated PTB	26 090	321	1.23	1.51 (1.28–1.78)	1.64 (1.39–1.94)
Preterm labor	30 421	249	0.82	Reference	Reference
32 weeks					
Preterm PROM	10 006	82	0.82	1.31 (1.02–1.67)	1.39 (1.08–1.78)
Indicated PTB	36 426	317	0.87	1.39 (1.18–1.63)	1.52 (1.29–1.79)
Preterm labor	43 817	275	0.63	Reference	Reference
33 weeks					
Preterm PROM	14 828	94	0.63	1.21 (0.97–1.52)	1.38 (1.10–1.73)
Indicated PTB	53 714	380	0.71	1.35 (1.17–1.56)	1.52 (1.31–1.76)
Preterm labor	69 344	363	0.52	Reference	Reference
34 weeks					
Preterm PROM	14 848	114	0.77	1.22 (0.99–1.49)	1.40 (1.14–1.71)
Indicated PTB	94 161	537	0.57	1.39 (1.23–1.56)	1.54 (1.37–1.75)
Preterm labor	128 116	528	0.41	Reference	Reference
35 weeks					
Preterm PROM	27 965	139	0.50	1.44 (1.20–1.72)	1.65 (1.37–1.97)
Indicated PTB	156 767	687	0.44	1.27 (1.15–1.40)	1.40 (1.26–1.55)
Preterm labor	230 450	797	0.35	Reference	Reference
36 weeks					
Preterm PROM	32 427	110	0.34	1.26 (1.04–1.53)	1.44 (1.19–1.76)
Indicated PTB	298 526	956	0.32	1.19 (1.09–1.29)	1.30 (1.19–1.42)
Preterm labor	439 253	1 184	0.27	Reference	Reference

* Adjusted for maternal age, race, education, marital status, and live birth order, and infant birth year and sex.

Table III

Comparison of US and Ohio birth certificate data

Group	US, 2001–2005	Ohio, 2007–2010
Total preterm births, n	1 923 522	58 856
Neonatal deaths, n	28 172	876
Neonatal mortality rate, %	1.46	1.49
PROM	2.86	2.54
Indicated PTB	1.68	1.60
Preterm labor	1.11	1.13
Postneonatal deaths, n	12 637	373
Postneonatal mortality rate, %	0.67	0.64
PROM	1.11	1.21
Indicated PTB	0.78	0.66
Preterm labor	0.53	0.49

Table IV

Incidence of cause-specific postneonatal death and adjusted HR (95% CIs) by preterm birth subtype

Gestational age and preterm birth subtype	Perinatal conditions		Birth defects		Infection and inflammation		Sudden infant death syndrome		Respiratory conditions		Trauma		Other causes	
	Adjusted HR*		Adjusted HR		Adjusted HR		Adjusted HR		Adjusted HR		Adjusted HR		Adjusted HR	
	%		%		%		%		%		%		%	
Total Sample														
Preterm PROM	0.05	3.73 (2.80–4.97)	0.14	1.90 (1.63–2.22)	0.19	2.67 (2.32–3.08)	0.33	2.22 (2.00–2.47)	0.14	1.59 (1.36–1.86)	0.19	3.49 (3.01–4.04)	0.07	1.62 (1.31–2.01)
Indicated PTB	0.03	2.41 (1.95–2.97)	0.15	2.04 (1.86–2.23)	0.10	1.54 (1.39–1.71)	0.25	1.71 (1.60–1.84)	0.09	1.11 (1.00–1.22)	0.10	1.94 (1.74–2.17)	0.04	1.04 (0.91–1.20)
Preterm labor	0.01	Reference	0.08	Reference	0.07	Reference	0.16	Reference	0.10	Reference	0.05	Reference	0.05	Reference
24–27 weeks														
Preterm PROM	0.49	1.52 (1.07–2.15)	0.30	1.37 (0.89–2.12)	1.32	1.10 (0.90–1.35)	2.01	1.15 (0.97–1.35)	0.13	0.92 (0.50–1.69)	1.74	1.31 (1.09–1.57)	0.09	1.01 (0.46–2.19)
Indicated PTB	0.48	1.52 (1.14–2.02)	0.32	1.47 (1.04–2.07)	1.39	1.17 (1.00–1.36)	2.29	1.33 (1.18–1.51)	0.13	1.17 (0.75–1.82)	1.68	1.29 (1.11–1.49)	0.08	1.10 (0.60–2.01)
Preterm labor	0.32	Reference	0.23	Reference	1.24	Reference	1.79	Reference	0.16	Reference	1.35	Reference	0.09	Reference
28–31 weeks														
Preterm PROM	0.08	2.08 (1.16–3.71)	0.26	1.75 (1.28–2.41)	0.32	1.92 (1.44–2.57)	0.52	1.65 (1.32–2.07)	0.19	1.14 (0.81–1.62)	0.27	2.09 (1.51–2.90)	0.07	0.93 (0.53–1.63)
Indicated PTB	0.09	2.15 (1.40–3.30)	0.30	1.97 (1.58–2.46)	0.27	1.67 (1.34–2.07)	0.57	1.84 (1.58–2.15)	0.14	0.93(0.73–1.20)	0.29	2.37 (1.87–3.01)	0.06	0.83 (0.57–1.22)
Preterm labor	0.04	Reference	0.16	Reference	0.18	Reference	0.33	Reference	0.19	Reference	0.13	Reference	0.09	Reference
32–36 weeks														
Preterm PROM	0.00	1.03 (0.31–3.39)	0.10	1.61 (1.31–1.97)	0.05	1.84 (1.38–2.45)	0.12	1.45 (1.21–1.74)	0.13	1.67 (1.39–2.00)	0.02	2.01 (1.28–3.15)	0.07	1.78 (1.39–2.27)
Indicated PTB	0.01	3.14 (1.98–5.00)	0.13	2.00 (1.80–2.23)	0.04	1.24 (1.04–1.48)	0.13	1.50 (1.36–1.66)	0.08	1.11 (0.99–1.24)	0.02	1.56 (1.19–2.05)	0.04	1.06 (0.90–1.23)
Preterm labor	0.00	Reference	0.07	Reference	0.03	Reference	0.09	Reference	0.09	Reference	0.01	Reference	0.05	Reference

* Adjusted for maternal age, race, education, marital status, and live birth order, and infant birth year and sex.