Stillbirth and Live Birth at Periviable Gestational Age: A Comparison of Prevalence and Risk Factors

Suzan L. Carmichael, PhD[1] Yair J. Blumenfeld, MD[2] Jonathan A. Mayo, MPH[1] Jochen Profit, MD[1] Gary M. Shaw, DrPH[1] Susan R. Hintz, MD[1] David K. Stevenson, MD[1]

[1] Division of Neonatal and Developmental Medicine, Department of Pediatrics, Stanford University School of Medicine, Stanford, California
[2] Division of Maternal-Fetal Medicine and Obstetrics, Department of Obstetrics and Gynecology, Stanford University School of Medicine, Stanford, California

Address for correspondence Suzan L. Carmichael, PhD, Division of Neonatal and Developmental Medicine, Stanford University School of Medicine, 1265 Welch Road, Room X111, Stanford, CA 94305 (e-mail: suzanc@stanford.edu).

Am J Perinatol 2019;36:537–544.

Abstract

Objective We compared the prevalence of and risk factors for stillbirth and live birth at periviable gestational age (20–25 weeks).

Study Design This is a cohort study of 2.5 million singleton births in California from 2007 to 2011. We estimated racial–ethnic prevalence ratios and used multivariable logistic regression for risk factor comparisons.

Results In this study, 42% of deliveries at 20 to 25 weeks' gestation were stillbirths, and 22% were live births who died within 24 hours. The prevalence of delivery at periviable gestation was 3.4 per 1,000 deliveries among whites, 10.9 for blacks, 3.5 for Asians, and 4.4 for Hispanics. Nonwhite race–ethnicity, lower education, uninsured status, being U.S. born, older age, obesity, smoking, pre-pregnancy hypertension, nulliparity, interpregnancy interval, and prior preterm birth or stillbirth were all associated with increased risk of both stillbirth and live birth at 20 to 25 weeks' gestation, compared with delivery of a live birth at 37 to 41 weeks.

Conclusion Inclusion of stillbirths and live births in studies of deliveries at periviable gestations is important.

Keywords
- stillbirth
- periviable gestation
- risk factor
- race–ethnicity
- preterm delivery

Periviable gestation commonly refers to deliveries at 20 to 25 weeks' gestation, a time frame that is considered to represent the border of viability.[1] These deliveries are rare but make a substantial contribution to infant mortality and long-term morbidity.[1] Current understanding of their causes is limited.

Most studies of deliveries at periviable gestation focus on live births, although exceptions do exist.[2,3] However, stillbirths (defined here as in utero fetal deaths delivered at 20 or more weeks' gestation) comprise a substantial proportion of deliveries at 20 to 25 weeks.[4] Stillbirth and live birth may even be considered competing outcomes during this time frame, due to variability in health care practices and reporting of these deliveries.[5] As such, understanding the proportion of live births and stillbirths during this time frame is important because it may impact neonatal mortality estimates and comparisons within and between institutions and populations.[6] In addition, stillbirth and preterm delivery (i.e., live-born delivery at <37 weeks' gestation) are known to share some of the same risk factors, including maternal medical conditions such as diabetes and hypertension, obesity, and a marked black–white disparity.[7] This finding may result in part from the fact that, at least in more developed countries, most

received
June 15, 2018
accepted after revision
August 3, 2018
published online
September 12, 2018

DOI https://doi.org/10.1055/s-0038-1670633.
ISSN 0735-1631.

stillbirths are delivered preterm—approximately 80% in the United States.[8] The extent to which these similarities in risk factors hold among stillborn and live-born deliveries at 20 to 25 weeks' gestation is uncertain. To fully understand delivery at periviable gestation, it is important to understand risk factors for stillbirth during this time window, and whether they are similar to risk factors for live birth. In general, there is a paucity of information about risk factors for stillbirth at periviable gestational age, and minimal attention is given to the proportion of deliveries at periviable gestational age that are stillbirths.

The objective of this study was to compare the prevalence of and risk factors for stillbirth and live birth at periviable gestational age (i.e., $20^{0/7}$–$25^{6/7}$ weeks' gestation), within a cohort of almost 2.5 million singleton births in California. We aimed to determine whether prevalence differs by race–ethnicity given the increased risk of stillbirth and early preterm delivery among blacks relative to whites.[9,10]

Methods

We examined deliveries that occurred in California from 2007 to 2011 at 310 hospitals. Data were derived from vital records, using files prepared by the California Office of Statewide Hospital Planning and Development that contain data from fetal death certificates, and linked data from live birth and infant death certificates. For California vital records, the definition of stillbirth is a fetal death delivered at ≥20 weeks' gestation; all deliveries meeting this definition receive a fetal death certificate. Gestational age at delivery was derived from vital records and based on best obstetric estimates.

Analyses included births to mothers who were non-Hispanic white, non-Hispanic black, Hispanic, or Asian; we excluded mothers who had other or missing race–ethnicity because some analyses focused on racial–ethnic differences. We excluded (1) infants who were nonsingletons, given that periviable delivery in that circumstance may have unique etiologies and (2) infants with gestational age <20 or >41 weeks' gestation (i.e., $>41^{6/7}$ weeks), and (3) infants with implausible birth weight for gestational age based on previously published criteria.[11] After these exclusions, our sample included 2,487,468 deliveries at 20 to 41 weeks' gestation (11,141 of which were stillbirths). There were 10,888 periviable births: 4,610 stillbirths, and 6,278 live births delivered at 20 to 25 weeks' gestation (i.e., $20^{0/7}$–$25^{6/7}$ weeks).

Analyses

First, we conducted analyses to describe the percentage of deliveries at 20 to 25 weeks' gestation that had the following outcomes: stillbirth, live birth, live birth who died <24 hours after delivery, live birth who died ≥24 hours after delivery (up to 1 year), and live birth who survived the first year. We analyzed live births separately depending on whether they did or did not live beyond the first 24 hours of life, given potential misclassification between these early infant and fetal deaths. We also examined the prevalence of each of these outcomes; for prevalence calculations, the denominator was all eligible deliveries that were stillborn or live born at 20 to 41 weeks' gestation. These analyses were conducted separately for each racial–ethnic group and for 2-week gestational time windows. For each outcome, we estimated racial–ethnic prevalence ratios (PRs) and their 95% confidence intervals (CIs), with non-Hispanic whites as the reference. Second, we examined the association of selected risk factors with each of the specified outcomes at 20 to 25 weeks' gestation. The comparison group for these analyses was live births delivered at term (37–41 weeks' gestation). These "term controls" represent the optimal outcome for all infants and include the vast majority of deliveries. This approach avoids selection bias due to conditioning on a collider. We used multivariable logistic regression analysis to generate odds ratios (ORs) and 95% CIs for these comparisons. Risk factors included maternal race–ethnicity, education, payer status, nativity, age, height, pre-pregnancy body mass index (BMI), smoking status during the first trimester, pre-pregnancy diabetes or hypertension, parity and interpregnancy interval, prior preterm birth, and prior stillbirth. BMI was computed as pre-pregnancy weight (kg) divided by height (m) squared and categorized using published guidelines.[12] The variables were based on data reported in vital records. Models included 3,545 stillbirths (77%) and 5,043 live births (80%) delivered at 20 to 25 weeks' gestation, and 2,048,890 term live births for comparison, who had complete data on covariates. As sensitivity analyses, we conducted logistic regression analyses that restricted the cases to deliveries at 22 to 25 weeks' gestation, to facilitate comparison with other studies of stillbirths that may be restricted to this more narrow gestational age range.

Results

►**Table 1** shows the distribution of maternal characteristics among all deliveries, as well as among stillbirths and live births delivered at 20 to 25 weeks' gestation. A majority of births were to Hispanic and multiparous mothers, 26% of mothers had less than a high school education, and 48% had California state public insurance (Medi-Cal). A description of characteristics of subgroups of live births born at 20 to 25 weeks' gestation that were based on whether or not they survived the first year postdelivery is provided in ►**Supplementary Table 1**, available in the online version.

The prevalence of delivery at periviable gestations was 3.4 per 1,000 deliveries among whites, 10.9 for blacks, 3.5 for Asians, and 4.4 for Hispanics (►**Table 2**). The black–white PR for having a stillbirth at 20 to 25 weeks was 2.5 (95% CI: 2.2, 2.7); for live birth, it was 4.0 (95% CI: 3.7, 4.3), and similarly elevated for the subcategories of live birth (►**Table 2**). Prevalences among Asians were similar to those among whites (PRs from 0.9 to 1.2). Prevalences for Hispanics were similar to those among whites for stillbirth (PR 1.1) and modestly elevated for live birth (PRs from 1.5 to 1.6). This pattern of results was similar within the 2-week gestational time periods.

In this cohort, 42% of the periviable deliveries were stillbirths (4,610/10,888), 22% (2,428) were live births who died <24 hours after delivery, 11% (1,151) were live births who died from 24 hours to 1 year after delivery, and 25%

Table 1 Characteristics of mothers who delivered a singleton stillborn or live-born infant in California from 2007 to 2011, overall and restricted to stillbirths and live births at 20 to 25 weeks' gestation

	All live births and stillbirths at 20–41 wk (n = 2,487,468)		Stillbirths at 20–25 wk (n = 4,610)		Live births at 20–25 wk (n = 6,278)	
	n	%	*n*	%	*n*	%
Race/Ethnicity						
Non-Hispanic white	703,721	28.3	1,172	25.4	1,214	19.3
Non-Hispanic black	146,868	5.9	599	13.0	1,009	16.1
Asian	314,678	12.7	479	10.4	617	9.8
Hispanic	1,322,201	53.2	2,360	51.2	3,438	54.8
Education						
Less than high school	622,197	25.5	1,302	29.8	1,705	28.4
High school graduation	647,743	26.6	1,174	26.9	1,889	31.5
Some college	573,286	23.5	1,186	27.2	1,565	26.1
College graduate	594,962	24.4	707	16.2	837	14.0
Missing	49,280		241		282	
Payer						
Medi-Cal	1,185,266	47.8	2,136	49.9	3,368	54.2
Private	1,140,323	46.0	1,835	42.8	2,342	37.7
Uninsured	58,632	2.4	182	4.3	276	4.4
Other	97,525	3.9	131	3.1	234	3.8
Missing	5,722		326		58	
Country of birth						
U.S. born	1,404,704	56.5	2,774	61.7	3,947	62.9
Foreign born	1,081,509	43.5	1,724	38.3	2,326	37.1
Missing	1,255		112		5	
Age (y)						
Mean (SD)	28.2 (6.3)		28.4 (7.0)		27.8 (6.7)	
Missing	37		13		0	
Height (in)						
Mean (SD)	63.6 (2.9)		63.6 (3.1)		63.5 (2.9)	
Missing	105,849		255		446	
Pre-pregnancy BMI[a]						
Underweight	94,473	4.1	120	2.9	183	3.4
Normal	1,141,438	49.9	1,655	39.9	2,020	37.6
Overweight	588,258	25.7	1,156	27.9	1,479	27.5
Obese I	282,223	12.4	648	15.6	939	17.5
Obese II	113,733	5.0	340	8.2	456	8.5
Obese III	65,411	2.9	231	5.6	294	5.5
Missing	201,932		460		907	
Smoking (first trimester)						
No	2,394,719	97.7	4,261	95.5	5,854	96.0
Yes	56,879	2.3	200	4.5	245	4.0
Missing	35,870		149		179	
Pre-pregnancy hypertension	12,245	0.5	84	1.8	82	1.3
Pre-pregnancy diabetes	11,045	0.4	61	1.3	47	0.8

(*Continued*)

Table 1 (*Continued*)

	All live births and stillbirths at 20–41 wk (n = 2,487,468)		Stillbirths at 20–25 wk (n = 4,610)		Live births at 20–25 wk (n = 6,278)	
	n	%	*n*	%	*n*	%
Parity						
Nulliparous	989,439	39.8	1,983	43.8	3,128	50.0
Multiparous	1,496,905	60.2	2,541	56.2	3,128	50.0
Missing	1,124		86		22	
Interpregnancy interval[b]						
< 6 months	74,921	5.1	161	7.0	260	8.5
6–23 months	507,510	34.3	647	28.1	782	25.7
24–47 months	420,213	28.4	541	23.5	680	22.3
≥ 48 months	476,393	32.2	956	41.5	1,322	43.4
Missing	17,868		236		84	
Prior preterm birth	15,830	0.6	124	2.7	262	4.2
Prior stillbirth						
No	2,457,430	98.9	4,026	90.0	5,973	95.6
Yes	27,998	1.1	449	10.0	277	4.4
Missing	2,040		135		28	

Abbreviations: BMI, body mass index; SD, standard deviation.
[a]Underweight (<18.5 kg/m^2), normal weight (18.5–24.9), overweight (25–29.9), and obesity class I (30.0–34.9), II (35.0–39.9), and III (≥40.0) based on World Health Organization International classification (http://apps.who.int/bmi/index.jsp?introPage=intro_3.html).
[b]Multiparous mothers only.

(2,699) were live births who survived at least 1 year. The percentage of deliveries at 20 to 25 weeks' gestation that were stillbirths was highest for whites, 49%, versus 37% for blacks, 44% for Asians, and 41% for Hispanics (►**Table 2**, ►**Fig. 1**). However, the percentage of deliveries that were live births who died within 24 hours after delivery was lowest for whites, 20%, versus 24% for blacks and 23% for Asians and Hispanics. When examining 2-week gestational age intervals, the percentage of deliveries that were stillborn was highest at 20 to 21 weeks (72, 61, 65, and 66% for whites, blacks, Asians, and Hispanics, respectively) and lowest for deliveries at 24 to 25 weeks (25, 19, 27, and 19%, respectively). Less than 1% of infants delivered at 20 to 21 weeks survived to 1 year of age, whereas a majority of infants delivered at 24 to 25 weeks survived.

We examined the potential associations of maternal characteristics with risk of stillbirth and live birth at 20 to 25 weeks' gestation, relative to having a liveborn delivery at term (i.e., 37–41 weeks' gestation), after adjustment for covariates (►**Table 3**). When compared with non-Hispanic whites, elevated odds for stillbirth and live birth at 20 to 25 weeks' gestation were observed for blacks (OR: 2.0 for stillbirth and 3.4 for live birth), Asians (ORs: 1.3 and 1.7), and Hispanics (ORs: 1.1 and 1.5). Lower education, uninsured status, being U.S. born, older age, obesity, smoking, prepregnancy hypertension, nulliparity, extremes of interpregnancy interval, and prior preterm birth or stillbirth were all associated with increased risk of both stillbirth and live birth at 20 to 25 weeks' gestation. The magnitudes of the ORs were similar for both outcomes for most variables, with some exceptions. In concordance with unadjusted results reported earlier, racial–ethnic disparities were stronger for live birth than stillbirth. In addition, ORs were higher for live birth than stillbirth for nulliparity (2.6 vs. 1.9) and prior preterm birth (9.0 vs. 3.9), whereas the ORs were lower for live birth than stillbirth for prior stillbirth (3.3 vs. 7.7) and pre-pregnancy hypertension (1.8 vs. 2.7). These patterns of results were similar for the survival-based subgroups of live-born cases (►**Supplementary Table 2**, available in the online version). They were also very similar for analyses that were restricted to cases that occurred at 22 to 25 weeks' gestation (data not shown).

Discussion

In this cohort of California births delivered at periviable gestational age (20–25 weeks), a substantial proportion were stillbirths—close to two-thirds of deliveries at 20 to 21 weeks and approximately one-fifth of deliveries at 24 to 25 weeks. Risk factor associations for stillbirth and live birth during this early time window were similar, which supports the concept that at least some aspects of the underlying etiologies of both outcomes may be similar. Stillbirth and live birth are not typically included in the same studies, and

Table 2 Distribution and prevalence of singleton stillbirths and live births at 20 to 25 weeks' gestation, by maternal race–ethnicity, gestational age at delivery, and survival (live births), and racial–ethnic prevalence ratios (relative to non-Hispanic whites), California, 2007 to 2011[a]

	Non-Hispanic white			Non-Hispanic black				Asian				Hispanic			
	N	% of births within group	Prevalence	*n*	% of births within group	Prevalence	Prevalence ratio (95% CI)	*n*	% of births within group	Prevalence	Prevalence ratio (95% CI)	*n*	% of births within group	Prevalence	Prevalence ratio (95% CI)
20–21 wk															
All births	689		0.98	428		2.91	2.98 (2.64, 3.36)	310		0.99	1.01 (0.88, 1.15)	1593		1.2	1.23 (1.13, 1.35)
All stillbirths	498	72.3	0.71	261	61.0	1.78	2.51 (2.16, 2.92)	200	64.5	0.64	0.90 (0.76, 1.06)	1046	65.7	0.79	1.12 (1.00, 1.24)
All live births	191	27.7	0.27	167	39.0	1.14	4.19 (3.40, 5.16)	110	35.5	0.35	1.29 (1.02, 1.63)	547	34.3	0.41	1.52 (1.29, 1.80)
Live births—died < 24 hours after birth	167	24.2	0.24	152	35.5	1.03	4.36 (3.50, 5.43)	96	31.0	0.31	1.29 (1.00, 1.65)	494	31	0.37	1.57 (1.32, 1.88)
Live births—died ≥24 hours after birth	18	2.6	0.03	14	3.3	0.1	3.73 (1.85, 7.49)	12	3.9	0.04	1.49 (0.72, 3.10)	42	2.6	0.03	1.24 (0.71, 2.16)
Live births—survived first year	6	0.9	0.01	1	0.2	0.01	0.80 (0.10, 6.63)	2	0.6	0.01	0.75 (0.15, 3 0.69)	11	0.7	0.01	0.98 (0.36, 2.64)
22–23 wk															
All births	818		1.16	551		3.75	3.23 (2.90, 3.60)	356		1.13	0.97 (0.86, 1.10)	1999		1.51	1.30 (1.20, 1.41)
All stillbirths	451	55.1	0.64	216	39.2	1.47	2.29 (1.95, 2.70)	162	45.5	0.51	0.80 (0.67, 0.96)	898	44.9	0.68	1.06 (0.95, 1.19)
All live births	367	44.9	0.52	335	60.8	2.28	4.37 (3.77, 5.07)	194	54.5	0.62	1.18 (0.99, 1.41)	1101	55.1	0.83	1.60 (1.42, 1.80)
Live births—died < 24 hours after birth	241	29.5	0.34	192	34.8	1.31	3.82 (3.16, 4.61)	127	35.7	0.4	1.18 (0.95, 1.46)	631	31.6	0.48	1.39 (1.20, 1.62)
Live births—died ≥24 hours after birth	60	7.3	0.09	65	11.8	0.44	5.19 (3.65, 7.37)	43	12.1	0.14	1.60 (1.08, 2.37)	223	11.2	0.17	1.98 (1.49, 2.63)
Live births—survived first year	66	8.1	0.09	78	14.2	0.53	5.66 (4.08, 7.86)	24	6.7	0.08	0.81 (0.51, 1.30)	247	12.4	0.19	1.99 (1.52, 2.61)
24–25 wk															
All births	879		1.25	629		4.28	3.43 (3.10, 3.80)	430		1.37	1.09 (0.97, 1.23)	2206		1.67	1.34 (1.24, 1.44)
All stillbirths	223	25.4	0.32	122	19.4	0.83	2.62 (2.10, 3.27)	117	27.2	0.37	1.17 (0.94, 1.47)	416	18.9	0.31	0.99 (0.84, 1.17)
All live births	656	74.6	0.93	507	80.6	3.45	3.70 (3.30, 4.16)	313	72.8	0.99	1.07 (0.93, 1.22)	1790	81.1	1.35	1.45 (1.33, 1.59)
Live births—died < 24 hours after birth	65	7.4	0.09	43	6.8	0.29	3.17 (2.16, 4.66)	34	7.9	0.11	1.17 (0.77, 1.77)	186	8.4	0.14	1.52 (1.15, 2.02)
Live births—died ≥24 hours after birth	146	16.6	0.21	106	16.9	0.72	3.48 (2.71, 4.47)	67	15.6	0.21	1.03 (0.77, 1.37)	355	16.1	0.27	1.29 (1.07, 1.57)
Live births—survived first year	445	50.6	0.63	358	56.9	2.44	3.85 (3.35, 4.43)	212	49.3	0.67	1.07 (0.90, 1.25)	1249	56.6	0.94	1.49 (1.34, 1.66)
20–25 wk															
All births	2386		3.39	1608		10.9	3.23 (3.03, 3.44)	1096		3.48	1.03 (0.96, 1.10)	5798		4.39	1.29 (1.23, 1.36)
All stillbirths	1172	49.1	1.67	599	37.3	4.08	2.45 (2.22, 2.70)	479	43.7	1.52	0.91 (0.82, 1.02)	2360	40.7	1.78	1.07 (1.00, 1.15)
All live births	1214	50.9	1.73	1009	62.7	6.87	3.98 (3.66, 4.33)	617	56.3	1.96	1.14 (1.03, 1.25)	3438	59.3	2.6	1.51 (1.41, 1.61)
Live births—died < 24 hours after birth	473	19.8	0.67	387	24.1	2.64	3.92 (3.43, 4.48)	257	23.4	0.82	1.22 (1.04, 1.41)	1311	22.6	0.99	1.48 (1.33, 1.64)
Live births—died ≥24 hours after birth	224	9.4	0.32	185	11.5	1.26	3.96 (3.26, 4.81)	122	11.1	0.39	1.22 (0.98, 1.52)	620	10.7	0.47	1.47 (1.26, 1.72)
Live births—survived first year	517	21.7	0.73	437	27.2	2.98	4.05 (3.57, 4.60)	238	21.7	0.76	1.03 (0.88, 1.20)	1507	26	1.14	1.55 (1.40, 1.71)

Abbreviation: CI, confidence interval.

[a]Prevalence reflects the number of births with the outcome of interest per 1,000 total births (i.e., live births plus stillbirths) delivered from 20 to 41 weeks' gestation. The reference for prevalence ratios is non-Hispanic whites. There were 703,721 total births to whites, 146,868 to blacks, 314,678 to Asians, and 1,322,201 to Hispanics.

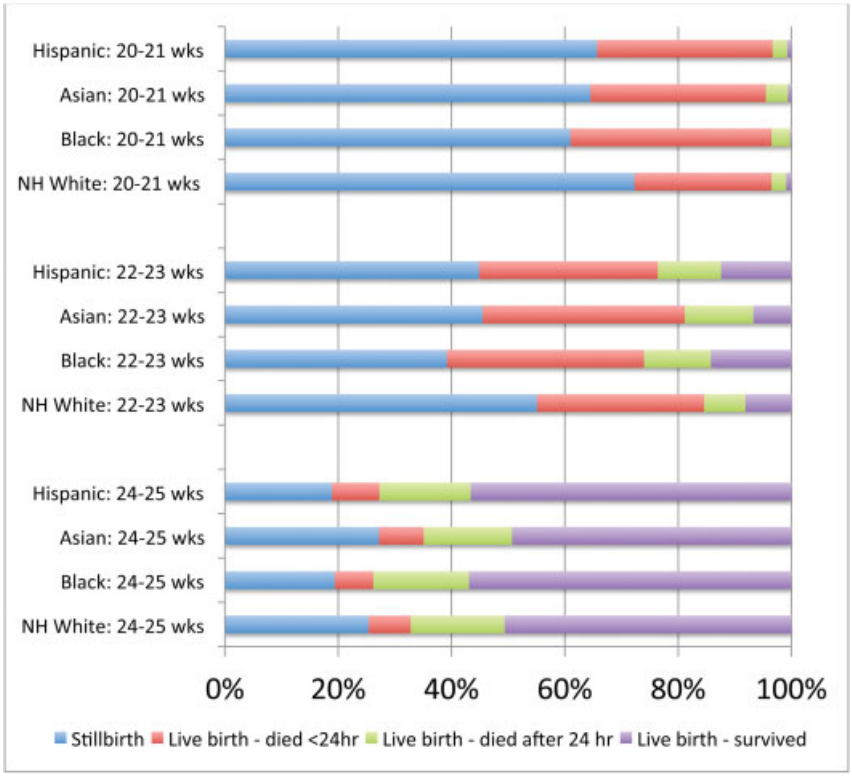

Fig. 1 Distribution of outcomes of singleton deliveries at 20 to 25 weeks' gestation, by maternal race–ethnicity and gestational age at delivery, California, 2007 to 2011. Outcomes were stillbirth, live birth who died <24 hours after delivery, live birth who died ≥24 hours after delivery (up to 1 year), and live birth who survived the first year. NH, non-Hispanic.

studies of deliveries at periviable gestational age are usually (but not always[2,3]) restricted to live births.[1,13,14] Based on our findings, we recommend that assessments and studies of deliveries at periviable gestation should incorporate both live births and stillbirths whenever possible. A greater effort to include both outcomes would likely provide a more thorough understanding of what causes delivery at periviable gestation, and how to prevent it. Prior studies have noted potential similarities in etiologies of stillbirth, preterm delivery, and infant mortality in general and advocated for the importance of better integration of investigations of perinatal outcomes.[8,15,16] However, we are unaware of prior studies that have specifically compared risk factors among deliveries within the periviable gestational age range.

Our findings have parallels to other cohorts of deliveries at periviable gestational age that included stillbirths and live births. In particular, the EPICure cohort from the United Kingdom (which included 3,133 deliveries at 22–26 weeks' gestation in 2006) and the EXPRESS cohort from Sweden (which included 1,011 deliveries at 22–26 weeks' gestation in 2004–2007) both reported that approximately 30% of births at 22 to 26 weeks' gestation were stillbirths.[2,3] In our study, 33% of deliveries at 22 to 25 weeks' gestation were stillbirths (2,605/7,868).

The black–white disparity in the occurrence of delivery at periviable gestation was strong, with a 4.2-fold increased risk of live birth and 2.5-fold increased risk of stillbirth among blacks. Disparities were also observed for Asians and Hispanics, but they were much more modest. The disparities remained after adjustment for a variety of maternal characteristics. The few prior studies that have examined racial–ethnic disparities in the prevalence of early stillbirth tend to agree with our findings for blacks and Hispanics but have not included Asians.[17] In addition, we observed that a greater proportion of deliveries at 20 to 25 weeks were live births than stillbirths among nonwhites, whereas proportions were similar among whites, which agrees with a recent investigation of U.S. births.[17] Extensive efforts have been aimed at understanding the black–white disparity in live-born preterm delivery, with minimal progress; fewer studies have examined contributors to disparities in stillbirth.[15,18] Given that the black–white disparity is so strong at these earliest gestational age,[14,19] studies focusing on this time period may be particularly important to advancing our understanding of it. The distribution of outcomes among the studied deliveries (i.e., stillbirth and live birth according to survival) also varied by race–ethnicity. This finding could derive from differences in underlying etiologic factors by race–ethnicity. Hospital-level variability in intervention and reporting practices related to periviable births may also contribute,[5,20,21] given that delivery hospital tends to vary nonrandomly by race–ethnicity. In addition, variability in intervention and reporting practices by race–ethnicity itself may contribute to observed disparities. Institutional assessments of newborn and obstetric quality of care do not typically include stillbirths in their denominator. This omission could introduce bias on performance evaluations related to newborn outcomes as well as disparities. Further investigation into such

Table 3 Association of maternal characteristics with risk of delivering a singleton stillborn or live-born infant at 20 to 25 weeks' gestation, relative to delivering a live-born infant at term (37–41 weeks), California, 2007 to 2011[a]

	Odds ratio (95% confidence interval)	
	Stillbirth at 20–25 wk (n = 3,545)	Live birth at 20–25 wk (n = 5,043)
Race/Ethnicity		
Non-Hispanic white	1.0 (ref)	1.0 (ref)
Non-Hispanic black	2.03 (1.79, 2.29)	3.43 (3.11, 3.78)
Asian	1.30 (1.13, 1.49)	1.70 (1.51, 1.92)
Hispanic	1.11 (1.01, 1.23)	1.47 (1.34, 1.60)
Education		
Less than high school graduation	1.37 (1.25, 1.51)	1.07 (0.99, 1.15)
High school graduation	1.0 (ref)	1.0 (ref)
Some college	1.05 (0.95, 1.15)	0.88 (0.82, 0.95)
College graduate or more	0.60 (0.53, 0.68)	0.51 (0.46, 0.56)
Payer		
Medi-Cal	0.94 (0.86, 1.02)	1.10 (1.02, 1.18)
Private	1.0 (ref)	1.0 (ref)
Uninsured	1.89 (1.58, 2.27)	2.58 (2.24, 2.97)
Other	0.73 (0.60, 0.88)	0.96 (0.83, 1.11)
Maternal country of birth		
U.S. born	1.0 (ref)	1.0 (ref)
Foreign born	0.79 (0.73, 0.86)	0.74 (0.69, 0.79)
Maternal age (per year)	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)
Maternal height (per inch)	0.99 (0.98, 1.01)	0.99 (0.98, 1.00)
Pre-pregnancy BMI[b]		
Underweight	0.81 (0.65, 0.99)	1.01 (0.86, 1.19)
Normal	1.0 (ref)	1.0 (ref)
Overweight	1.28 (1.18, 1.39)	1.36 (1.27, 1.46)
Obese I	1.40 (1.27, 1.55)	1.74 (1.60, 1.89)
Obese II	1.86 (1.63, 2.11)	2.05 (1.84, 2.28)
Obese III	2.04 (1.75, 2.37)	2.08 (1.83, 2.37)
Smoking (first trimester)		
No	1.0 (ref)	1.0 (ref)
Yes	1.48 (1.25, 1.76)	1.50 (1.30, 1.73)
Pre-pregnancy diabetes		
No	1.0 (ref)	1.0 (ref)
Yes	1.74 (1.27, 2.38)	1.27 (0.92, 1.73)
Pre-pregnancy hypertension		
No	1.0 (ref)	1.0 (ref)
Yes	2.74 (2.14, 3.53)	1.79 (1.40, 2.31)
Parity and interpregnancy interval		
Nulliparous	1.92 (1.74, 2.13)	2.60 (2.38, 2.84)
< 6 months	1.55 (1.28, 1.87)	1.87 (1.59, 2.19)
6–23 months	1.0 (ref)	1.0 (ref)
24–47 months	0.95 (0.84, 1.08)	1.00 (0.89, 1.12)
≥ 48 months	1.28 (1.14, 1.44)	1.45 (1.31, 1.61)
Prior preterm birth		
No	1.0 (ref)	1.0 (ref)
Yes	3.85 (3.10, 4.77)	8.95 (7.77, 10.3)
Prior stillbirth		
No	1.0 (ref)	1.0 (ref)
Yes	7.67 (6.80, 8.66)	3.33 (2.90, 3.83)

Abbreviation: BMI, body mass index.
[a]All variables in the table are adjusted for each other; the comparison group for each model included 2,048,890 singleton live births delivered at 37 to 41 weeks' gestation.
[b]See ►**Table 1** for category definitions.

factors is important but beyond the scope of the current analysis.

Strengths of our study include its population-based design and large size. The generalizability of our findings beyond California is uncertain, but likely enhanced by the fact that one in eight U.S. births occurs in California, and the diversity of the cohort with respect to race–ethnicity and socioeconomic status. Generalizability to women with missing data are also uncertain; however, given that the percentage of women with any missing data was similar for those with an early stillbirth (23%) or live birth (20%), we do not expect that missing data compromised the internal validity of our results. Our list of studied risk factors is by no means exhaustive, and more detailed studies are needed for us to better understand causes, and how to prevent delivery at periviable gestational age. Our intent was to illustrate whether these available risk factors had similar associations with early stillbirth and early live birth. Analyses included data on deliveries from 2007 to 2011 because vital records were revised in 2007 (e.g., the obstetric estimate for gestational age at delivery and maternal weight and height were first included then), and 2011 was the most recent year available to us. It would be helpful to be able to report more recent data years, especially since survival of infants born at the studied gestational age has been increasing over time,[22] but we expect that the general patterns of associations that we observed would likely persist in more recent years. A potential limitation of the stillbirth data are that while the gestational age at delivery is known, the gestational age of the in utero demise is not; the potential impact of this lag time on our results is unknown. In addition, we did not incorporate data about reported cause of

the stillbirths because a specific cause was not available for most cases. However, at these early gestational ages, causes may be more homogeneous than if stillbirths at all gestational age were included. We did not exclude infants based on the presence of congenital anomalies given that their reporting in vital records is incomplete and likely to vary for live births versus stillbirths. We focused on deliveries at 20 to 25 weeks given that 20 weeks is the minimal gestational age at which stillbirths are recorded, and it concurs with the definition of periviable birth that is often used in the United States.[1] As expected, the viability of deliveries at 20 to 21 weeks is low (less than 1% survived infancy), but we considered their inclusion to be important since in the United States, they are recorded. Our reporting of results that restricted the cases to later gestational age windows (i.e., 22–25 weeks) and 2-week time periods should facilitate comparison with other studies that restricted their cases to narrower gestational age ranges. Finally, we were unable to obtain placental pathology data, autopsy data, genetic data, or infectious workup data from the stillbirths. Prior studies by the Stillbirth Collaborative Research Network have highlighted the importance of a comprehensive evaluation of all stillbirths and we hope that future studies incorporate this type of information when possible.[23,24]

In conclusion, our results suggest that some aspects of the etiologies of stillbirth and live birth at periviable gestational age may overlap. Given this finding, the substantial proportion of deliveries that are stillborn during this gestational window, inclusion of stillbirths, as well as live births in ongoing studies of periviable gestations is important if we are to understand the true burden of delivery during this time period and its etiology. In addition, studies focused on deliveries at these earliest gestational age will further the understanding of racial–ethnic disparities in perinatal outcomes, given how strong they are during this time window. Investigators have previously advocated for more "enlightened" datasets[15] and a more "united front"[16] with regard to more frequent inclusion of stillbirths in studies of perinatal outcomes; our findings suggest that this message is particularly important for understanding delivery at periviable gestational age.

Funding
This work was partially supported by the March of Dimes Prematurity Research Center at Stanford University School of Medicine and the Stanford Child Health Research Institute.

Conflict of Interest
None.

References

1 Raju TN, Mercer BM, Burchfield DJ, Joseph GF. Periviable birth: executive summary of a Joint Workshop by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development, Society for Maternal-Fetal Medicine, American Academy of Pediatrics, and American College of Obstetricians and Gynecologists. J Perinatol 2014;34(05):333–342
2 Costeloe KL, Hennessy EM, Haider S, Stacey F, Marlow N, Draper ES. Short term outcomes after extreme preterm birth in England: comparison of two birth cohorts in 1995 and 2006 (the EPICure studies). BMJ 2012;345:e7976
3 Fellman V, Hellström-Westas L, Norman M, et al; EXPRESS Group. One-year survival of extremely preterm infants after active perinatal care in Sweden. JAMA 2009;301(21):2225–2233
4 Ray JG, Urquia ML. Risk of stillbirth at extremes of birth weight between 20 to 41 weeks gestation. J Perinatol 2012;32(11):829–836
5 Deb-Rinker P, León JA, Gilbert NL, et al; Canadian Perinatal Surveillance System Public Health Agency of Canada. Differences in perinatal and infant mortality in high-income countries: artifacts of birth registration or evidence of true differences? BMC Pediatr 2015;15:112
6 Profit J, Woodard LD. Perils and opportunities of comparative performance measurement. Arch Pediatr Adolesc Med 2012;166 (02):191–194
7 Fretts R. Stillbirth epidemiology, risk factors, and opportunities for stillbirth prevention. Clin Obstet Gynecol 2010;53(03):588–596
8 MacDorman MF, Gregory EC. Fetal and perinatal mortality: United States, 2013. Natl Vital Stat Rep 2015;64(08):1–24
9 Carmichael SL, Blumenfeld YJ, Mayo J, et al; March of Dimes Prematurity Research Center at Stanford University School of Medicine. Prepregnancy obesity and risks of stillbirth. PLoS One 2015;10(10):e0138549
10 Carmichael SL, Cullen MR, Mayo JA, et al. Population-level correlates of preterm delivery among black and white women in the U.S. PLoS One 2014;9(04):e94153
11 Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. Obstet Gynecol 1996;87 (02):163–168
12 National Institutes of Health. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults—the evidence report. Obes Res 1998;6(Suppl 2):51S–209S
13 Ecker JL, Kaimal A, Mercer BM, et al; American College of Obstetricians and Gynecologists and the Society for Maternal–Fetal Medicine. #3: periviable birth. Am J Obstet Gynecol 2015;213(05):604–614
14 DeFranco EA, Hall ES, Muglia LJ. Racial disparity in previable birth. Am J Obstet Gynecol 2016;214(03):394.e1–394.e7
15 Spong CY, Iams J, Goldenberg R, Hauck FR, Willinger M. Disparities in perinatal medicine: preterm birth, stillbirth, and infant mortality. Obstet Gynecol 2011;117(04):948–955
16 Goldenberg RL, McClure EM, Bhutta ZA, et al; Lancet's Stillbirths Series steering committee. Stillbirths: the vision for 2020. Lancet 2011;377(9779):1798–1805
17 Wingate MS, Smith RA, Petrini JR, Barfield WD. Disparities in gestational age-specific fetal mortality rates in the United States, 2009-2013. Ann Epidemiol 2017;27(09):570–574
18 Rowland Hogue CJ, Silver RM. Racial and ethnic disparities in United States: stillbirth rates: trends, risk factors, and research needs. Semin Perinatol 2011;35(04):221–233
19 Willinger M, Ko CW, Reddy UM. Racial disparities in stillbirth risk across gestation in the United States. Am J Obstet Gynecol 2009; 201(05):469.e1–469.e8
20 Rysavy MA, Li L, Bell EF, et al; *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Neonatal Research Network. Between-hospital variation in treatment and outcomes in extremely preterm infants. N Engl J Med 2015;372 (19):1801–1811
21 Lorch SA, Baiocchi M, Ahlberg CE, Small DS. The differential impact of delivery hospital on the outcomes of premature infants. Pediatrics 2012;130(02):270–278
22 Stoll BJ, Hansen NI, Bell EF, et al; *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Neonatal Research Network. Trends in care practices, morbidity, and mortality of extremely preterm neonates, 1993–2012. JAMA 2015; 314(10):1039–1051
23 Pinar H, Goldenberg RL, Koch MA, et al. Placental findings in singleton stillbirths. Obstet Gynecol 2014;123(2 Pt 1):325–336
24 Stillbirth Collaborative Research Network Writing Group. Causes of death among stillbirths. JAMA 2011;306(22):2459–2468