Published in final edited form as:

Am J Perinatol. 2021 October ; 38(12): 1263–1270. doi:10.1055/s-0040-1712165.

Factors Associated with Early Neonatal and First-Year Mortality in Infants with Myelomeningocele in California from 2006 to 2011

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Abstract

Objective—The aim of this study is to examine factors associated with early neonatal (death within first 7 days of birth) and infant (death during the first year of life) mortality among infants born with myelomeningocele.

Study Design—We examined linked data from the California Perinatal Quality Care Collaborative, vital records, and hospital discharge records for infants born with myelomeningocele from 2006 to 2011. Survival probability was calculated using Kaplan–Meier Product Limit method and 95% confidence intervals (CI) using Greenwood’s method; Cox proportional hazard models were used to estimate unadjusted and adjusted hazard ratios (HR) and 95% CI.

Results—Early neonatal and first-year survival probabilities among infants born with myelomeningocele were 96.0% (95% CI: 94.1–97.3%) and 94.5% (95% CI: 92.4–96.1%), respectively. Low birthweight and having multiple co-occurring birth defects were associated with increased HRs ranging between 5 and 20, while having congenital hydrocephalus and receiving hospital transfer from the birth hospital to another hospital for myelomeningocele surgery were associated with HRs indicating a protective association with early neonatal and infant mortality.

Conclusion—Maternal race/ethnicity and social disadvantage did not predict early neonatal and infant mortality among infants with myelomeningocele; presence of congenital hydrocephalus and the role of hospital transfer for myelomeningocele repair should be further examined.

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Conflict of Interest

None declared.

Keywords

infant mortality; health status disparity; neonatal mortality; myelomeningocele; open spina bifida

Myelomeningocele, also known as open spina bifida, is a major structural birth defect of the central nervous system characterized by incomplete closure of the neural tube during embryonic development. The condition typically leads to paralysis, loss of sensation, bowel and bladder dysfunction, pain, and depression.^{1–4} In the United States, spina bifida is estimated to affect 4 per 10,000 live births, and approximately 1,500 to 1,700 infants are born with the condition annually.⁵

Medical and surgical advancements in the last few decades have significantly improved both survival and quality of life among infants born with spina bifida.^{6–9} In spite of improved survival, mortality remains a significant concern, especially during infancy.^{7,10,11} Studies on survival time trends among infants born with spina bifida show an improvement in cohorts born in later years compared with those born during the late 1970s and early 1980s.^{8,10} The first-year mortality among infants born with open spina bifida in the United States after mandatory folic acid fortification was lower (8%, during October 1998 to December 2001), compared with the mortality among their counterparts born during the prefortification period (10%, during January 1995 to December 1996).¹²

Few studies have examined individual-level factors associated with infant mortality in children with spina bifida in the United States; they have reported associations with birth weight, gestational age, having multiple birth defects, level of spina bifida lesion, and maternal race/ethnicity, education, and prepregnancy body mass index.^{8,10,13–15} Associations with factors indicative of social disadvantage (e.g., poverty and insurance payer status), receipt of prenatal care, and delivery or repair hospital characteristics have not been examined. A more contemporary understanding of such factors is needed. There are no studies on factors associated with mortality in the first week after birth among infants with spina bifida in the United States.

The objective of our study was to examine the association of infant, maternal, and hospital characteristics with mortality by day 7 (henceforth referred to as early neonatal mortality) and by 1 year of age (henceforth referred to as infant mortality) among infants with myelomeningocele born in California between 2006 and 2011. We used population-based data from the California Perinatal Quality Care Collaborative (CPQCC) linked with vital records and hospital discharge data.

Materials and Methods

Study Design and Data Source

Study subjects included infants born with spina bifida from 2006 to 2011 in California, as reported by CPQCC. CPQCC collects data on infants admitted to 139 neonatal intensive care units (NICUs) in California, which represents over 90% of NICUs in the state. CPQCC is a comprehensive data source with information on maternal, fetal, and obstetric

complications, with standard definitions that also align with those specified by the Vermont Oxford Network. Additional information on CPQCC is available at <https://www.cpqcc.org/>.

We linked CPQCC data with files prepared by the California Office of Statewide Health Planning and Development (OSHPD), which are commonly referred to as “linked birth cohort files.” For each year of birth, the OSHPD files include linked data from birth and infant death certificates and hospital discharge records for the mother and baby from all hospitalizations that occurred during pregnancy, at delivery, and during the year after delivery. Files are linked via probabilistic linkage using variables such as date and time of birth. Linkage is successful for >97% of births. In addition, we merged the linked birth cohort files back to the original electronic birth certificates (using a common identifier in both files) to obtain maternal addresses at delivery. For each hospitalization of an infant (including birth), OSHPD files included information on hospital name, diagnostic and procedure codes, dates and length of stay, and transfers.

Subject Selection

During birth years 2006 to 2011, 626 infants were identified to have a CPQCC diagnostic code indicating spina bifida. Of those, 603 were successfully linked to the OSHPD birth cohort files and included in our analysis.

Study Variables

Infant characteristics included sex (female vs. male), gestational age (preterm <37 weeks vs. term 37p weeks), and birth weight (low birthweight <2,500 g vs. not 2,500p gm) from birth certificates, and the presence or absence of congenital hydrocephalus and any other co-occurring major birth defects (multiple defects) that were not related to the central nervous system derived from both CPQCC and OSHPD files. Maternal age at delivery was examined as a continuous variable. Factors related to disparity included maternal race-ethnicity and three markers of social disadvantage: (1) maternal education, (2) medical care payer (health insurance), and (3) residential census tract poverty. Medical care payer status was derived from OSHPD and indicates mother’s expected principal source of payment for medical care. To determine census tract poverty level, we geocoded maternal addresses, used the geocodes to assign census tracts, and then derived poverty information from 2007 to 2011 American Community Survey 5-year estimates. The California Environmental Health Tracking Program Geocoding Service geocoded subjects’ addresses. Geocoding was successful for 96% of the subjects ($n = 581$). Census tract poverty was defined as the percent of the tract population with household income below the poverty level.

Hospital care-related factors included level of neonatal care capacity at the birth hospital. The level of care was based on categories defined by the American Academy of Pediatrics, including well newborn nursery (level I), Special Care Nursery (level II), NICU (level III), and regional NICUs (level IV).¹⁶ Due to low frequencies, we grouped levels I and II as one category, and levels III and IV as another category. Hospital repair volume was defined as the number of meningocele or myelomeningocele operations (identified based on The International Classification of Diseases, Ninth Revision, Clinical Modification procedural codes 03.51 and 03.52) performed at the hospital annually and dichotomized as nine or

more versus less than nice repairs per year. Transfer from birth hospital before repair was categorized as any versus none. Time when the infant received first spina bifida repair surgery was examined from OSHPD records and categorized as timely (48 hours after birth) or delayed (>48 hours after birth) repair.

Statistical Analysis

Early neonatal and infant mortality rate for all infants with spina bifida was calculated using the number of deaths among infants with spina bifida divided by the number of total live births. The survival probability was calculated using Kaplan–Meier Product Limit method, and 95% confidence interval (CI) for the estimate of survival probability was calculated using Greenwood's method. Cox proportional hazards regression was used to examine the association of infant, maternal, and hospital-care related factors with both early neonatal and infant mortality. Unadjusted and adjusted hazard ratios (HR) with corresponding 95% CIs were estimated. Variables were included in adjusted analysis if they were significant in the bivariate analysis; in addition, we included maternal race-ethnicity due to prior evidence suggesting its association with mortality.⁸ Due to a strong correlation between birth weight and gestational age, only gestational age was included in the adjusted models. Census tract poverty level was categorized (<25th percentile, 25–75th percentile, and >75th percentile).

All analyses were performed using SAS 9.4 (SAS Institute, Inc. Cary, NC). The study was approved by the California Committee for the Protection of Human Subjects. The committee recommends suppressing report of cells sizes that are 15 or less; the reporting of our results reflects this recommendation.

Results

Overall, 24 of 603 infants with myelomeningocele died during the first seven days of their life, with a survival probability of 96.0% (95% CI: 94.1–97.3%). In the first year of life, 33 infants died, with a survival probability of 94.5% (95% CI: 92.4–96.1%). The infant, maternal, and hospital care-related characteristics of all infants with myelomeningocele are presented in ►Table 1. There was an equal distribution of males and females, and approximately 20% of the infants were born preterm or had low birthweight. Congenital hydrocephaly was commonly reported, and approximately 30% of the infants had multiple co-occurring birth defects, as abstracted from the CPQCC and OSPHD records (►Table 1). About 60% of cases were born to Hispanic and 25% to non-Hispanic White mothers, and 70% had at least completed high school. Total 16% of the mothers lived in areas that were grouped under less than 25th percentile census tract poverty level, while 65% used Medi-Cal or other government-based payer for medical care. Among the hospital-related variables examined, we noted that 75% of all cases were delivered at level III/IV hospitals, and approximately 50% were transferred from the birth hospital to a different hospital for myelomeningocele repair surgery soon after birth (►Table 1).

In the bivariate analysis, low birthweight, preterm gestation, and having multiple co-occurring birth defects were all significantly associated with early neonatal and infant mortality, with increased HRs ranging between 5 and 20. Presence of congenital hydrocephalus was the only infant factor that was inversely associated (unadjusted hazard

ratio: 0.42; 95% CI: 0.19, 0.94 for early neonatal mortality and unadjusted HR: 0.45; 95% CI: 0.23–0.88 for infant mortality; ►Table 2). Receiving a transfer from the birth hospital to another hospital for myelomeningocele repair also showed a significant association, with significantly decreased HRs (unadjusted HR: 0.23; 95% CI: 0.09–0.63 for early neonatal mortality and unadjusted HR: 0.38; 95% CI: 0.18–0.81 for infant mortality; ►Table 2). Contrary to our expectation, we did not find any significant associations with variables indicating social disadvantage as 95% confidence intervals around the HRs included 1.0.

Results from the adjusted analyses yielded similar findings as noted in our bivariate analyses; however, HRs were attenuated (►Table 2). We did not find a racial-ethnic disparity in early neonatal or infant mortality after adjusting for birth weight, congenital hydrocephalus, co-occurring birth defects, and hospital transfer from the birth hospital to a different hospital for myelomeningocele repair, although there was a slightly elevated risk for infants born to Hispanic compared with non-Hispanic White mothers (adjusted HR: 2.48; 95% CI: 0.82–7.52 for early neonatal mortality and adjusted HR: 1.79; 95% CI: 0.75–4.29 for infant mortality; ►Table 2).

We conducted a subanalysis limiting our study to only those cases that had a myelomeningocele diagnostic code reported in both CPQCC and OSHPD ($n = 561$). Findings were consistent with those reported above using all CPQCC cases ($n = 603$).

Discussion

This study, which was based on a state-wide population, found that the proportion of first-year deaths among infants born with spina bifida was 5.5%, and up to 70% of deaths occurred during the first week of life. Early neonatal and first-year mortality were associated with low birth weight, presence of congenital hydrocephalus and multiple birth defects, and receiving hospital transfer from the birth hospital to a different hospital for myelomeningocele repair surgery. Contrary to our expectation, maternal race-ethnicity and social disadvantage did not predict the outcomes in our study population.

We were unable to find any studies in the United States that examined early neonatal mortality among children with myelomeningocele or factors associated with it, so we could not compare past findings with the current study. Only one study was identified that reported on mortality prior to age 1 year, but spanning an age interval from birth to age 1 month. This study included population-based surveillance data on myelomeningocele cases born between years 1979 and 1994, to mothers residing in the metropolitan Atlanta counties, and the birth to 1 week survival rate in this birth cohort was 90.2% (95% CI: 86.5–94.1%).¹⁰ A recent multicountry analysis on mortality in spina bifida-affected births, at ages 1 day, 2 to 6 days, 7 to 27 days, and 27 to 365 days, included data from four US population-based birth defects surveillance registries (Arkansas, Metropolitan Atlanta, Texas, and Utah).¹⁷ There was a considerable variation in the proportion of babies that died at aforementioned ages by surveillance site. Overall, among all registries, national and international, the contributed data, 4.2% deaths among cases occurred at age 1 day, and 2.7% deaths at age 2 to 6 days in the early neonatal period.¹⁷

The infant mortality rate we noted is much lower than that reported by the Metropolitan Atlanta Congenital Defects Program for infants born with spina bifida between years 1979 and 1994 (13%),¹⁰ which examined births from the period prior to the implementation of mandatory fortification policy of cereal grains with folic acid in the United States (i.e., year 1998). A study in New York State for births from 1983 to 2006, spanning both pre- and postfortification period, reported 12% of all infants with spina bifida died by age 1 year.⁷ An aggregated analysis of multistate population-based US birth defects registry study examined births from 1979 to 2001 and stratified by fortification status reported first-year mortality proportions as 9.7, 9.5, and 7.9% during the pre-, optional-, and mandatory fortification periods, respectively.¹² Another multistate (Georgia, California, Iowa, and New York) analysis reported 6.4% infants with spina bifida who were born during years 1998 to 2002 (postfortification period) died before age 1 year.⁸ It is necessary to note that the aforementioned studies^{7,8,12} were not completely independent of each other as they had some of the same registries providing data for overlapping study years. Overall, our study had the lowest rate of infant mortality compared with prior studies, which were conducted during the postfortification years in the United States. Potential explanations could include improved care in more recent years, and/or inherent variation in study data sources and surveillance and follow-up methods. Differences in exposure to folic acid fortification could also contribute to differences in results between studies.

The three population-based studies in the United States that have examined infant and maternal factors are either from the prefortification period¹⁰ or included a timeframe that spanned pre-, interim-, and postfortification periods.^{8,12}

We compared our findings with the MACDP study that included births during prefortification years (1979–1994)¹⁰ to examine if infant and maternal factors associated with infant mortality in spina bifida differed by fortification policy in the United States. We observed that both our study and the MACDP study found infant mortality in spina bifida to be significantly associated with low birthweight, preterm birth, and having multiple birth defects.

The severity of spina bifida, as measured by the location of the lesion, is documented to be milder during the postfortification period compared with the prefortification period,¹⁸ which was linked to an increased survival during the postfortification period in the United States.¹² We could not examine severity of lesion in our study due to lack of validated data. Shin et al (2012)⁸ reported that maternal black race, multiple births, low birthweight, presence of major heart defects, and spina bifida lesion level significantly increased the risk of infant mortality for children born between 1997 and 2003, a period that predominantly represents the postfortification era in the United States. Another study examining postfortification period in the United States for mothers, who were eligible for the National Birth Defects Prevention Study and with estimated dates of delivery from 1998 to 2011, found a significantly increased risk of infant mortality among spina bifida cases with multiple co-occurring birth defects, very preterm gestation, multiple gestation, high-level spina bifida lesions, and non-Hispanic Black mothers.¹⁵

We found a protective association for infant mortality if the infant also had a diagnosis of congenital hydrocephalus. This contradicted a previous study where congenital hydrocephalus increased the risk of death in infancy among those with spina bifida.¹⁰ A higher proportion of mothers in our study may have received prenatal care compared with previous studies, and in severe cases of myelomeningocele, congenital hydrocephalus could have been identified in utero at the time of prenatal visits, and the cases may have been managed optimally immediately after birth to prevent or reduce mortality related to complications stemming from hydrocephalus.

There were no significant disparities in mortality by social disadvantage, measured using maternal education, residential census tract poverty level, and medical care payer status. The strong association between infant mortality and maternal race/ethnicity in myelomeningocele cases born between 1973 and 2003 reported in the multiregistry study by Shin et al (2012)⁸ was not seen in our study. Lopez et al (2018)¹⁴ examined disparities in infant mortality among spina bifida cases born between 1999 and 2007 in a US-based multiregistry study focusing on Hispanic subgroups (Mexican, Puerto Rican, and Cuban). Their study found 9.4 and 7.6% of Hispanic (combined subgroups) and non-Hispanic White infants, respectively, died in infancy; however, the race/ethnicity was not a statistically significant predictor of infant mortality. Wang et al, (2016) studied births between 1999 and 2007 from 12 population-based birth defects surveillance programs in the United States and found no association between race/ethnicity and survival up to 1 year of age among infants with spina bifida.¹⁹ This study examined outcomes by neonatal period (<28 days of age) and postneonatal infancy period (28 days to <1 year of age), but not early neonatal period.¹⁹

The marginal positive association with poverty observed in our study needs further investigation. We could not find other studies on factors related specifically to census tract poverty status or medical insurance payer status and their association with mortality among infants with spina bifida.

We are unaware of previous studies examining hospital care-related variables and infant mortality in spina bifida. In our study, infant mortality was not significantly associated with the level of neonatal care at birth hospital or hospital repair volume; confidence intervals were quite imprecise likely due to the limited number of deaths available for study. The inverse association with hospital transfer noted in our study is likely attributable to less severe cases of spina bifida being born at hospitals that were not the planned level III/IV hospitals for repair, and perhaps due to some cases which may not have been prenatally diagnosed. The analysis was limited by lack of information on prenatal diagnosis or severity of spina bifida to assess how these factors could have influenced hospital transfer independently. About half of the infants were transferred and 25% were born at level I/II hospitals. These findings highlight a more general need to understand why these births did not all occur at level III/IV hospitals. Ideally, these infants should be born at hospitals equipped to care for them and conduct timely repairs,²⁰ which typically occur within a couple of days of birth in California.²¹ Transfer puts these infants at medical risk and separates mothers from infants and should be avoided when possible. Further research is needed to understand these observed associations and how to improve the location of delivery for these infants.

There were several strengths to our study. We used multisource data with more cases of spina bifida than any other study in the United States within the past two decades, providing relatively timely information compared with previously published studies (birth years 2006–2011), on infant mortality and factors associated with those born with spina bifida in a large, racially, and ethnically diverse state (one in eight US births occurs in California). Unlike previous large multistate studies with state-level differences in demographic factors, birth years, follow-up years, and length of follow-up, our findings are based on findings from a birth cohort in a single state, with standard case identification and record linkage procedures. We were able to examine associations between infant mortality and some predictor variables for the first time, including residential census tract poverty level, medical insurance status, and selected hospital-related characteristics.

There were several limitations in our study. We expect a small degree of underestimation of infant mortality in our study due to missing deaths. However, the number of deaths missed in the current study by relying on vital records alone is likely to be small given the relatively low out-migration in California (2.5% during years 2007 to 2016 as reported by the California Legislative Analyst's Office; <https://lao.ca.gov/laoecontax/article/detail/265>). The utility of the National Death Index (NDI) in capturing additional deaths has been discussed in a recent birth defects study. A study in Texas on heterotaxy, a complex birth defect, used NDI as an additional source of identification for deaths that occurred in and out of the state. NDI linkage found only two additional deaths.²² We also lacked information on prenatal diagnosis of myelomeningocele, which could influence the choice of birth hospital; however, 95% of women in our study started prenatal care in the first or second trimester (data not shown) and would therefore likely have had an ultrasound and in turn, a prenatal diagnosis of spina bifida. Our study was limited to examining sociodemographic and hospital-related factors that were available to us. We were also not able to examine mortality by level of lesion, which is a known predictor with ascending lesions significantly associated with mortality among infants with spina bifida.^{10,15,23}

In conclusion, our study had the lowest rate of infant mortality compared with prior studies, which were conducted during the postfortification years in the United States. We also examined early neonatal mortality among infants with myelomeningocele and factors associated with this outcome for the first time. Factors related to case complexity, including low birthweight, presence of congenital hydrocephaly, and multiple co-occurring birth defects, were strongly associated with both early neonatal and infant mortality; associations with social disadvantage were not significant. The role of prenatal identification of congenital hydrocephalus and timely surgical intervention to control its complications, through the use of a shunt or reservoir, could be an indirect explanation and should be further explored to untangle the protective association we noted with congenital hydrocephalus and early neonatal and infant mortality. Transfer of infants from the birth hospital to repair hospital was relatively frequent; a better understanding of reasons for transfer, and how to reduce its occurrence, is needed. Findings from our study are descriptive and should be confirmed in additional contemporary studies of prevalence of early neonatal and infant mortality, and associated factors, among infants born with myelomeningocele to identify preventable risk factors and promotable protective factors.

Acknowledgments

The authors thank the California Environmental Health Tracking Program Geocoding Service for geocoding subjects' addresses.

Funding

This study received its financial support from the National Institute on Minority Health and Health Disparities (grant number R01 MD007796).

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Key Points

- Mortality in myelomeningocele is a concern
- Social disadvantage was not associated with death
- Hospital-based factors should be further examined

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Table 1

Infant, maternal, and hospital care-related characteristics for infants with myelomeningocele, California
Perinatal Quality Care Collaborative from 2006 to 2011^a

Characteristics	All cases (<i>n</i> = 603) <i>n</i> (%)
Infant	
Sex	
Female	298 (49.4)
Male	305 (50.6)
Gestational age (wk)	
37+	458 (76.0)
< 37	121 (20.1)
Birth weight (g)	
2,500+	500 (82.9)
< 2,500	103 (17.1)
Congenital hydrocephalus	
No	182 (30.2)
Yes	421 (69.8)
Co-occurring birth defects	
Multiple	104 (17.3)
Isolated	499 (82.8)
Maternal	
Maternal age (y)	Mean (SD) = 27.3 (6.3)
<i>n</i> (%)	
Maternal race-ethnicity	
Non-Hispanic White	155 (25.7)
Hispanic	376 (62.4)
Other	50 (8.3)
Maternal education	
Less than high school	216 (35.8)
High school graduate	146 (24.2)
Some college or higher	210 (34.8)
Census tract poverty ^b	
< 25 percentile	99 (16.4)
25–75 percentile	286 (47.4)
> 75 percentile	196 (32.5)
Medical insurance	
Nongovernment (private)	202 (33.5)
Medi-Cal/other government	397 (65.8)
Hospital care-related	
Level of care at birth hospital	
Level I/II	148 (24.5)

Level III/IV	455 (75.5)
Hospital repair volume	
9/year	251 (48.6)
< 9/year	257 (49.7)
Hospital transfer from birth hospital before myelomeningocele repair ^c	
No transfer	288 (47.8)
Transferred	315 (52.2)
Age at first myelomeningocele repair ^d	
48 hours (timely repair)	399 (88.3)
> 48 hours (delayed repair)	53 (11.7)

Abbreviations: n, frequency; SD, standard deviation.

^aFrequencies and percentages may not equal total and 100%, respectively, due to missing data.

^bDetermined based on 2007 to 2011 American Community Survey 5-year estimates.

^cDenominator is 517 indicating those who received myelomeningocele repair.

^dDenominator is 452 indicating those who received myelomeningocele repair within 28 days (data source: California Office of Statewide Health Planning and Development).

Hazard ratios for factors associated with early neonatal and infant mortality among infants with myelomeningocele, California Perinatal Quality Care Collaborative from 2006 to 2011^a

Table 2

Characteristics	Early neonatal mortality (death within 7 days of birth)		Infant mortality (death during the first year of life)	
	Unadjusted HR (95% CI)	Adjusted HR (95% CI) ^b	Unadjusted HR (95% CI)	Adjusted HR (95% CI) ^b
Infant				
Sex				
Female	Reference		Reference	
Male	1.38 (0.61–3.11)		1.34 (0.67–2.67)	
Gestational age (wk)				
37+	Reference		Reference	
< 37	7.41 (3.14–17.48)		5.19 (2.58–10.44)	
Birth weight (g)				
2,500+	Reference		Reference	
< 2,500	19.97 (7.45–53.51)		10.89 (5.28–22.47)	
Congenital hydrocephalus				
No	Reference		Reference	
Yes	0.42 (0.19–0.94)		0.45 (0.23–0.88)	
Co-occurring birth defects				
Multiple	Reference		Reference	
Isolated	10.16 (4.35–23.75)		9.17 (4.51–18.64)	
Maternal				
Maternal age (y)	1.04 (0.97–1.10)		1.03 (0.98–1.09)	
Maternal race-ethnicity				
Non-Hispanic White	Reference		Reference	
Hispanic	1.56 (0.52–4.70)		1.19 (0.50–2.81)	
Other	Not calculated ^d		1.33 (0.34–5.14)	
Maternal education				
Less than high school	1.02 (0.36–2.87)		1.07 (0.42–2.76)	
High school graduate	Reference		Reference	
Some college or higher	0.46 (0.13–1.64)		0.99 (0.38–2.59)	

Characteristics	Early neonatal mortality (death within 7 days of birth) Unadjusted HR (95% CI) Adjusted HR (95% CI) ^b	Infant mortality (death during the first year of life) Unadjusted HR (95% CI) Adjusted HR (95% CI) ^b
Census tract poverty ^c		
< 25 percentile	2.19 (0.76–6.31)	1.96 (0.80–4.80)
25–75 percentile	Reference	Reference
> 75 percentile	1.84 (0.73–4.67)	1.60 (0.73–3.52)
Medical insurance		
Nongovernment (private)	Reference	Reference
Medi-Cal/other government	0.86 (0.35–2.09)	0.89 (0.42–1.89)
Hospital care-related		
Level of care at birth hospital		
Level I/II	Reference	Reference
Level III/IV	1.65 (0.56–4.81)	1.48 (0.61–3.59)
Hospital repair volume		
9/year	Reference	Reference
< 9/year	Not calculated ^d	1.31 (0.29–5.85)
Hospital transfer from birth hospital before myelomeningocele repair		
Not transferred	Reference	Reference
Transferred	0.23 (0.09–0.63)	0.38 (0.18–0.81)
Age at first myelomeningocele repair ^a		
48 hours (timely repair)	Reference	Reference
> 48 hours (delayed repair)	Not calculated ^d	0.44 (0.20–0.95)

Abbreviations: CI, confidence interval; HR, hazard ratio.

^aAnalyses included 452 infants with repair data, 24 of whom died within 7 days (early neonatal mortality), and 33 of whom died during the first year of life (infant mortality).

^bEach variable was adjusted for all other variables in the model.

^cDetermined based on 2007 to 2011 American Community Survey 5-year estimates.

^dNot calculated as one of the cell frequencies was less than Q43.