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Factors Associated with Timeliness of Surgical Repair among Infants with Myelomeningocele: California Perinatal Quality Care Collaborative, 2006 to 2011

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Abstract

Objective—To examine factors associated with timely (0–2 days after birth) myelomeningocele surgical repair.

Study Design—We examined 2006 to 2011 births from the California Perinatal Quality Care Collaborative, linking to hospital discharge and vital records. Selected maternal, infant, and delivery hospital characteristics were evaluated to understand disparities in timely repair. Poisson regression was used to estimate adjusted risk ratios (aRRs) and 95% confidence intervals (CIs).

Results—Overall, 399 of the 450 (89%) infants had a timely repair and approximately 80% of them were delivered in level III/IV hospitals. Infants with hydrocephalus were significantly less likely to have a delayed myelomeningocele repair compared with those without (aRR = 0.22; 95% CI = 0.13, 0.39); infants whose medical care was paid by Medi-Cal or other nonprivate insurance were 2.2 times more likely to have a delayed repair compared with those covered by a private insurance (aRR = 2.23; 95% CI = 1.17, 4.27). Low birth weight was a significant predictor for delayed repair (aRR = 2.06; 95% CI = 1.10, 3.83).

Conclusion—There was a significant disparity in myelomenigocele repair based on medical care payer. Families and hospitals should work together for timely repair in hospitals having specialized multidisciplinary teams. Findings from the study can be used to follow best clinical practices for myelomeningocele repair.

Keywords

health care; disparities; myelomeningocele; open spina bifida; pediatric; surgery; spina bifida; timeliness

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Conflict of Interest

None declared.

Myelomeningocele, also known as open spina bifida, is a type of neural tube defect, characterized by failure of closure of the neural tube during early embryologic development. The condition affects various organ systems in the body, and typically leads to paralysis, loss of sensation, bowel and bladder dysfunction, pain, and depression.[1–4] Co-occurring hydrocephalus and Chiari malformation are common.[5,6] Advances in medical and surgical care in the past few decades have significantly improved both survival and quality of life among infants born with myelomeningocele.[4,7] The most common surgical procedures for myelomeningocele in the United States are among children younger than 1 year that include lesion closure, shunt insertion, and shunt revision.[8] Sociodemographic factors including age, sex, race and ethnicity, and insurance status have been associated with adverse health outcomes among those affected.[9]

The American College of Obstetricians and Gynecologists (ACOG) recommends that the delivery of a fetus with nonlethal myelomeningocele should be planned in a hospital that provides tertiary neonatal care and has personnel capable of managing the spinal defects and any immediate complications.[10] Health care guidelines by the Spina Bifida Association recommend such surgical repair to be performed within 0 to 2 days after birth (postnatal) to reduce the risk of meningitis and nerve damage.[11] Delaying the repair (≥3 or more days after birth) increases the risk of meningitis and other complications.[12] The proportion of cases repaired soon after birth has significantly improved in the past few decades,[4] and the technology and practice of fetal surgeries for myelomeningocele in selected cases are gaining prominence.[13]

Timely myelomeningocele repair is not ubiquitous in the United States. Radcliff et al (2016) examined prevalence and factors associated with timeliness of postnatal surgical repair of open spina bifida using a large population-based study design among infants born in Florida between 1998 and 2007, and reported that only 75% of those examined received a timely surgery, and infants born in lower level nursery care hospitals had a lower likelihood of having timely repairs.[14] Haq et al (2012) conducted a case series analysis (n = 25) on timeliness of postnatal myelomeningocele repair from a single hospital in the United Kingdom and reported that the majority of myelomeningocele repairs were done within the first 2 days after birth (23 out of 25 cases).[15] Findings from the Nationwide Inpatient Sample database (1988–2010) indicated that 84% had a timely repair, but age at repair was available for only 63% of their study population.[16] Recently, a hospital-based study from British Columbia reported that 98% of myelomeningocele cases born between 1996 and 2006 had a repair surgery within 48 hours after birth.[4]

The objective of our study was to examine the prevalence of timely surgical repair (0–2 days after birth) and associated clinical, demographic, and delivery hospital characteristics among infants with myelomeningocele born in California from 2006 to 2011. We used population-based data from the California Perinatal Quality Care Collaborative (CPQCC) to identify infants with myelomeningocele, in conjunction with additional information from hospital discharge and vital records data.

Materials and Methods

Study Design and Data Source

We used a population-based, observational study design. Study subjects were infants born with myelomeningocele from 2006 to 2011 in California, and identified from the CPQCC. CPQCC collects data on infants admitted to 139 neonatal intensive care units (NICUs) in California and represents more than 90% of NICUs in the state.[17] 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/.

For the current study, CPQCC data were linked 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 infant 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. These linkages are successful for >97% of live 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 delivery), 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 myelomeningocele. Of those, 603, who were all liveborn, were successfully linked between CPQCC and hospital discharge records (OSHPD). We excluded infants: (1) who were not linked between CPQCC and OSHPD, (2) who had fetal surgery for myelomeningocele repair or whose repair occurred after 28 days of age, or (3) who did not receive a repair within the first 28 days after birth (►Fig. 1). Eight cases underwent fetal surgeries for myelomeningocele repair. We were concerned that repairs received after 28 days were not generalizable to the target population of our study or may have been a factor of data entry errors. Thus, the final analytic sample included 450 infants who met all study criteria.

Study Variables

The outcome was timeliness of first recorded postnatal repair of myelomeningocele, identified from hospital discharge records based on dates and the International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) procedural codes 03.51 for repair of spinal meningocele and 03.52 for repair of spinal meningomyelocele. Timeliness was examined as a dichotomous variable where repair on day 0, 1, or 2 was considered to be timely. Repairs that occurred on days 3 to 28 were coded as delayed repairs. Variables related to disparity included maternal race and ethnicity and three markers of social disadvantage: (1) maternal education, (2) medical care payer, and (3) level of poverty in the census tract in which the mother resided. Medical care payer status was derived from OSHPD and indicates mother’s expected principal source of payment. 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 99% (n = 448) of cases. Census tract poverty was defined as the per cent of the tract population with household income below the poverty level. Infant characteristics included sex (female vs. male), gestational age (<37 vs. 37+ weeks), and birth weight (<2,500 vs. 2,500+ g) from birth certificates, and the presence or absence of hydrocephalus or any other co-occurring major birth defects that were not related to the central nervous system (hereafter referred to as isolated vs. multiple cases), based primarily on CPQCC and OSHPD data.

For hospital care-related characteristics, we assigned level of neonatal care capacity 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).[18] Hospital repair volume was defined as the number of meningocele or meningomyelocele operations (identified based on ICD-9-CM procedural codes 03.51 and 03.52) performed at the hospital per year. Transfer from birth hospital before repair was categorized as no transfer, transfer from a level I/II to level III/IV hospital, and transfer from a level III/IV to another level III/IV hospital.

Statistical Analysis

Unadjusted and adjusted risk ratios (cRR and aRR, respectively) and 95% confidence intervals (CIs), for the association of each variable with timeliness of repair, were estimated using Poisson regression models. Predictors included in the multivariable models were selected a priori based on previous literature and included infant characteristics (i.e., sex, birth weight, gestational age, presence of hydrocephalus, and co-occurring birth defects), maternal characteristics (i.e., age, census tract poverty level, race and ethnicity, education, medical care payer, and prenatal care initiation), and hospital care-related characteristics (i.e., level of neonatal care capacity at birth hospital, hospital repair volume, and hospital transfer from birth hospital before repair). Due to substantial correlation between gestational age and birth weight, only birth weight was included in the adjusted model. Census tract poverty level was examined both as a continuous variable and by quartiles, and as both methods yielded similar results, we elected to present our results using the continuous variable. We also included mother's payer type at delivery, as a measure of socioeconomic status; it was highly concordant with payer type for the infant at the time of surgery. All analyses were conducted 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

Among the 450 infants included in our analyses, 49% were female, 16% were born preterm (<37 weeks of gestation), 82% had hydrocephalus, and 13% had other major co-occurring birth defects. Among the mothers of these infants, 62% of were Hispanic and 68% had

Medi-Cal or other nonprivate insurance. In total, 78% of the infants were delivered in a level III/IV hospital, and 49% were transferred from the birth hospital for repair (►Table 1).

In total, 89% (399 out of 450) of infants had a timely myelomeningocele repair at 0 to 2 days after birth (►Table 1). Infants who received a late repair were more likely to be low birth weight compared with those who had a timely repair, less likely to have hydrocephalus, and more likely to have Medi-Cal or other nonprivate insurance rather than private insurance (►Table 1).

Unadjusted and adjusted analyses for factors associated with timely repair are presented in ►Table 2. In models that were not adjusted for any covariates, we found that infants with hydrocephalus were significantly less likely to have a delayed repair (cRR = 0.21, 95% CI = 0.12, 0.37). Having a low birth weight, Medi-Cal or other nonprivate payment for care and repair hospital volume of ≤2/year for myelomeningocele repairs were associated with increased risk of delayed repair, but CIs included 1.0. After adjusting for covariates, low birth weight (aRR = 2.06; 95% CI = 1.10, 3.83) and presence of hydrocephalus (aRR = 0.22; 95% CI = 0.13, 0.39) were significant predictors of a decreased likelihood of a delayed myelomeningocele repair. Medical insurance status was a significant predictor of repair timeliness where infants whose medical care was paid by Medi-Cal or other nonprivate health insurance were 2.2 times more likely to have a delayed repair compared with those covered by a private insurance (aRR = 2.23; 95% CI = 1.17, 4.27). Six per cent of women in the nonprivate insurance group had reported other forms of medical care payment (i.e., not Medi-Cal). An analysis excluding women on other forms of medical care payment, and including only those on private versus Medi-Cal insurance yielded a similar RR for the association between insurance type and increased likelihood of delayed repair (aRR = 2.30; 95% CI = 1.18, 4.46) as reported earlier. Hospital care-related characteristics were not associated with the timeliness of repair in multivariable analysis.

Discussion

Using linked, population-based data from multiple sources in California, we found that 89% of infants born with myelomeningocele received a timely (0–2 days after birth) surgical repair for closure of the lesion. As expected, infants with hydrocephalus were less likely to have delays in repair compared with their counterparts, probably to address and minimize hydrocephalus-associated complications. However, delayed repair was more likely among infants who were on Medi-Cal or other nonprivate insurance, suggesting a socioeconomic status-related disparity in care. Low birth weight increased the risk of delayed repair by twofold. While hospital care-related factors (level of care at birth hospital, hospital repair volume, and transfer from birth hospital before repair) did not significantly predict timeliness of repair, about one-fourth of all births with myelomeningocele occurred in level I/II hospitals, not abiding by the ACOG recommendation that the delivery of a fetus with myelomeningocele should be planned in a hospital that provides tertiary neonatal care and has multidisciplinary specialized care model capable of managing the spinal defects and any immediate complications.[10] We also examined the proportion of births in level 1/II hospitals including infants who died, and it was similar to that observed in the current study. In addition, 49% of infants were transferred from the delivery hospital to another hospital for

repair. Transfer itself was not associated with late repair. It is possible, however, that transfer was associated with other negative impacts on care and infant morbidity; an investigation of these potential impacts was beyond the scope of the present study. Regardless, our findings suggest that there is room for improvement in the management and care of infants born with myelomeningocele in California.

We compared our findings to a previous population-based study on timeliness of myelomeningocele repair and factors associated with it, as both studies employed similar study methods. The study by Radcliff et al (2016), using statewide birth defects registry data from Florida, examined surgical repairs among 199 myelomeningocele-affected infants born between 1998 and 2007.[14] In their study, the prevalence of timely repair, defined as repair at 0 to 2 days of life, was 76%. The prevalence of timely repair in our study from California, which is based on a larger number of cases (n = 450) and more recent birth years (2006–2011), is higher (89%). The factors that predicted timely repair in the Florida cohort were hydrocephalus and preterm birth, where both were associated with higher likelihood of timely repair (adjusted prevalence ratio [aPR] = 1.48; 95% CI = 1.02, 2.14 and aPR = 1.19, 95% CI = 1.01, 1.41, respectively). In our study, infants with hydrocephalus were also more likely to receive a timely repair, but low birth weight was associated with delayed repair. Insurance status of the mother was a significant predictor of timely repair in California but not in Florida. For hospital care-related variables, the aforementioned Florida study[14] and our study both showed a higher likelihood of timely repair among infants born in specialty care hospitals compared with those born in level I/II care hospitals; however, this finding was statistically significant in Florida and not in California. These variations in study findings, which had similar study designs, could be partly attributed to differences in sociodemographic and hospital-level characteristics in both states. Other previous studies examining infants with myelomeningocele repair were published using national hospital administrative data.[16,19] We could not compare our findings on the proportion of infants who received a timely repair or factors associated with timely repair with the above two studies because of difference in study designs and inclusion/exclusion criteria for infants with myelomeningocele repair.

Medical care insurance was significantly associated with timeliness of repair in our study. Medi-Cal is the Medicaid program available to Californians and covers health services needed by low-income individuals. Our finding that infants on Medi-Cal insurance were significantly more likely to receive a delayed repair compared with those on private insurance is concerning and a marker of socioeconomic disparity. Further investigation should be conducted to determine why repair may be delayed among these infants and how to prevent it.

Contrary to our expectations, there were no significant disparities in timeliness of repair by the other variables reflecting social disadvantage, including lower maternal education and residential census tract poverty status. Timeliness of repair was also not statistically associated with selected hospital care-related characteristics including level of neonatal care at birth hospital and transfer in level of care between birth and repair hospital, although there was a pattern of increasing risk of delayed repair with a decrease in the repair hospital volume.

Our study had several strengths. We used multisource, population-based data with a large number of infants with myelomeningocele. California is racially and ethnically diverse, which allowed our results to be representative of major racial-ethnic groups, including a large proportion of infants born to Hispanic mothers. Linkages between CPQCC and OSHPD allowed us to validate diagnoses for myelomeningocele, hydrocephalus, and other co-occurring birth defects. All 450 infants included in our analysis had diagnostic codes indicating myelomeningocele in both CPQCC and OSHPD. We were able to examine predictors for timeliness of myelomeningocele-based social disadvantage and hospital care-related variables, including transfer from the birth hospital before repair.

There were limitations to this study. Twenty-three out of the 626 myelomeningocele cases found in CPQCC could not be linked to OSHPD, resulting in fewer eligible infants in our analytic study sample. CPQCC includes most NICUs in the state (>90%). It is possible that some cases were missed (e.g., cases who were born at a non-CPQCC hospital and/or died before transfer to a CPQCC hospital), and also, the CPQCC coding of myelomeningocele has not been specifically validated. However, most infants with this condition are likely to be cared for in a CPQCC NICU, and NICU staff are likely to correctly identify infants with myelomeningocele. The state's birth defects registry is an excellent case-finding source but covers only approximate 20% of the state's population; therefore, we chose to use CPQCC data. Diagnostic codes for hydrocephaly or multiple birth defects in CPQCC and OSHPD could not be validated. We also lacked information on prenatal diagnosis of myelomeningocele in CPQCC, which could influence the choice of birth hospital; however, 95% of women in our study started prenatal care in the first or second trimester, and would therefore likely have had an ultrasound and in turn, a prenatal diagnosis of spina bifida. We were limited to the hospital care-related variables that were available to us in CPQCC. We did not explore interaction or confounding by repair hospital level because repairs occurred at 31 hospitals in total, and 29 of them were level III or IV, which limited our power to analyze the role of repair hospital status in timeliness of care. The current study did not examine fetal myelomeningocele repair, a procedure that is being offered as an alternate standard of care option after prenatal diagnosis of spina bifida.[13,20] Infants who underwent fetal surgery were ineligible to participate in the current study as they did not have open myelomeningocele at birth.

Our study shows that the majority of infants born with myelomeningocele in California are receiving a timely repair; however, about one-tenth of infants still had a delay in the repair time, beyond the recommended period, thus putting them at risk of adverse health outcomes, and this delay was associated with the type of medical care insurance. Families should be informed about the risks of delayed myelomeningocele repair and the importance of delivering in specialty hospitals that support neonatal intensive care, when planning a delivery of pregnancy affected by myelomeningocele. Our findings suggest that infants without private insurance are less likely to receive timely repair; a better understanding of social disadvantage and the part it plays in timely surgical care are needed to address disparities in myelomeningocele care and inform health care practices. Further efforts are also needed to determine why delivery at lower level hospitals and hospital transfer for repair are so frequent, given that they may impact infant outcomes. The hospital care-related factors for timeliness of repair can be expanded to variables that were not available to us in

CPQCC. Such knowledge will be integral to allow best clinical practices that prevent adverse health outcomes, disability, and mortality associated with myelomeningocele.

Conclusion

Most cases in California receive timely myelomeningocele surgery postnatally; delayed surgery is significantly associated with medical care payer status. Families should be educated on the importance of timely repair and delivering in hospitals with specialized multidisciplinary NICUs adhering to best clinical care practices to prevent adverse health outcomes associated with myelomeningocele.

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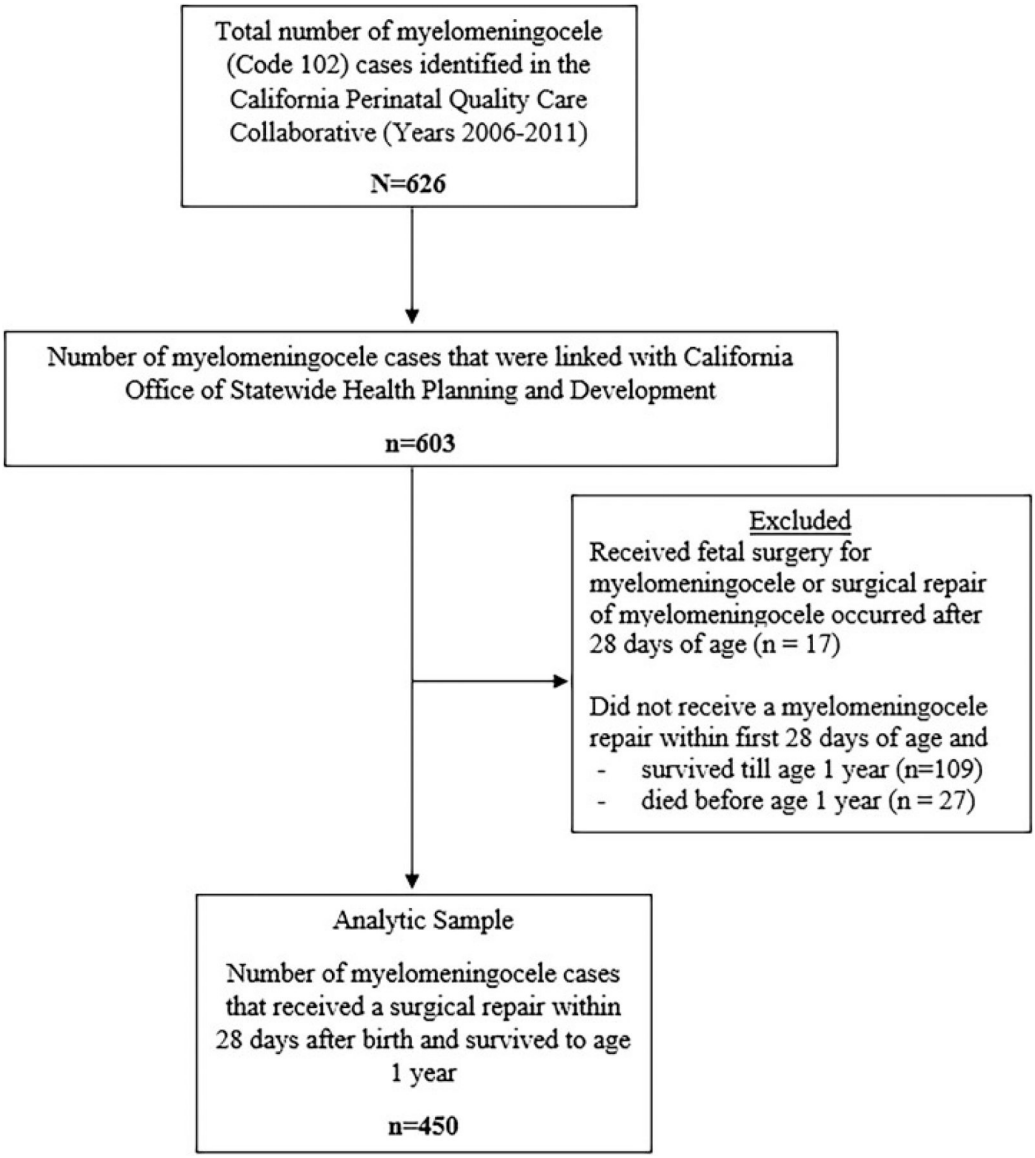

Fig. 1.
Subject selection flow chart.

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Table 1

Infant, maternal, and hospital care-related characteristics for infants with meningomyelocele repair, stratified by timeliness of repair, California Perinatal Quality Care Collaborative, 2006 to 2011[a]

Characteristics	Repair time 0–2 days after birth (timely repair) (*N* = 399)	Repair time 3+ days after birth (delayed repair) (*N* = 51)	All cases (*n* = 450)
	***n* (%)**	***n* (%)**	***n* (%)**
Infant			
Sex			
Female	197 (49.4)	25 (49.0)	222 (49.3)
Male	202 (50.6)	26 (51.0)	228 (50.7)
Gestational age (wk)			
37+	316 (79.2)	[sc] (>80)	358 (79.6)
< 37	65 (16.3)	[sc] (<20)	74 (16.4)
Birth weight (g)			
2,500+	352 (88.2)	[sc] (>75)	392 (87.1)
< 2,500	47 (11.8)	[sc] (<25)	58 (12.9)
Hydrocephalus			
No	55 (13.8)	26 (51.0)	81 (18.0)
Yes	344 (86.2)	25 (49.0)	369 (82.0)
Co-occurring birth defects			
Multiple	51 (12.8)	[sc] (<20)	60 (13.3)
Isolated	348 (87.2)	[sc] (>80)	390 (86.7)
Maternal			
Maternal age in years	Mean (SD) = 27.1 (6.2)	Mean (SD) = 27.8 (7.1)	Mean (SD) = 27.2 (6.3)
Census tract poverty level[b]	Mean (SD) = 17.9 (11.5)	Mean (SD) = 17.3 (10.5)	Mean (SD) = 17.8 (11.4)
Maternal race and ethnicity			
Non-Hispanic white	106 (26.6)	[sc] (<25)	118 (26.2)
Non-Hispanic black	[sc] (<5)	[sc] (<10)	20 (4.4)
Hispanic	249 (62.4)	32 (62.7)	281 (62.4)
Other	[sc] (<5)	[sc] (<10)	15 (3.3)

Characteristics	Repair time 0–2 days after birth (timely repair) (*N* = 399)	Repair time 3+ days after birth (delayed repair) (*N* = 51)	All cases (*n* = 450)
	***n* (%)**	***n* (%)**	***n* (%)**
Maternal education			
Less than high school	139 (34.8)	[sc] (<30)	152 (33.8)
High school graduate	97 (24.3)	[sc] (<35)	113 (25.1)
Some college or higher	142 (35.6)	20 (39.2)	162 (36.0)
Medical insurance			
Private	132 (33.1)	[sc] (<25)	143 (31.8)
Medi-Cal/other	264 (66.2)	[sc] (>75)	304 (67.6)
Prenatal care initiation			
Trimester 1 or 2	377 (94.5)	[sc] (>90)	426 (94.7)
Trimester 3 or none	22 (5.5)	[sc] (<10)	24 (5.3)
Hospital care related			
Level of care at birth hospital			
Level I/II	85 (21.3)	[sc] (<25)	97 (21.6)
Level III/IV	314 (78.7)	[sc] (>75)	353 (78.4)
Hospital repair volume			
≥ 9/year	196 (49.1)	21 (41.2)	217 (48.2)
6–8/year	109 (27.3)	[sc] (<30)	123 (27.3)
3–5/year	64 (16.0)	[sc] (<20)	73 (16.2)
≤ 2/year	30 (7.5)	[sc] (<15)	37 (8.2)
Hospital transfer from birth hospital before repair			
No transfer	207 (51.9)	23 (45.1)	230 (51.1)
Transfer from level of care I/II to III/IV	77 (19.3)	[sc] (<25)	88 (19.6)
Transfer from level of care III/IV to III/IV	115 (28.8)	[sc] (<35)	[sc] (<30)

Abbreviations: *n*, frequency; [sc], small cell sizes (15 or less); SD, standard deviation.

Note: Data were suppressed for cells with 15 or fewer subjects, as well as for a counterpart cell so that cell sizes could not be calculated by subtraction.

[a] Frequencies and percentages may not equal total and 100%, respectively, due to missing data.

[b] Determined based on 2007 to 2011 American Community Survey 5-year estimates.

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Table 2

Risk ratios for factors associated with myelomeningocele repair at 3 or more days after birth versus 0 to 2 days, California Perinatal Quality Care Collaborative, 2006 to 2011[a]

Characteristics	Unadjusted risk ratio (95% confidence interval)	Adjusted risk ratio[b] (95% confidence interval)
Infant		
Sex		
Female	Reference	Reference
Male	1.01 (0.59, 1.75)	1.01 (0.61, 1.70)
Gestational age (wk)		
37+	Reference	–
< 37	1.04 (0.51, 2.13)	
Birth weight (g)		
2,500+	Reference	Reference
< 2,500	1.86 (0.95, 3.62)	2.06 (1.10, 3.83)
Hydrocephalus		
No	Reference	Reference
Yes	0.21 (0.12, 0.37)	0.22 (0.13, 0.39)
Co-occurring birth defects		
Multiple	Reference	Reference
Isolated	1.39 (0.68, 2.86)	1.17 (0.50, 2.77)
Maternal		
Maternal age in years	1.02 (0.97, 1.06)	1.02 (0.98, 1.07)
Census tract poverty level[c]	0.99 (0.97, 1.02)	1.00 (0.97, 1.02)
Maternal race and ethnicity		
Non-Hispanic white	Reference	Reference
Non-Hispanic black	0.98 (0.22, 4.39)	0.82 (0.22, 3.07)
Hispanic	1.12 (0.58, 2.17)	1.15 (0.60, 2.21)
Other	2.62 (0.85, 8.13)	1.27 (0.43, 3.75)
Maternal education		

Characteristics	Unadjusted risk ratio (95% confidence interval)	Adjusted risk ratio[b] (95% confidence interval)
Less than high school	0.60 (0.29, 1.26)	0.67 (0.33, 1.37)
High school graduate	Reference	Reference
Some college or higher	0.87 (0.45, 1.68)	1.10 (0.58, 2.06)
Medical insurance		
Private	Reference	Reference
Medi-Cal/other	1.71 (0.88, 3.33)	2.23 (1.17, 4.27)
Prenatal care initiation		
Trimester 1 or 2	Reference	Reference
Trimester 3 or none	0.72 (0.18, 2.98)	0.69 (0.20, 2.40)
Hospital care related		
Level of care at birth hospital		
Level I/II	Reference	Reference
Level III/IV	0.89 (0.47, 1.71)	0.93 (0.22, 3.96)
Hospital repair volume		
≥ 9/year	Reference	Reference
6–8/year	1.18 (0.60, 2.31)	1.04 (0.55, 1.94)
3–5/year	1.27 (0.58, 2.78)	1.04 (0.48, 2.23)
≤ 2/year	1.96 (0.83, 4.60)	1.74 (0.76, 4.00)
Hospital transfer from birth hospital before repair		
No transfer	Reference	Reference
Transfer from level of care I/II to III/IV	1.25 (0.61, 2.56)	1.06 (0.20, 5.55)
Transfer from level of care III/IV to III/IV	1.29 (0.69, 2.41)	1.26 (0.67, 2.36)

[a] Analyses included 399 infants with repair within 0 to 2 days of delivery and 51 infants with later repair.

[b] Each variable was adjusted for all other variables in the model.

[c] Determined based on 2007 to 2011 American Community Survey 5-year estimates.