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Survival of infants with congenital diaphragmatic hernia in California: Impact of hospital, clinical, and sociodemographic factors

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Abstract

Objective.—To understand factors associated with care and survival among babies with congenital diaphragmatic hernia (CDH).

Study design.—We used data on California births (2006–2011) to examine birth hospital level of care, hospital transfer before repair, and survival.

Result.—Among 577 infants, 25% were born at lower-level hospitals, 62% were transferred, and 31% died during infancy. Late or no prenatal care had the strongest association with birth at lower-level hospitals (adjusted Relative Risk (ARR)=1.9, 95% confidence interval (CI)=1.0–3.6). Birth at lower-level hospitals was associated with transfer (ARR=1.2, CI=1.1–1.4), and transferred infants tended to be less clinically complex. Infants with low birthweight, other birth defects, low Apgar scores, and late or no prenatal care had 2–4-fold higher risk of mortality than their comparison groups.

Conclusions.—These data support the importance of prenatal care and delivery planning into higher-level hospitals for optimal care and outcomes for newborns with CDH.

INTRODUCTION

Congenital diaphragmatic hernia (CDH) is a rare congenital anomaly (2.5 per 10,000 live births) involving a defect in the diaphragm and displacement of abdominal organs into the thoracic cavity, which impedes lung development. It is associated with approximately 30–40% mortality during infancy as well as long-term neurodevelopmental impairment among

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survivors, and it is costly to treat.[12] Specific genetic abnormalities and environmental exposures have been proposed to contribute to the risk of CDH, but its etiology remains largely uncertain.[3] Infants with CDH often have pulmonary hypoplasia and pulmonary hypertension, thereby necessitating complex management approaches immediately at birth to maximize survival and minimize short and long-term morbidity.

The care of infants born with CDH is complex, and definitive management may include advanced respiratory treatment, extracorporeal life support, and surgical repair. It has been suggested that delivery of infants with CDH at hospitals with high-level neonatal intensive care units (NICUs) that are capable of this definitive management is preferable to post-delivery transport, so that access to optimized care is immediate.[2] However, the extent to which infants with CDH are inborn versus transported to higher-level care NICUs and the impact of these practices on health outcomes is not well understood. Prior studies suggest that transport may be associated with higher mortality,[45] but further study is needed, especially in populations that more completely capture population-based referral patterns. The extent to which individual-level clinical or sociodemographic factors are associated with where infants with CDH are born, whether they are transferred, and whether they survive also merits further study, so that at-risk infants can be better identified.

To address these gaps in understanding, this paper describes level of care of the birth hospital, inter-hospital transfer before repair, and survival to one year of age among infants born with CDH, based on data from a cohort of over three million births in California from 2006–2011. Secondly, it examines the association of clinical and sociodemographic factors with these outcomes. To do so, we used linked data from vital records, hospital discharge records, and the California Perinatal Quality Care Collaborative (CPQCC), which collects information from NICUs.

METHODS

Study data and linkages.

We examined infants born with CDH among the 3,271,380 births that occurred in California from 2006–2011. Data from birth and infant death certificates and hospital discharge records were linked by the California Office of Statewide Health Planning and Development (OSHPD). For each year of births, the OSHPD files are linked to hospital discharge records for the mother and baby from hospitalizations that occurred during pregnancy, at delivery, and during the year after delivery. For each hospitalization, OSHPD files include hospital, diagnostic and procedure codes, dates and length of stay, and transfer status. Cases were identified by CPQCC based on a specific code for CDH in their data collection system. CPQCC collects clinical data on infants admitted to >90% of NICUs in California, including infants with life-threatening birth defects such as CDH, and neonates requiring critical interhospital transport (cpqcc.org). OSHPD and CPQCC files were merged based on common variables present in both files. In addition, we merged the OSHPD files back to the original electronic birth certificates to obtain maternal addresses at delivery (based on a common identifier in both files). During the study period, CPQCC reported 719 infants with CDH. After excluding 42 infants whose birth certificates were not linked to hospital

discharge records, 7 who had fetal surgery, and 12 who survived infancy but had no record of hernia repair (potential data errors), 658 infants were available for analysis.

Study variables.

Sociodemographic variables included maternal race-ethnicity, education, payer, age, parity (number of prior live births), initiation of prenatal care (began in first or second trimester, versus later or not at all), all from birth certificates, and census tract poverty. To determine census tract poverty level, we used geocoded maternal addresses to assign census tracts, and then derived poverty information from 2007–2011 American Community Survey files. The California Environmental Health Tracking Program (CEHTP) Geocoding Service conducted the geocoding,[6] which was successful for 99% (n=650) of cases. Tract poverty was defined as the percent of the tract population with household income below the poverty level.

Clinical covariates related to case complexity included infant birthweight (<2500 gm vs. higher) and gestational age at delivery (<37 weeks versus later) from the birth certificate; 5-minute Apgar score (<7 vs higher) from CPQCC (or birth certificate, if missing from CPQCC); and the presence of additional major birth defects, primarily reported by CPQCC, which was categorized to indicate the presence of major congenital heart defects (i.e., we did not include septal defects or patent ductus arteriosus), other major birth defects, or neither (see Supplementary Table for details). Other data related to the severity or side of the hernia, or whether prenatal diagnosis was made, were not available.

We derived information on the following infant and care-related outcomes: level of neonatal care of the birth hospital, transfer from the birth hospital before CDH repair, and survival. Hospital level of neonatal care was assigned by NICU directors, based on American Academy of Pediatrics guidelines. For analyses, we grouped them as I-II or III-IV (surgery is unlikely at the former). Briefly, level I hospitals have a well newborn nursery (i.e. no neonatal intensive care unit); level II units are designed to primarily care for infants of >32 weeks of gestational age and weighing >1500 g with limited capacity for mechanical ventilation and generally not equipped to care for surgical patients; level III units are capable of providing comprehensive care for infants born at <32 weeks of gestational age and <1500 g, including mechanical ventilation; and level IV units include a full range of pediatric medical and surgical specialists, including pediatric neurosurgery.[7,8] Transfer was defined as being transferred from the birth hospital to another hospital before CDH repair. We examined transfer patterns across all levels of birth and transfer hospitals (i.e., possibly ranging from transfer from a level I birth hospital to another level I hospital, to transfer from a level IV birth hospital to another level IV hospital). We created a variable to more succinctly summarize the most common transfer patterns, in order to avoid small cell sizes in further analyses: 1) no transfer, 2) transfer from a level I-II birth hospital to a level III-IV hospital; and 3) transfer from a level III-IV birth hospital to another level III-IV hospital. We examined survival during the first year of life (i.e., up to 364 days from the date of birth), based on reporting from infant death certificates.

Analyses.

In total, 658 infants were identified for analysis, among whom 577 had complete covariate data. We first examined the distribution of each covariate and outcome among all cases. We used log binomial regression to estimate relative risks (RR) and 95% confidence intervals (CI) reflecting the association of covariates with birth hospital level of care (I-II versus III-IV) and transfer (any versus none). Models included sociodemographic variables and variables related to case complexity (we included birthweight but excluded gestational age, since these variables are highly correlated, and data were more complete for birthweight). The model for transfer also included level of care of the birth hospital. We also examined separate models for transfer from level I-II hospitals or transfer from level III-IV hospitals, but we only include results for the overall model since results from these two models were similar. We conducted a sensitivity analysis of the transfer model, excluding the 40 infants who died on their first day of life, to see if associations with transfer changed, since these infants may not have had the opportunity for transfer. To examine the association of covariates with mortality, we used Cox proportional hazards models to estimate hazard ratios (HR) and 95% CIs. The proportional hazards assumption was met based on Kolmogorov-type Supremum test results. As above, models included sociodemographic variables and variables related to case complexity. We conducted a sensitivity analysis of the mortality model, excluding infants who died on their first day of life, to see if the association of transfer with survival changed. The study was approved by the California Committee for the Protection of Human Subjects and the Stanford University Institutional Review Board.

Code availability.

All analyses were conducted using SAS 9.4 (SAS Institute, Inc. Cary, NC). Code used to analyze the data are available from the authors upon request.

RESULTS

Overall, 52% of the mothers of infants born with CDH were Hispanic, 46% had greater than a high school education, 50% had public insurance at delivery, and 98% began prenatal care in the first or second trimester, and 14% of the infants with CDH had an accompanying cardiac or non-cardiac birth defect (Table 1). In total, 25% of the infants were born at level I-II hospitals and 75% at level III-IV hospitals; 62% of the infants (n=357) were transferred for repair. Almost a third of the infants died (31%, 180/577). Half (50%) of the deaths occurred during the first week of life (early neonatal mortality, n=90), 29% from 7–28 days (late neonatal mortality, n=52), and 21% later during infancy (i.e., >28 days, n=38). Among the 180 infants who died, 33% died after repair surgery (59/180); 67% died before surgery (121/180, 39 of whom died after transfer but before surgery); and 43% (77/180) died after discharge from their delivery hospitalization.

Transfer varied by level of care of the birth hospital (Table 2). Very few infants born at level I (3%) or level II (5%) hospitals were not transferred, whereas 30% born at level III and 88% born at level IV hospitals were not transferred (Table 2). Most infants who were transferred were transferred to level IV hospitals. Overall, 80% of CDH repairs occurred at level IV

hospitals and 20% at level III hospitals; only three occurred at a level II hospital and none at a level I hospital (data not shown).

Among infants born at level I-II hospitals, 96% were transferred, 24% of those who were transferred died, and 100% of those who were not transferred died (Table 3). Among infants born at level III-IV hospitals, 50% were transferred, 20% of those who were transferred died, and 45% of those who were not transferred died. Among infants who were transferred, 61% (217/357) were born at level III-IV hospitals, whereas among infants who were not transferred, 97% (214/220) were born at level III-IV hospitals.

The analysis of level of care of birth hospital yielded minimal evidence of association with the study variables, especially after adjustment for covariates (Table 4). As one example, after adjustment, maternal education less than high school was associated with a 1.3-fold increased risk of delivering at a level I-II, versus level III-IV, hospital (95% CI 0.9–1.9), but maternal education greater than high school was also associated with increased risk (adjusted RR 1.3, 95% CI 0.9–2.0). Late or no prenatal care was associated with a 1.9-fold increased risk of delivering at a level I-II hospital (95% CI 1.0–3.6). Relative risks for variables related to case complexity were all less than one, but all confidence intervals included 1.0.

Adjusted relative risks for the association of covariates with transfer (any vs. none) ranged from 0.9–1.1, with one exception; infants born at level I-II hospitals were 20% more likely to be transferred than infants born at level III-IV hospitals (RR 1.2, 95% CI 1.1–1.4) (Table 4). The unadjusted and adjusted relative risks tended to be similar, with some notable differences; i.e., the unadjusted relative risk for transfer among infants born at a level I-II hospital was 1.9 (versus 1.2 after adjustment), and unadjusted relative risks ranged from 0.6–0.8 for the clinical factors (versus 0.9–1.0 after adjustment). After excluding infants who died on their first day of life, RRs were similar (e.g., the adjusted RR for transfer was 1.2, 95% CI 0.9–1.5).

Adjusted hazard ratios for mortality indicated that infants who were low birthweight, had other accompanying cardiac or non-cardiac birth defects, had a low 5-minute Apgar score, and whose mothers started prenatal care in the third trimester or not at all had approximately two- to four-fold higher risk of mortality than their respective comparison groups; 95% CIs for these estimates excluded 1.0 (Table 5). Among infants with other birth defects who survived, 42% (10/24) had cardiac defects, of whom 60% (6/10) also had non-cardiac defects; among infants with other birth defects who died, 63% (35/56) had cardiac defects, of whom 54% (19/35) also had non-cardiac defects. Adjusted hazard ratios for the sociodemographic variables were closer to 1.0 and their CIs did include 1.0. Transfer from birth hospital to another hospital for repair was associated with 70% lower risk of mortality (adjusted HR 0.3, 95% CI 0.2–0.5). After excluding infants who died on the first day of life from the model, the adjusted HR for transfer was 0.5 (95% CI 0.3–0.7); the pattern of results for other variables did not change substantially (data not shown).

DISCUSSION

Among infants born with CDH in California, 25% were born at hospitals with level I-II neonatal care capacity, 62% were transferred to another hospital for repair, and 31% did not survive infancy. Most sociodemographic and clinical variables did not substantially influence these outcomes, with the exception that infants who had clinical risk factors (e.g., low birthweight, other major birth defects) were at higher risk of dying, and infants whose mothers had late or no prenatal care initiation were at higher risk of being born at level I-II hospitals and of dying.

We are unaware of studies reporting level of care of birth hospital within other contemporary, large cohorts of infants with CDH. It is typically thought that delivery at a Level I-II hospital should be avoided for infants with CDH, given that infants with CDH are likely to need services offered only at higher-level hospitals. However, 25% of infants in this cohort were born at Level I-II hospitals. Late or no prenatal care was associated with 1.9-fold increased risk of this outcome, suggesting that lack of prenatal diagnosis, or complications leading to rapid delivery at an unanticipated location may have contributed.

We also examined hospital transfer; 62% of infants were transferred. Transfer is an important part of care, but ideally, it should be pre-empted when possible, especially for infants with potentially life-threatening conditions like CDH. Transfer can incur unnecessary medical risk, results in at least short-term separation of mothers from their newborns, and is expensive.[9,10] Some prior data on transfers among infants with CDH are available but tend to be based on highly selected study populations (e.g., from single or few institutions) and focus on mortality among transferred infants rather than predictors of transfer itself. A study by Aly et al. of over 2,000 cases cared for in selected U.S. hospitals from 1997 to 2004 reported that 48% of infants were transported before surgery, and that infants who were transported were 1.5 times more likely to die after surgery than non-transported infants.[4] A smaller study of 140 prenatally diagnosed cases born from 2005–2008 and treated within a network of Canadian pediatric surgical centers reported that infants who were transported to the centers for care were more likely to die.[5] In contrast, our study found that infants who were transferred were more likely to survive. Decision-making around where to deliver and whether to transfer an infant is complex, and many factors could contribute to the differences in findings. The prior studies noted above were conducted among more restricted subgroups of infants, rather than being population-based, which could affect their results. Given that most (98%) of women in our study received prenatal care by the second trimester, we expect that at least the most severe CDH cases could have been prenatally diagnosed and advised to be delivered at level III-IV hospitals. On the other hand, less severe cases may not have been detected on ultrasound; although the diaphragm is formed by the seventh week of gestation, visceral herniation may not occur until later, up to the time of delivery, if the extent of abnormal musculature is limited and the hernia is small.[11] It is thus possible that the cases who were transferred in our study (at least those transferred from I-II to III-IV level hospitals) had less severe hernias and this contributed to their better survival. In addition, clinical risk factors were less common among infants who were transferred, which also suggests that they were inherently a lower-risk group. At the other extreme, transfer may not occur for some very severe or complex cases with multiple anomalies, because the

family had prospectively made the decision for comfort care. It is also possible that some births may occur intentionally at a level II or level III center and then transfer to a level IV center that does not have a delivery service. We were unable to distinguish this type of transfer from a transfer in which the place of birth was not intentionally planned based on the diagnosis of CDH. Unfortunately, we do not have information on prenatal diagnosis or severity of the hernia to enable us to directly assess the contribution of these factors to our findings. In addition, CPQCC reporting would miss cases that were born at non-CPQCC hospitals who died before transfer to a CPQCC hospital. However, because CPQCC includes data from >90% of NICUs in California, and >90% of non-CPQCC hospitals are Level I, we do not expect this source of under-reporting to be a major contributor to our findings.

Many of the studied factors did not predict which CDH infants were likely to deliver at level I-II (versus III-IV) hospitals, be transferred, or die. Notably, race-ethnicity and variables related to socioeconomic status were not associated with the outcomes. Potential predictors that were not available in this study but that would be useful to examine in the future include, for example, prenatal diagnosis, planned delivery hospital, distance from a mother's home to the birth hospital versus repair hospital, and more detail regarding case severity, especially information that could be detected prenatally (e.g., size and sidedness of the hernia, observed-to-predicted estimated fetal lung volume, position of the liver). Also, detailed information about the specialty services and expertise available at some level III-IV sites was not available in this dataset. These factors may be particularly important to understanding why so many infants were delivered at a level III-IV hospital but transferred for repair, and why non-transferred infants had higher mortality. At this point, further study is needed in order to understand these complexities and what changes in practice could improve outcomes among these vulnerable infants.

Mortality estimates among liveborn infants with CDH have varied widely across studies. Some contributing factors are years of study (approaches to care may have changed over time), extent of follow-up (e.g., some studies follow infants only through hospital discharge, whereas others follow them through infancy), exclusions (e.g., some studies exclude cases who die before repair, or complex cases such as those with underlying genetic abnormalities), and study design (varying from single-center studies, to those that are population-based). More recent, population-based studies tend to estimate infant mortality to be approximately 30%, which is similar to our study.[12–14] Improvements in survival in recent decades may be attributable to improvements in care. Increased termination of pregnancy, especially of more severe cases, may also contribute.[14] In our study, clinical factors were associated with increased risk of dying, which agrees with prior studies.[21215] We examined a more extensive set of sociodemographic variables than most prior studies (maternal race-ethnicity, education, payer and census tract poverty), but these factors were not predictive of mortality. The study by Aly et al. reported that babies born to black mothers were 2.4 times more likely to die, after adjustment for factors such as newborn co-morbidities, age at repair, and transport.[4] Stevens et al. also reported worse survival among black infants after adjustment for other factors, among infants born from 1995–2004.[16] Both of these studies were limited to infants born at or transferred to participating hospitals, which may have influenced the findings.[17] Sola et al., in a study of the Kids Inpatient Database from a sample of U.S. hospitals, considered race/ethnicity, type of insurance, and

zip code median income; they reported black race-ethnicity as the only significant predictor after adjustment for the other factors.[18] However, the study was based on ICD-9 codes for diagnosis, only 40% of cases (1,095/2,774) had evidence of repair, and 30% were missing data on race-ethnicity. A recent state-wide study of 1,025 infants with CDH born in Florida from 1998–2012, however, did not find that maternal race-ethnicity or education was associated with infant survival.[12]

Important strengths of the current study include its state-wide data capture, large and diverse study population, and use of linked data from vital records, administrative data, and CPQCC. Many studies of care and mortality among infants with CDH are limited to data from either the delivery hospitalization or the repair hospitalization, and they are unable to determine mortality after discharge.[14] In our study, over half of the infants were transferred for repair, 43% of deaths occurred after discharge from the delivery hospitalization, and almost one-fourth of all deaths occurred after 28 days, thus illustrating the usefulness of the linked data resources. We relied on diagnosis data from CPQCC, which has advantages. For example, some prior studies that use administrative data have relied on ICD-9 codes to identify cases, [1218] but the ICD-9 code for CDH (756.6) does not differentiate eventration of the diaphragm from CDH. The percent of infants with other major birth defects (14%) was lower than other prior studies;[31314] we primarily relied on CPQCC codes for specific birth defects, and this system likely errs on the side of including more severe birth defects than, for example, reliance on ICD-9 codes. Although our study had access to a wide range of variables, it was also lacking some factors which will be important for future studies, e.g., prenatal diagnosis and severity of the hernia (as noted above), planned delivery hospital, specialty services available at each hospital such as availability of extracorporeal membrane oxygenation (ECMO), and immediate complications in the newborn. We were unable to identify cases with known syndromes or chromosomal abnormalities with certainty; however, we expect them to comprise a relatively small proportion of all cases (5–15%).[31314] The diversity and size of the study population are advantages. As this was a population-based study conducted in the state of California, we recognize that our findings may not be generalizable to other states that have varying geographical and healthcare system patterns. However, California uses level of care classification criteria specified by the American Academy of Pediatrics, which is a nationally recognized organization, and regional systems and networks across the U.S. may consider our findings applicable to their practice. Additionally, our results are applicable to a substantial proportion of U.S births, since one in eight U.S. births occurs in California.

In conclusion, this California state-wide study of infants with CDH found that a substantial proportion were born at level I-II hospitals or underwent hospital transfer before repair. Sociodemographic factors (e.g., race-ethnicity and markers of socioeconomic status) were not predictive of delivery hospital level of care, hospital transfer, or mortality. Factors related to case complexity (low birthweight, other accompanying birth defects, and low Apgar score) were not predictive of level of care or transfer, but they were predictive of mortality. These data support the importance of prenatal care, diagnosis, and delivery planning into level III-IV centers wherein the care and outcomes for newborns with CDH can be optimized.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1.

Characteristics of 577 infants born with congenital diaphragmatic hernia, California, 2006–2011.

Sociodemographic covariates:	***n***	**Percent**
Maternal race-ethnicity		
Non-Hispanic white	186	32
US-born Hispanic	137	24
Foreign-born Hispanic	167	29
Non-Hispanic black	23	4
Asian/Pacific Islander	30	5
Other	34	6
Maternal education		
Less than high school completion	159	28
Completed high school	152	26
Greater than high school	266	46
Census tract poverty		
Lowest quartile	155	27
Middle quartiles	277	48
Highest quartile	145	25
Payer		
Medi-Cal/Other government	300	52
Non-government	277	48
Maternal age (years)		
<20	44	8
20–34	415	72
35+	118	20
Parity (number of previous live births)		
0	245	42
1 or more	332	58
Initiation of prenatal		
1st or 2nd trimester	≤565	98
3rd trimester or none	≤15	2
Indicators of case complexity:		
Birthweight (gm):		
<2500	138	24
2500 or more	439	76
Gestational age (weeks):		
<37	136	24
37 or more	441	76
Presence of other major birth defects:		
None	497	86
Congenital heart defects	45	8

Sociodemographic covariates:	n[I]	Percent
Other	35	6
5-Minute Apgar score:		
<7	233	40
7 or higher	344	60
Outcomes:		
Level of neonatal care of birth hospital:		
I	40	7
II	106	18
III	286	50
IV	145	25
Transfer from birth hospital before repair:		
None	220	38
From I-II to III-IV	129	24
From III-IV to III-IV	217	38
Other	1	<1
Mortality:		
Died at 0–6 days of age	90	16
Died at 7–28 days	52	9
Died at 29–364 days	38	7
Survived	397	69

[I]For variables for which any categories have less than 15 observations, we provide an estimate rounded up to the nearest unit of 5. Exact sample sizes are not provided due to an OSPHD requirement that cell sizes less than 15 not be specified.

Table 2.

Description of hospital transfer before repair, by level of care of the birth hospital, among 577 infants born with congenital diaphragmatic hernia in California, 2007–2011.

	Percent (number) of transfers by birth hospital level of care[I]			
	Level I birth hospital (n=40)	**Level II birth hospital (n=106)**	**Level III birth hospital (n=286)**	**Level IV birth hospital (n=145)**
No transfer	3 (≤5)	5 (≤5)	30 (87)	88 (127)
Transfer to level I or II hospital	3 (≤5)	0	0	0
Transfer to level III hospital	38 (≤15)	10 (≤15)	6 (18)	4 (≤10)
Transfer to level IV hospital	58 (≤25)	85 (≤90)	63 (181)	8 (≤15)

[I]For variables for which any categories have less than 15 observations, we provide estimates rounded up to the nearest unit of 5. Exact sample sizes are not provided due to an OSPHD requirement that cell sizes less than 15 not be specified. Column percentages may not add to 100% due to rounding.

Table 3.

Level of neonatal care of birth hospital, transfer before repair, and mortality, among infants born with congenital diaphragmatic hernia, California, 2006–2011.

Level of care of birth hospital	Percent (number) of infants (column percent)[I]	Percent (number) who died during infancy (row percent)
I or II (25% of infants)		
Transferred	96 (≤140)	24 (≤35/≤140)
Not transferred	4 (≤10)	100 (≤10/≤10)
Total	100 (146)	27 (40/146)
III or IV (75% of infants)		
Transferred	50 (217)	20 (44/217)
Not transferred	50 (214)	45 (97/214)
Total	100 (431)	33 (141/431)
Overall		
Transferred	62 (357)	22 (77/357)
Not transferred	38 (220)	47(103/220)
Total	100 (577)	31 (180/577)

[I]For variables for which any categories have less than 15 observations, we provide estimates rounded up to the nearest unit of 5. Exact sample sizes are not provided due to an OSPHD requirement that cell sizes less than 15 not be specified.

Table 4.

Association of sociodemographic, clinical and hospital characteristics with: a) delivery at a hospital with I-II versus III-IV level of neonatal care, and b) transfer from the birth hospital to another hospital for repair, among 577 infants born with congenital diaphragmatic hernia, California, 2006–2011.

	Relative risk (95% CI) for delivery at a level I-II (versus level III-IV) hospital[I]		Relative risk (95% CI) for transfer to another hospital before repair (versus no transfer)[I]	
Characteristics:	**Unadjusted**	**Adjusted**	**Unadjusted**	**Adjusted**
Maternal race-ethnicity				
Non-Hispanic white	Reference	Reference	Reference	Reference
US-born Hispanic	1.2 (0.8–1.8)	1.1 (0.7–1.7)	1.0 (0.8–1.1)	1.0 (0.9–1.1)
Foreign-born Hispanic	1.4 (1.0–2.0)	1.2 (0.8–1.9)	1.0 (0.9–1.2)	1.0 (0.9–1.1)
Non-Hispanic black	0.6 (0.2–1.7)	0.5 (0.2–1.6)	0.7 (0.5–1.2)	0.9 (0.8–1.1)
Asian/Pacific Islander	0.6 (0.2–1.5)	0.6 (0.2–1.6)	0.8 (0.5–1.1)	1.0 (0.8–1.1)
Other	0.8 (0.4–1.7)	0.8 (0.4–1.8)	0.7 (0.5–1.1)	1.0 (0.8–1.1)
Maternal education				
Less than high school completion	1.4 (1.0–2.0)	1.3 (0.9–1.9)	1.1 (0.9–1.3)	1.0 (0.9–1.1)
Completed high school	Reference	Reference	Reference	Reference
Greater than high school	1.0 (0.7–1.4)	1.3 (0.9–2.0)	1.0 (0.8–1.1)	1.0 (0.9–1.1)
Census tract poverty				
Lowest quartile	1.0 (0.7–1.4)	1.1 (0.7–1.5)	1.0 (0.8–1.1)	1.0 (0.9–1.1)
Middle quartiles	Reference	Reference	Reference	Reference
Highest quartile	1.2 (0.9–1.7)	1.0 (0.7–1.4)	1.1 (1.0–1.3)	1.0 (0.9–1.1)
Payer				
Medi-Cal/Other government	1.4 (1.1–1.9)	1.2 (0.8–1.7)	1.1 (1.0–1.3)	1.0 (0.9–1.1)
Non-government	Reference	Reference	Reference	Reference
Maternal age (per year)	0.98 (0.96–1.00)	0.97 (0.95–1.00)	0.99 (0.98–1.00)	1.00 (0.99–1.00)
Parity (number of previous live births)				
0	Reference	Reference	Reference	Reference
1 or more	1.2 (0.9–1.5)	1.2 (0.9–1.6)	1.0 (0.9–1.1)	1.0 (0.9–1.1)
Initiation of prenatal care				
1st or 2nd trimester	Reference	Reference	Reference	Reference
3rd trimester or none	1.7 (0.9–3.2)	1.9 (1.0–3.6)	0.9 (0.6–1.5)	1.0 (0.8–1.2)
Birthweight (gm):				
<2500	0.8 (0.6–1.2)	0.9 (0.7–1.3)	0.8 (0.7–1.0)	1.0 (0.9–1.1)
2500 or more	Reference	Reference	Reference	Reference
Presence of other major birth defects:*				
None	Reference	Reference	Reference	Reference
Congenital heart defects	0.8 (0.4–1.4)	0.8 (0.4–1.5)	0.6 (0.5–0.9)	0.9 (0.8–1.1)
Other	0.7 (0.3–1.4)	0.6 (0.3–1.4)	0.7 (0.4–1.0)	0.9 (0.8–1.1)
5-Minute Apgar score:				

	Relative risk (95% CI) for delivery at a level I-II (versus level III-IV) hospital[I]		Relative risk (95% CI) for transfer to another hospital before repair (versus no transfer)[I]	
Characteristics:	**Unadjusted**	**Adjusted**	**Unadjusted**	**Adjusted**
<7	0.8 (0.6–1.1)	0.8 (0.6–1.1)	0.8 (0.7–0.9)	1.0 (0.9–1.0)
7 or higher	Reference	Reference	Reference	Reference
Level of care of birth hospital:				
Level I or II	n.a.	n.a.	1.9 (1.7–2.1)	1.2 (1.1–1.4)
Level III or IV			Reference	Reference

[I]The model for level of care included 146 infants delivered at a level I-II hospital and 431 infants delivered at a level III-IV hospital. The model for transfer included 357 infants who were transferred and 220 infants who were not transferred. Both models included all variables in the table unless noted otherwise.

Table 5.

Association of sociodemographic, clinical and hospital characteristics with mortality during infancy, among infants born with congenital diaphragmatic hernia, California, 2006–2011.

Characteristics:	Percent survived (number survived / total in stratum)[I]	Unadjusted hazard ratio (95% CI) for mortality	Adjusted hazard ratio (95% CI) for mortality[II]
Maternal race-ethnicity			
Non-Hispanic white	69% (≤130/186)	Reference	Reference
US-born Hispanic	64% (≤90/137)	1.2 (0.8–1.8)	1.1 (0.7–1.6)
Foreign-born Hispanic	74% (≤125/167)	0.8 (0.6–1.2)	0.8 (0.5–1.2)
Non-Hispanic black	61% (≤15/23)	1.3 (0.6–2.6)	1.2 (0.6–2.4)
Asian/Pacific Islander	73% (≤25/30)	0.8 (0.4–1.7)	0.4 (0.2–0.9)
Other	59% (≤20/34)	1.4 (0.8–2.6)	0.8 (0.5–1.5)
Maternal education			
Less than high school completion	67% (106/159)	1.0 (0.7–1.5)	1.4 (0.9–2.2)
Completed high school	68% (103/152)	Reference	Reference
Greater than high school	71% (188/266)	0.9 (0.6–1.3)	1.0 (0.6–1.5)
Census tract poverty			
Lowest quartile	68% (106/155)	0.9 (0.7–1.3)	0.8 (0.6–1.2)
Middle quartiles	68% (187/277)	Reference	Reference
Highest quartile	72% (104/145)	0.8 (0.6–1.2)	0.9 (0.6–1.4)
Payer			
Medi-Cal/Other government	70% (211/300)	0.9 (0.7–1.2)	0.7 (0.5–1.0)
Non-government	67% (186/277)	Reference	Reference
Maternal age			
<20	57% (25/44)		
20–34	69% (285/415)	0.99 (0.96–1.01)[II]	1.0 (0.96–1.02)[III]
35+	74% (87/118)		
Parity (number of previous live births)			
0	67% (165/245)	Reference	Reference
1 or more	70% (232/332)	0.9 (0.7–1.2)	1.0 (0.7–1.3)
Initiation of prenatal care			
1st or 2nd trimester	70% (≤395/563)	Reference	Reference
3rd trimester or none	21% (≤15/14)	4.2 (2.3–7.8)	3.0 (1.5–6.0)
Birthweight (gm):			
<2500	46% (63/138)	2.9 (2.2–3.9)	1.9 (1.4–2.6)
2500 or more	76% (334/439)	Reference	Reference
Presence of other birth defects:[I]			
None	75% (≤375/497)	Reference	Reference
Congenital heart defects	22% (≤10/45)	4.8 (3.3–7.0)	2.9 (1.8–4.6)
Other	40% (≤15/35)	3.5 (2.2–5.6)	3.1 (1.9–5.1)
5-Minute Apgar score:			

Characteristics:	**Percent survived (number survived / total in stratum)** *I*	**Unadjusted hazard ratio (95% CI) for mortality**	**Adjusted hazard ratio (95% CI) for mortality** *II*
<7	46% (108/233)	4.5 (3.3–6.2)	4.1 (2.9–5.7)
7 or higher	84% (289/344)	Reference	Reference
Level of care of birth hospital:			
Level I or II	73% (107/146)	0.8 (0.5–1.1)	1.3 (0.9–2.0)
Level III or IV	67% (290/431)	Reference	Reference
Transfer from birth hospital for repair:			
Yes	78% (280/357)	0.4 (0.3–0.5)	0.3 (0.2–0.5)
No	53% (117/220)	Reference	Reference

I. For variables for which any categories have less than 15 observations, we provide estimates rounded up to the nearest unit of 5. Exact sample sizes are not provided due to an OSPHD requirement that cell sizes less than 15 not be specified.

II. Adjusted hazard ratios are from a model that included 577 infants and all variables in the table.

III. The hazard ratio for age is per one-year change in maternal age.