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The Association Between Hospital Obstetric Volume and Perinatal Outcomes in California

Jonathan M. SNOWDEN, PhD¹, Yvonne W. CHENG, MD, PhD², Caitlin KONTGIS, MS³, and Aaron B. CAUGHEY, MD, PhD¹

¹Department of Obstetrics and Gynecology, Oregon Health and Science University, Portland OR

²Department of Obstetrics, Gynecology and Reproductive Medicine, University of California, San Francisco

³Department of Geography, Center for Sustainability and the Global Environment, University of Wisconsin, Madison

Abstract

Objective—To analyze the association between hospital obstetric volume and perinatal outcomes in California.

Study Design—This was a retrospective cohort study of births occurring in California in 2006. Hospitals were divided into four obstetric volume categories. Unadjusted rates of neonatal mortality and birth asphyxia were calculated for each category, overall and among term deliveries with birthweight >2500g. Multivariable logistic regression was used to control for confounders. Deliveries in rural hospitals were analyzed separately using different volume categories.

Results—Prevalence of asphyxia increased with decreasing hospital volume overall and among term, non-low-birthweight infants, from 9 per 10,000 live births at highest-volume hospitals to 18/10,000 live births at the lowest-volume hospitals ($p<0.001$). Similar trends were observed in rural hospitals, with rates increasing from 7 to 34 per 10,000 live births in low-volume rural hospitals ($p<0.001$).

Conclusion—These findings provide evidence for an inverse association between hospital obstetric volume and birth asphyxia.

Keywords

Asphyxia; health facility size; healthcare systems; neonatal mortality

Introduction

While much evidence has documented the benefits of regionalization of high-risk obstetrics to high-volume hospitals with specialized care,^{1–3} there is not a similar consensus regarding

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Corresponding author: Jonathan M. Snowden, PhD, Department of Obstetrics and Gynecology, Oregon Health and Science University, 3181 SW Sam Jackson Park Rd, Mail code: L466, Portland, OR 97239, Phone: (503) 494-0904, Fax: (503) 494-4473, Mobile: (650) 704-9967, snowden@ohsu.edu.

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the role of regionalization and hospital volume in low-risk or general obstetric practice. Some studies have found that perinatal outcomes such as neonatal mortality and asphyxia are less prevalent in high-volume hospitals,^{4, 5} while others have reported a lack of association or suggested that lower-volume settings may be better for some outcomes in low-risk pregnancies.^{6, 7}

Proposed mechanisms underlying the potential protective effect for high obstetric volume in lower-risk births are systems factors such as staffing, medical equipment, continuous presence of onsite anesthesia, availability of subspecialists, and readiness to handle fluctuations in patient flow.^{4, 8} Among the studies of hospital obstetric volume on neonatal outcomes in lower-risk deliveries, most have been conducted outside the United States, mostly in Europe and Australia.^{4-6, 9} Neonatal mortality is commonly analyzed as a marker of quality in obstetric/perinatal care.¹⁰⁻¹² Additionally, birth asphyxia and intrapartum fetal death are also frequently used as indicators of quality of obstetric care,^{9, 11, 13, 14} and some suggest that these outcomes may be sensitive markers of quality of obstetric care.^{15, 16}

The effects of hospital volume and regionalization of obstetric care are complicated by geographical and socioeconomic factors, including variations in patient mix and the urban/rural character of a given region.^{6, 8} When evaluating the ability of different-sized maternity units to provide high-quality care, we often make the assumption that patients could conceivably be referred to an alternative hospital with maternity services. In rural and frontier regions, that assumption may not hold.⁸

In this paper, we analyze the role of obstetric volume in perinatal outcomes in California. We analyzed this association in the overall population of births, and in a lower-risk subpopulation of term births with birthweight >2500g, in order to assess the impact of volume without the factors of prematurity and growth restriction, which may drive rates of some adverse outcomes. We studied neonatal mortality and birth asphyxia as primary outcomes, and consider the potential confounding roles of patient mix, academic hospital affiliation, and hospital geography (rural versus non-rural). We hypothesized that lower-volume hospitals would be characterized by higher rates of asphyxia. Because the rural setting is highly correlated with obstetric volume and mutually exclusive with academic affiliation in these data, we analyzed the role of obstetric volume in California's rural hospitals separately, testing the hypothesis that the effect of obstetric volume on perinatal outcomes may differ between rural and non-rural locations.

Materials and Methods

This study employed a retrospective cohort design, analyzing linked birth/infant death certificates with hospital discharge diagnoses for births occurring in California in 2006. Data linkage of California Patient Discharge Data, Vital Statistics Birth Certificate Data, and Vital Statistics Death Certificate Data was conducted by the state Office of Statewide Health Planning and Development (OSHPD) Healthcare Information Resource Center, under the California Health and Human Services Agency (CHHS). The linked dataset includes health information from maternal records for antepartum hospital admissions for the nine months prior to delivery and postpartum admissions up to one year post delivery. Also included are birth records and records for all infant admission and diagnoses in the first year of life. This linked dataset does not include information on out-patient visits. The record linkage number, a unique, encrypted alphanumeric code specific to each mother/baby pair, was employed to link records for mother and baby. The reporting of births and deaths in California is nearly 100% comprehensive, and CHHS personnel code the data according to uniform specifications, perform rigorous quality checks, and review the birth cohort file before release. Human subjects approval was obtained from the Institutional Review Board at

Oregon Health & Science University, the Committee on Human Research at the University of California, San Francisco, and the California OSHPD Committee for the Protection of Human Subjects. Because the linked dataset did not contain potential patient privacy and identification information, informed consent was exempted.

Births were linked to hospital of delivery in the dataset by a unique hospital code; births missing this code were excluded from analysis. Maternity hospitals were divided into four categories on the basis of obstetric volume, defined as the total number of deliveries occurring in the hospital during 2006. In order to minimize the incorporation of births at unintended locations such as emergency rooms or hospitals without designated Labor and Delivery units, hospitals with fewer than 50 deliveries in 2006 were excluded from analysis. The category cutoffs were selected to divide the hospitals into strata of varying obstetric volume for analysis, while maintaining a sufficient number of hospitals in each group. The categories were labeled numerically, increasing with volume. The lowest volume category (category 1) included hospitals with up to 1,200 deliveries in 2006; these hospitals had a monthly average of 100 deliveries or less. The category cutoffs preceded at intervals of 1,200 deliveries: Category 2 included smaller-to-intermediate facilities with between 1,200 and 2,400 deliveries; Category 3 hospitals had between 2,400 – 3,600 deliveries, and the high volume category (4) was made up of hospitals with 3,600 or more deliveries in 2006.

Since prior research has demonstrated that obstetric practice differs between academic and community medical centers,^{17, 18} and between rural and urban regions,^{19, 20} we also stratified our analysis by teaching hospital status and geographic setting to explore institutional-level factors that might be associated with obstetric volume and also affect obstetric care. Maternity hospitals were designated as teaching hospitals if they had an Ob-Gyn residency program or had obstetric rotations for Ob-Gyn residents. The geographic distinction of interest was rural/non-rural, because gradations of urbanization/suburbanization within metropolitan regions have less bearing on access to multiple maternity hospitals. Rural regions of the state are served by fewer labor and delivery (L&D) units located in expansive and sparsely-populated regions, so regionalization of births occurring in these hospitals is less feasible, and standards of volume likely differ in rural regions.²¹ There is no universally agreed-upon definition of rural,²² so we employed a system relying on multiple sources, designating maternity hospitals as rural if they met one of the following criteria: hospitals designated as rural by the California OSHPD,²³ hospitals in towns with a California Association of Rural Health Clinics member clinic,²⁴ and hospitals located in rural ZIP codes according to the Rural-Urban Commuting Area (RUCA) codes (RUCA-2 codes 4 – 10).^{22, 25} After preliminary analysis indicated that rural hospitals should be analyzed separately, we devised three obstetric volume categories for rural hospitals, dividing the hospitals approximately into tertiles by volume: 50 – 599 deliveries (Category R1), 600 – 1,699 deliveries (R2), and 1,700 deliveries or greater (R3).

We examined the frequency of neonatal death (death in the first 28 days of life) and neonatal asphyxia among live births within obstetric volume categories, separately for rural and non-rural hospitals. Cases of neonatal asphyxia were identified using the International Statistical Classification of Diseases and Related Health Problems, revision 9 (ICD-9) codes 768.5, 768.6, 768.7 and 768.9. In addition to overall rates of neonatal mortality and asphyxia, we calculated rates among the lower-risk population of births at full term gestation (37 – 42 weeks) that were not low birthweight (>2,500 grams), because low birthweight and preterm birth are strongly predictive of neonatal death and are not equally distributed among high-low-volume hospitals.

To adjust for patient mix and hospital characteristics among the lower-risk sub-population, we employed multivariable logistic regression to calculate the odds of asphyxia associated

with medium- and lower-volume maternity units. Regression models were run stratified by rural geography. Individual characteristics analyzed to account for patient mix were race/ethnicity, education (binary, ≥ 12 years or <12 years), and advanced maternal age (>35 years old). Teaching hospital status was controlled for in the non-rural analysis. Because of the non-independence of outcomes within hospitals, the logistic regression accounted for clustering at the hospital level and calculated robust standard errors. All analyses excluded congenital anomalies as determined by diagnosis codes on the birth certificate and the infant's medical record (ICD-9 codes 740–759.9). Analyses were conducted using Stata (version 12, StataCorp; College Station, TX) and R (version 2.13.1, R Foundation for Statistical Computing; Vienna, Austria).

Results

This study included a total of 268 hospitals performing at least 50 deliveries in 2006, for a total of 527,617 births. There were more hospitals in the lowest volume category, Category 1 (Figure 1). The intermediate volume categories included fewer hospitals but more deliveries, while Category 4 included a relatively small number of hospitals delivering up to 7,900 babies in 2006.

Institutional characteristics of the hospitals varied by hospital volume (Table 1). Rural geography was highly correlated with low volume; almost half of the lowest volume hospitals were rural, while none of the highest volume hospitals were. Conversely, the proportion of teaching hospitals increased across volume categories. There was no overlap between rural hospitals and teaching hospitals; for these methodological reasons and the aforementioned practical considerations, we present the remainder of the results stratified by geography, non-rural (i.e., urban and suburban) versus rural. The urban coastal regions of the California had no rural hospitals, while the northern and eastern extremes of the state had only rural hospitals, and the central regions were characterized by a mixture of the two (Figure 2).

Demographic and clinical characteristics of the patient populations differed by hospital obstetric volume and by geography (Table 2). For the non-rural hospitals, prevalence of preterm birth and low birthweight increased with increasing hospital volume. Category 3 and 4 hospitals had a patient mix comprising fewer white patients, as compared to hospitals with lower volume. In rural hospitals, middle- and higher-volume hospitals had a majority of Hispanic patients with lower educational attainment as compared to patients at the smallest rural hospitals, which had a majority of white patients.

Table 3 presents unadjusted prevalence of asphyxia and neonatal death per 10,000 non-anomalous live births, for all births and restricted to term births with birthweight >2500 g. Asphyxia decreased with increasing hospital volume among all births, from a high of 20 per 10,000 live births in Category 1 to 11/10,000 in Category 4 ($p<0.001$). When restricting to the lower-risk sub-population, the trend was in the same direction and the differences remained significant, decreasing from 18 per 10,000 live births at lower-volume hospitals to 9/10,000 in Category 4 hospitals. There appeared to be an increased rate of neonatal death ($P<0.05$) in medium- and higher-volume hospitals as compared to Category 1, but the difference was not apparent when restricting to term births with birthweight >2500 g, where the risk was universally low (2 to 3 per 10,000 live births, $P=0.376$).

Similar trends were observed among deliveries at rural hospitals. Asphyxia rates steeply decreased across categories of increasing rural hospital volume (40 per 10,000 live births in Category R1 hospitals to 8/10,000 in R3 hospitals, $P<0.001$); the decrease attenuated only slightly when restricting to term deliveries with birthweight >2500 g. There appeared to be a

non-significant increase in neonatal mortality with increased rural hospital volume, but this trend was not evident when restricting to term, non-low-birthweight births.

To control for potential confounding, the association between hospital volume and asphyxia was assessed using multivariable logistic regression, restricting to the lower-risk subpopulation and adjusting for maternal race/ethnicity, education, advanced maternal age, teaching hospital (in the non-rural model), and intra-hospital clustering (Table 4). With the highest volume category as the reference (Categories 4 and R3), there were significantly elevated odds of neonatal asphyxia among births at lower volume hospitals, in both the rural and non-rural analysis. Odds of asphyxia were approximately doubled at Category 1 non-rural hospitals (adjusted Odds Ratio [aOR], 2.10; 95% confidence interval [CI], 1.18 – 3.74) and Category 2 hospitals (aOR, 1.92; 95% CI, 1.04 – 3.56). The adjusted odds of asphyxia in Category 3 hospitals did not differ from the odds in the highest volume category (Table 4). The smallest rural hospitals, Category R1, also had elevated odds of asphyxia (aOR, 3.69; 95% CI, 1.90 – 7.18), while the aOR was not significantly different between the middle and upper rural volume categories.

Comment

In this large cohort of live births in California, we observed an increased prevalence of birth asphyxia in lower-volume hospitals in rural and non-rural settings. This finding was observed both overall and among term deliveries with birthweight >2500g. Furthermore, the association remained statistically significant after multivariable regression adjustment for both small rural and non-rural hospitals. These associations adjusted for factors at the patient and hospital level, so it is less likely that they are biased due to hospital or patient differences between volume categories.

Our study findings corroborate the work of a German group that found an inverse association between hospital obstetric volume and adverse neonatal outcomes among low-risk births,^{4, 9} extending this association to a United States population. Further, after stratifying rural hospitals and analyzing these births separately, we observed that a similar association exists in the small hospitals that serve the rural populations of California. This distinction between rural and non-rural hospitals is important to take into account when considering the policy implications of these results.⁸ These findings might argue against the safety of low-volume labor and delivery units in urban settings with multiple high-obstetric-volume hospitals nearby. If it would be logistically feasible for the women served by these hospitals to be referred to nearby higher-volume hospitals, then it might be advisable to concentrate low-risk maternity services in urban, high-obstetric-density areas. However, given the increasing scarcity of obstetrical care in rural regions of the West,^{20, 21, 26} the finding of increased risk at lower rural hospital volume will likely need different policy approaches to achieve improvement.

The sparse population of the regions served by these hospitals, the distance between the hospitals with labor and delivery units, and the fact that patients traveling to rural hospitals often already have higher travel times than their non-rural counterparts all lead to the conclusion that centralization of obstetric care in such settings is likely not feasible.²⁷ Instead, efforts should focus on equipping these hospitals with the staff, training, and other resources needed to provide high-quality obstetric care in the absence of high patient volume and the beneficial factors that flow from it.

Though overall neonatal death rates were elevated in the medium- and high-volume hospitals, when this analysis was restricted to a lower-risk subpopulation, neonatal death rates dropped considerably and this association was no longer statistically different by hospital volume. These findings corroborate the observation that variations in perinatal

mortality are largely driven by case-mix of high-risk pregnancies complicated by factors including intrauterine growth restriction and preterm birth, and that birth asphyxia may be a more sensitive measure of quality of obstetric care.¹⁵

The limitations of this study should be taken into account when interpreting these findings. Analysis of linked birth certificate/hospital discharge data precluded detailed chart review which would have increased validity of outcome ascertainment. When analyzing observational data, it is challenging to eliminate the possibility of uncontrolled confounding and determine whether observed associations are causal. However, for a question such as this, where randomization of hospital volume is not feasible, observational data may be the best option available. We acknowledge that differences in case mix between the volume categories, if not adjusted for, could bias results. In this case, high-volume referral hospitals are likely to have more high-risk patient populations, so residual confounding would likely attenuate rather than amplify the present findings. The cutoffs we used to categorize obstetric volume divided hospitals into categories by size and maintained an adequate number of independent units (i.e., hospitals) in each category, however the specific cut-points chosen were arbitrary. The analysis of data from California may limit the valid inference of study findings to other settings (or other US states). Still, California is a large and diverse state with substantial geographical variation; its births account for approximately one eighth of all US births annually and mirrors the heterogeneous population in the US.

We do not propose that hospital volume causes adverse outcomes, *per se*; rather hospital volume is assumed to be an indicator of systems factors that may drive the outcomes. Future work is needed to examine these specific factors to determine the mechanism of how volume can be associated with perinatal outcomes, and thus enable solutions to improve maternal and child health care. Another potential way to improve health care delivery would be to identify factors that predict adverse perinatal outcomes less severe than mortality, and to refer these pregnancies to higher-volume facilities. Unfortunately, we found the differences persisted even in a lower-risk population and obstetric emergencies such as placental abruption or cord prolapse can occur in any obstetric patient. Ultimately, a policy of regionalization for low-risk obstetrics must balance safety, convenience, access, and patient satisfaction to ensure an optimal match between patient population and institutional capacity for a given region.

This study found evidence of a protective effect for increased hospital volume on birth asphyxia in California. If further work confirms the apparent higher risk conferred by delivery of lower-risk pregnancies in a setting of low obstetric volume, providers and patients should consider how to improve outcomes for these lower-risk births. Solutions may differ based on the geographic setting of the hospital and the patients served.

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Figure 1.
California hospitals by obstetric volume in 2006 (deliveries/year)
Legend: Histogram showing distribution of hospitals by volume; dashed lines indicate hospital volume category cutoffs.

Figure 2.

Presence and geography of maternity hospitals in California in 2006, by county

Legend: Map demonstrating the geographic distribution of maternity hospitals in California counties.

Table 1

Institutional characteristics of California hospitals with labor and delivery, by hospital volume.

	Overall (n=268 hospitals)		Hospital volume category (deliveries/year)							
	n	%	1: 50 – 1199 (n=98)		2: 1200 – 2399 (n=84)		3: 2400 – 3599 (n=55)		4: 3600 (n=31)	
			n	%	n	%	n	%	n	%
Rural	57	21	48	49	6	7	3	5	0	0*
Teaching hospitals §	26	10	2	2	6	7	9	16	9	29*

* P<0.001 on Fisher's exact test

§ There was no overlap between rural hospitals and teaching hospitals.

Table 2

Demographic and clinical profile of California births in 2006 by hospital obstetric volume.

	Non-rural					Rural			
	Overall (N=488,622 births; n=211 hospitals)	Hospital volume (deliveries/year)				Overall (N=38,995 births; n=57 hospitals)	Hospital volume (deliveries/year)		
		1 50 – 1199 (N=36,038; n=50)	2 1200 – 2399 (N=139,548; n=78)	3 2400 – 3599 (N=155,883; n=52)	4 3600 (N=157,153; n=31)		R1 50 – 599 (N=11,818; n=36)	R2 600 – 1699 (N=14,941; n=16)	R3 1700 (N=12,236; n=5)
LBW	7.3	5.6	6.6	7.4	8.2	5.3	5.0	5.3	5.6
PTB	11.1	8.7	9.9	11.5	12.4	10.2	9.0	10.0	11.7
Singleton birth	96.7	97.9	97.2	96.6	96.2	98.1	98.1	97.8	98.4
Nulliparous	39.5	38.4	39.9	39.2	39.7	35.7	39.5	34.5	33.5
Advanced maternal age	18.2	18.9	18.1	17.2	19.2	10.4	11.1	10.5	9.7
Prior cesarean	15.0	14.9	14.3	14.8	15.7	15.1	12.4	17.4	14.9
Education 12 yrs	47.4	47.0	45.9	48.4	48.0	30.6	37.5	31.8	22.6
Race/ethnicity									
White	32.9	39.1	35.2	31.9	30.3	39.4	63.0	31.5	26.3
Black	5.5	4.8	4.6	5.9	6.2	2.6	2.6	1.9	3.6
Hispanic	46.5	42.2	46.9	46.3	47.4	51.9	25.5	62.0	64.9
Asian-American	12.4	10.9	10.6	13.2	13.5	2.5	2.9	1.8	3.0
Other	2.7	3.0	2.7	2.7	2.6	3.6	6.0	2.8	2.2

LBW: low birthweight; PTB: preterm birth

All number in table are percentages.

Table 3
Prevalence of asphyxia and neonatal death by hospital volume, among non-anomalous live births

			Hospital volume category (deliveries/year)			
			1 (50 – 1199)	2 (1200 – 2399)	3 (2400 – 3599)	4 (3600)
Non-rural	Asphyxia (per 10,000)	All births	20	19	12	11 [*]
		Excl. PTB, LBW	18	17	10	9 [*]
	Neonatal death (per 10,000)	All births	12	20	21	23 [‡]
		Excl. PTB, LBW	2	3	2	3
Rural	Asphyxia (per 10,000)		R1 (50–599)	R2 (600 – 1699)	R3 (1700)	
		All births	40	15	8 [*]	
	Neonatal death (per 10,000)	Excl. PTB, LBW	34	11	7 [*]	
		All births	17	22	30	
		Excl. PTB, LBW	5	3	6	

LBW: low birthweight; PTB: preterm birth

[‡] P<0.05 for chi-square test

^{*} P<0.001 for chi-square test

Table 4

Results of multivariable logistic regression of asphyxia, restricted to term births with birthweight >2500g

Hospital volume category	aOR* (95%CI)	P-value §
1	2.10 (1.18, 3.74)	0.012
2	1.92 (1.04, 3.56)	0.038
3	1.07 (0.64, 1.81)	0.791
4	Ref.	Ref.
Rural hospital volume category	aOR** (95%CI)	P-value §
R1	3.69 (1.90, 7.18)	<0.001
R2	1.53 (0.87, 2.69)	0.138
R3	Ref.	Ref.

aOR: adjusted odds ratio; 95% CI: 95% confidence interval.

* Regression adjusted for maternal race/ethnicity, education, advanced maternal age, and teaching hospital

** Regression adjusted for maternal race/ethnicity, education, and advanced maternal age.

§ Robust standard errors correcting for clustering by hospital