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The Association between Hospital Obstetrical Volume and Maternal Postpartum Complications

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Abstract

Objective—To examine the relationship between delivery volume and maternal complications.

Study Design—We used administrative data to identify women admitted for childbirth in 2006. Hospitals were stratified into deciles based upon delivery volume. We compared composite complication rates across deciles.

Results—We evaluated 1,683,754 childbirths in 1045 hospitals. Deciles 1 and 2 hospitals had significantly higher rates of composite complications than Decile 10 (11.8%, 10.1%, vs. 8.5%, $P < .0001$). Deciles 9 and 10 hospitals had modestly higher composite complications as compared to Decile 6 (8.8%, 8.5%, vs 7.6%, $P < .0001$). Sixty percent of Decile 1 and 2 hospitals were located within 25 miles of the nearest greater volume hospital.

Conclusions—Women delivering at very low volume hospitals have higher complication rates, as well as those delivering at exceeding high volume hospitals. Most women delivering in extremely low volume hospitals have a higher volume hospital located within 25 miles.

Keywords

obstetrical volume; patient safety; perinatal epidemiology; postpartum complications

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Introduction

Over 4 million women give birth annually in the United States (U.S.)¹, making childbirth the single most common reason for hospitalization among young women. Childbirth in the U.S. is generally safe with major complications rates (e.g. hemorrhage or infection) of less than 10 percent.^{2, 3, 4} At the same time, there is growing appreciation that the variation in hospital outcomes that have been observed in many medical and surgical diagnoses may also exist for childbirth.

More than two decades of research has documented a relationship between higher hospital volume and improved clinical outcomes for medical and surgical diagnoses^{5–14}, but data in the area of maternal childbirth outcomes are sorely lacking. The paucity of empirical studies of the volume-outcome relationship for maternal complications is striking given the clinical volume and economic impact of childbirth in the U.S. In addition, methodologic limitations of the few published studies relating to a volume-outcome relationship for the maternal outcomes of childbirth make it difficult to interpret the conflicting findings.^{15–19}

Our objective was to rigorously examine the relationship between hospital volume and maternal childbirth outcomes. Specifically, we set out to examine the association between hospital childbirth volume and important maternal complications (e.g. hemorrhage infection, death) and whether the volume-outcome relationship might differ for vaginal and cesarean deliveries.

Materials and Methods

We used a 100% sample of State Inpatient Data (SID) for year 2006 from eleven states (Arizona, California, Florida, Iowa, Massachusetts, Maryland, North Carolina, New York, New Jersey, Washington, and Wisconsin) to identify all patients hospitalized with childbirth (International Classification of Diseases, 9th Clinical Modification (ICD-9_CM) codes of 650 or 640x–676.9x (N = 1,683,754). Maternal childbirth admissions were stratified into cesarean deliveries (CD) (ICD-9 procedure code of 74); or normal spontaneous vaginal deliveries (VD) (ICD-9 diagnosis codes of 640.x through 676.9x, and the absence of a code for CD).

We excluded patients who delivered after transfer from another acute care hospital because transfer patients are more complex than patients admitted through other routes and administrative data do not adequately capture this excess complexity leading to potentially biased results.²⁰ All other cases of childbirth (spontaneous vaginal deliveries, cesarean deliveries, forceps and vacuum) were included in the analysis of “all deliveries” (Figure 1). Our analysis of spontaneous vaginal deliveries excluded instrument deliveries using forceps or vacuums because use of such devices suggests a more complicated delivery and may introduce unwanted heterogeneity. Application of these criteria left us with a cohort of what we would describe as routine childbirth admissions without obvious evidence of complicating factors.

The SID databases used in this study were developed by the Agency for Healthcare Research and Quality (AHRQ) as part of the healthcare utilization project (HCUP) in

partnership with individual states (see:<http://hcupnet.ahrq.gov/> for more information). We deliberately acquired SID data from these eleven states included in this study because they represented all regions of the U.S., included a disproportionate percentage of the U.S. population, and covered a mix of urban and rural regions. SID data include many elements that are included on the UB-92 hospital discharge abstract and have been used extensively in prior health services research including prior obstetrical studies.^{21–23} Key data elements include: patient demographics; admitting hospital; primary and secondary diagnoses and procedures, as captured by ICD-9-CM codes; the diagnosis related group (DRG); admission source (e.g., emergency department, transfer from another hospital); admission and discharge dates; patient's primary insurance (categorized as Medicare; private insurance; Medicaid; self-pay; other); type of insurance (fee-for-service or HMO); and disposition at the time of hospital discharge (e.g., transfer to another acute care hospital, deceased).

We calculated three separate measures of childbirth volume for each hospital by summing the total number of deliveries that were performed during 2006: 1) total childbirth volume; 2) spontaneous vaginal delivery volume; 3) cesarean delivery volume. Hospitals were then stratified into deciles of volume for each of the three delivery categories; thus, a hospital could be in the highest (tenth) decile of volume for total childbirth but the eighth decile for vaginal deliveries.

We identified six key adverse outcomes of childbirth that have been evaluated in prior studies using administrative data including hemorrhage, severe perineal lacerations (3rd or 4th degree lacerations), operative complications, infection, thrombotic complications and mortality.^{2, 3, 24} Outcomes of interest for vaginal deliveries included all of the outcomes described above with the exception of operative complications which are not relevant to vaginal delivery. Outcomes of interest for cesarean deliveries included all outcomes except for severe perineal lacerations which are not relevant to cesarean deliveries. From an analytic standpoint, our primary outcome was a composite measure representing the occurrence of one-or-more adverse outcomes in a given patient. We identified comorbid illnesses using the method developed by Elixhauser *et al.*, and supplemented this by high risk obstetrical conditions that have been identified previously.^{25, 26}

Statistical Analysis

We used bivariate methods including the t-test and Cochran-Mantel-Haenszel statistics to compare the demographic characteristics (e.g., age, race) of patients across hospital volume deciles. We used similar methods to compare insurance coverage, and the incidence of comorbid illnesses across deciles of hospital volume. All analyses were conducted separately for spontaneous vaginal deliveries, cesarean sections, and all deliveries in aggregate. We used similar methods to compare the unadjusted incidence of in-hospital maternal complications across hospital volume-deciles.

Finally, we used a series of logistic regression models to evaluate the association between rates of childbirth complications and hospital obstetrical volume after adjusting for differences in patient demographics and comorbidity. We used the patient as the unit of analysis, with volume being measured at the hospital level. The standard errors, 95 percent

confidence intervals, and associated significance levels for adjusted odds ratios based on logistic regression accounted for clustering using hospital random effect models. For purposes of these analyses, the outcome (dependent variable) was an indicator variable representing the occurrence of the composite outcome. The dependent variables of interest were a series of indicator variables representing the decile of hospital volume with hospitals in the highest volume decile serving as the reference category. The models included 19 covariates including patient age, race, payor and a number of important comorbid illness (for a list of all covariates please see Table 4). Separate analyses were performed for: 1) all childbirths in aggregate; 2) spontaneous vaginal deliveries only and 3) cesarean deliveries only. We applied three separate models to each patient cohort: 1) unadjusted; 2) adjusted for patient demographics alone, and 3) adjusted for patient demographics plus comorbidities.

Because we hypothesized that more complex patients would be selectively referred to higher volume hospitals we conducted a number of sensitivity analyses. Specifically, we stratified both vaginal deliveries and cesarean deliveries into high-risk and low-risk cohorts. High-risk patients were defined as those with any of the following conditions typically considered cause for concern among obstetricians: advanced age; asthma; cerebral hemorrhage; hypertensive disorders; diabetes; obesity; chorioamnionitis; congenital heart disease, liver anomalies, renal anomalies, thyroid disease, mental disorder, multiple gestation, preterm gestation, pulmonary embolism, and uterine rupture. The low-risk cohort included patients without any of these conditions. We also replicated our analyses to examine alternative methods for categorizing hospital volume (e.g. quintiles, quartiles) and defining high and low volume hospitals.

All statistical analyses were performed using SAS 9.2 (SAS Institute Inc., Cary, NC). The study was approved by the Institutional Review Board of the University of Iowa.

Results

We identified a total of 1,683,754 childbirths. After excluding transfer cases, (N=4945), our final cohort of spontaneous vaginal deliveries, forceps deliveries, vacuum extractions, and cesarean deliveries included 1,678,809 admissions to 1045 hospitals. After excluding forceps and vacuum assisted deliveries (N = 94,188), there were a total of 1,047,848 spontaneous vaginal deliveries in 1011 hospitals (34 hospitals only delivered by cesarean), and 536,773 cesarean deliveries in 1030 hospitals (15 hospitals only delivered by vaginal route). For hospitals that performed both vaginal and cesarean deliveries the cesarean delivery rate ranged from 13.0% to 96.7% across 1030 hospitals (mean = 31.3%; median = 30.3%). The mean hospital childbirth volume was 1606.5 (interquartile range [IQR] 442.0 – 2299.0), mean vaginal delivery volume was 1036.4 (IQR: 308.0 – 1472.0) and mean cesarean delivery volume was 521.1 (IQR: 135 – 754).

The characteristics of spontaneous vaginal delivery patients stratified by hospital volume deciles are displayed in Table 1. Women who delivered in lower volume hospitals tended to be younger, more likely to be white, and more likely to be categorized as self-pay when compared with women who delivered at higher volume hospitals. Women undergoing vaginal delivery in lower volume hospitals tended to have fewer comorbid conditions

including advanced maternal age, hypertension and diabetes (Table 1). Conversely, women having vaginal deliveries in high volume hospitals were more likely to be older, Hispanic or black, and had more comorbid illness. Results were similar for cesarean deliveries (Table 2), with low volume hospitals treating a higher proportion of uninsured younger white women, while high volume hospitals treated more women with advanced age and comorbid illness.

In analyses of unadjusted outcomes (Table 3 and Figure 2), we found higher rates of the composite adverse outcome and most of the individual adverse outcomes in the lowest volume hospitals (Deciles 1 and 2) when compared with all other hospitals within all deliveries, vaginal deliveries, or cesarean deliveries. For example, looking at all deliveries in aggregate the incidence of the composite outcome in Decile 1 was 11.8%, in Decile 2 was 10.1%, but ranged from 7.6% to 8.8% for the other eight deciles in aggregate ($p < .0001$). Looking at spontaneous vaginal deliveries in isolation and cesarean deliveries in isolation, we saw similar results with higher unadjusted rates of both the composite and most individual adverse outcomes in Decile 1 and Decile 2 hospitals. We also observed a modest increase in unadjusted complication rates in the highest volume hospitals (Deciles 8–10) when compared with intermediate volume hospitals (Deciles 5–7). This effect was particularly apparent in cesarean deliveries (Table 3). To ensure the robustness of our findings we repeated our analyses examining the relationship between volume and outcome while stratifying hospitals based upon total delivery volume rather than vaginal or cesarean volume; thus, in these analyses we explored the relationship between vaginal delivery outcomes and volume after stratifying hospitals by their total delivery volume and did analogous analyses for cesarean deliveries. We found that the volume-outcome relationship was similar irrespective of the measure of volume that was used. We also calculated the proportion of cesarean deliveries according to hospital decile to cesarean volume (Table 3) and found no difference in the proportion of deliveries that were cesarean sections across volume deciles.

In analyses adjusting for patient demographics and comorbidities (Table 4), we again found higher risk of adverse outcomes in lowest volume hospitals (Decile 1 and 2). Specifically, odds of experiencing the composite outcome were between 43% and 60% higher for Decile 1 hospitals (with Decile 10 serving as the reference category) even after adjusting for patient demographics and comorbidity ($p < .05$). Alternatively, odds of adverse outcomes appeared modestly lower for intermediate volume hospitals (Deciles 5 and 6) with the effect particularly notable for cesarean deliveries.

To ensure the robustness of our findings, we conducted additional supplemental analyses. First, we repeated our unadjusted and adjusted analyses examining outcomes across deciles of hospital volume after stratifying patients into high risk and low risk subgroups. Unadjusted analyses produced similar results to our main analyses with higher complication rates in the lowest volume hospitals for both the high risk and low risk patient strata irrespective of delivery route (Appendix Tables 1a, 1b, 1c). Adjusted results in the high and low risk subgroups were also similar to the main analyses with higher odds of experiencing the composite outcomes in the lowest volume hospitals (Appendix Tables 1d, 1e, 1f). Additional results were significant for high risk patients having higher odds of adverse outcomes as compared to low risk subgroups in the lowest volume hospitals ($p < .05$).

Interestingly, in our supplementary analyses high volume hospitals again appeared to have marginally higher rates of adverse outcomes in both the high risk and low risk strata. We also conducted additional analyses using alternative methods for stratifying hospitals according to volume (e.g., quartiles, quintiles) and results were again similar.

Comment

In an analysis of over 1.6 million maternal hospitalizations for childbirth, we identified a number of important findings. First, we found markedly higher rates of maternal complications for deliveries in low volume hospitals. Second, we found modestly higher rates of complications for deliveries at exceedingly high volume hospitals – a finding that, if not related to unmeasured difference in comorbidity, would give one pause. Third, we found marked variation in cesarean delivery rates across hospitals.

The finding of higher rates of adverse outcomes at low volume hospitals has been well documented in medical and surgical literature^{5–14}, but has not been well studied in obstetrics. Prior studies evaluating the volume-outcome relationship in obstetrics have been limited to studies from single state populations, data that is now greater than a decade old, and conflicting results about the volume-outcome relationship.^{15–19} In addition, many prior obstetrical volume-outcome studies focused exclusively on neonatal outcomes without investigating maternal complications.^{27–33} Our study provides important new evidence of higher maternal complication rates at very low volume hospitals.

The finding of higher obstetrical complication rates in low volume hospitals is not necessarily unexpected. The mean overall childbirth volume for Decile 1 hospitals was 31.6 per year and for Decile 2 hospitals 204.8 per year. Moreover, the mean cesarean section volume for Decile 1 and Decile 2 hospitals were 13.2 and 64.1 respectively. With such low volumes, it seems logical that complication rates would be high, especially given the importance of both experience and teamwork in the healthcare setting. Several hospitals in our study had only one or two admissions for childbirth during 2006, suggesting that such deliveries represented emergent cases done at hospitals without an experienced physician or obstetrical team.

Alternatively, it is interesting to think about how the healthcare system might be changed in a way that might reduce the need for mothers to give birth at extremely low volume hospitals. In supplementary analyses, we explored the role of distance in women giving birth at Decile 1 and Decile 2 hospitals. Notable, we found 60 % of Decile 1 and Decile 2 hospitals were located within 25 miles of a higher obstetrical volume hospital (Decile 4 or greater, mean distance 25.9 miles). Practically speaking, our results would suggest that a certain percentage of deliveries at very low volume hospitals might reasonably be transitioned to higher volume hospitals with little inconvenience to patients or their families. It is also important to consider our findings in the context of existing guidelines related to childbirth. The American Congress of Obstetrics and Gynecology (ACOG) readily recommend that women threatening to deliver preterm be transferred to tertiary centers,³⁴ yet, there is no equivalent guideline for establishing minimum hospital delivery volume and tiered maternal referrals based on patient safety.

Second, it is interesting that we consistently found modestly higher rates of complications for deliveries at exceedingly high volume hospitals. There are several potential explanations for our findings. First, it is possible, and indeed highly likely, that the higher rates of adverse outcomes in the highest volume hospitals represent the higher risk of the population that our highest volume hospitals serve. Patients who are referred to high volume hospitals for childbirth have a greater likelihood of having medical conditions with an increased severity of illness that is poorly represented in claims data.²⁰ The finding that the higher rates of adverse outcomes persisted after adjustment for patient demographics and comorbidities may merely reflect unmeasured differences in comorbidity that are not captured well in administrative data. Alternatively, it is possible that extremely high volume hospitals truly do have higher complication rates for childbirth. Specifically, if our highest volume hospitals were too busy, staffed by trainees without adequate supervision, and under extreme financial pressure, higher complication rates might well be expected. Further study is needed to examine this issue in greater detail.

Third, we found marked variation in mean hospital cesarean delivery rates across hospitals (13.0% to 96.7%). These results are consistent with several prior studies that found highly variable rates of cesarean deliveries with significant regional variation.^{35–37} The reasons for these differences remain unknown, and far exceeded the expected variation that can be explained by differences in patient risk factors alone. These findings suggest that there is insufficient outcomes-based evidence to guide effective clinical decision making. Future research is needed to further explain unknown variation in rates of cesarean deliveries especially given our finding of higher rates of maternal complications after cesarean as compared to vaginal delivery.

There are a number of limitations to our study. First, our study relied on administrative data, and thus may have been subject to bias if diagnoses or procedures were systematically miscoded more often by one group of hospitals. We have, however, no reason to believe that this happened, and prior studies have shown that there is reliable coding of obstetrical diagnoses and procedures.³⁸ Second, our analysis was limited to eleven states and thus results must be generalized to other states with care. Third, the structure of the SID data precluded us from tracking maternal complications that may have occurred after discharge; likewise, we lacked the ability to link mothers to their newborns and track complications jointly in both. Fourth, similar to all studies that use large administrative databases, our investigation is restricted to the variables that are considered necessary for claims data. Consequently, certain clinical information is not available for analysis.

In conclusion, our study suggests elevated complication rates for women hospitalized for childbirth at extremely low volume hospitals, as well as modestly higher rates of complications for deliveries at exceedingly high volume hospitals. Further study is needed to elucidate whether the higher rates of complications at higher volume hospitals merely reflect unmeasured severity of illness or are a result of more intangible factors. Since a significant proportion of low volume hospitals are located in close proximity to higher volume facilities, physicians and patients should carefully consider the need for delivery at low volume hospitals when viable alternatives exist.

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References

1. Martin JA, Kung HC, Mathews TJ, et al. Annual summary of vital statistics: 2006. *Pediatrics*. 2008; 121:788–801. [PubMed: 18381544]
2. Duff, P. Maternal and Perinatal Infection. In: Gabbe, S.; Niebyl, JR.; Simpson, JL., editors. *Obstetrics: Normal and Problem Pregnancies*. New York: Churchill Livingstone; 2002.
3. ACOG Practice Bulletin: Clinical Management Guidelines for Obstetrician-Gynecologists Number 76, October 2006: postpartum hemorrhage. *Obstetrics and gynecology*. 2006; 108:1039–47. [PubMed: 17012482]
4. Heron M, Hoyert DL, Murphy SL, Xu J, Kochanek KD, Tejada-Vera B. Deaths: final data for 2006. *Natl Vital Stat Rep*. 2009; 57:1–134. [PubMed: 19788058]
5. Hannan EL, O'Donnell JF, Kilburn H Jr, Bernard HR, Yazici A. Investigation of the relationship between volume and mortality for surgical procedures performed in New York State hospitals. *JAMA : the journal of the American Medical Association*. 1989; 262:503–10.
6. Showstack JA, Rosenfeld KE, Garnick DW, Luft HS, Schaffarzick RW, Fowles J. Association of volume with outcome of coronary artery bypass graft surgery. Scheduled vs nonscheduled operations. *JAMA : the journal of the American Medical Association*. 1987; 257:785–9.
7. Phillips KA, Luft HS, Ritchie JL. The association of hospital volumes of percutaneous transluminal coronary angioplasty with adverse outcomes, length of stay, and charges in California. *Med Care*. 1995; 33:502–14. [PubMed: 7739274]
8. Hannan EL, Racz M, Ryan TJ, et al. Coronary angioplasty volume-outcome relationships for hospitals and cardiologists. *JAMA : the journal of the American Medical Association*. 1997; 277:892–8.
9. Thiemann DR, Coresh J, Oetgen WJ, Powe NR. The association between hospital volume and survival after acute myocardial infarction in elderly patients. *The New England journal of medicine*. 1999; 340:1640–8. [PubMed: 10341277]
10. Steiner CA, Bass EB, Talamini MA, Pitt HA, Steinberg EP. Surgical rates and operative mortality for open and laparoscopic cholecystectomy in Maryland. *The New England journal of medicine*. 1994; 330:403–8. [PubMed: 8284007]
11. Birkmeyer JD, Siewers AE, Finlayson EV, et al. Hospital volume and surgical mortality in the United States. *The New England journal of medicine*. 2002; 346:1128–37. [PubMed: 11948273]
12. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. *The New England journal of medicine*. 2003; 349:2117–27. [PubMed: 14645640]
13. Finks JF, Osborne NH, Birkmeyer JD. Trends in hospital volume and operative mortality for high-risk surgery. *The New England journal of medicine*. 2011; 364:2128–37. [PubMed: 21631325]

14. Ross JS, Normand SL, Wang Y, et al. Hospital volume and 30-day mortality for three common medical conditions. *The New England journal of medicine*. 2010; 362:1110–8. [PubMed: 20335587]
15. Grobman WA, Feinglass J, Murthy S. Are the Agency for Healthcare Research and Quality obstetric trauma indicators valid measures of hospital safety? *American journal of obstetrics and gynecology*. 2006; 195:868–74. [PubMed: 16949428]
16. Heaphy PE, Bernard SL. Maternal complications of normal deliveries: variation among rural hospitals. *J Rural Health*. 2000; 16:139–47. [PubMed: 10981365]
17. Chang JJ, Stamilio DM, Macones GA. Effect of hospital volume on maternal outcomes in women with prior cesarean delivery undergoing trial of labor. *Am J Epidemiol*. 2008; 167:711–8. [PubMed: 18192674]
18. Garcia FA, Miller HB, Huggins GR, Gordon TA. Effect of academic affiliation and obstetric volume on clinical outcome and cost of childbirth. *Obstetrics and gynecology*. 2001; 97:567–76. [PubMed: 11275029]
19. Janakiraman V, Lazar J, Joynt KE, Jha AK. Hospital volume, provider volume, and complications after childbirth in U.S. hospitals. *Obstetrics and gynecology*. 2011; 118:521–7. [PubMed: 21826039]
20. Rosenberg AL, Hofer TP, Strachan C, Watts CM, Hayward RA. Accepting critically ill transfer patients: adverse effect on a referral center's outcome and benchmark measures. *Ann Intern Med*. 2003; 138:882–90. [PubMed: 12779298]
21. Cram P, Bayman L, Popescu I, Vaughan-Sarrazin MS, Cai X, Rosenthal GE. Uncompensated care provided by for-profit, not-for-profit, and government owned hospitals. *BMC Health Serv Res*. 2010; 10:90. [PubMed: 20374637]
22. James AH, Patel ST, Watson W, Zaidi QR, Mangione A, Goss TF. An assessment of medical resource utilization and hospitalization cost associated with a diagnosis of anemia in women with obstetrical bleeding in the United States. *J Womens Health (Larchmt)*. 2008; 17:1279–84. [PubMed: 18752459]
23. Weber AM, Meyn L. Episiotomy use in the United States, 1979–1997. *Obstetrics and gynecology*. 2002; 100:1177–82. [PubMed: 12468160]
24. Peleg D, Kennedy CM, Merrill D, Zlatnik FJ. Risk of repetition of a severe perineal laceration. *Obstetrics and gynecology*. 1999; 93:1021–4. [PubMed: 10362174]
25. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care*. 1998; 36:8–27. [PubMed: 9431328]
26. Srinivas SK, Epstein AJ, Nicholson S, Herrin J, Asch DA. Improvements in US Maternal Obstetrical Outcomes From 1992 to 2006. *Med Care*. 2010; 48:487–93.10.1097/MLR.0b013e3181d68840 [PubMed: 20393363]
27. Rosenblatt RA, Reinken J, Shoemack P. Is obstetrics safe in small hospitals? Evidence from New Zealand's regionalised perinatal system. *Lancet*. 1985; 2:429–32. [PubMed: 2863454]
28. Viisainen K, Gissler M, Hemminki E. Birth outcomes by level of obstetric care in Finland: a catchment area based analysis. *J Epidemiol Community Health*. 1994; 48:400–5. [PubMed: 7964341]
29. LeFevre M, Sanner L, Anderson S, Tsutakawa R. The relationship between neonatal mortality and hospital level. *J Fam Pract*. 1992; 35:259–64. [PubMed: 1517721]
30. Larson EH, Hart LG, Rosenblatt RA. Is non-metropolitan residence a risk factor for poor birth outcome in the U.S.? *Soc Sci Med*. 1997; 45:171–88. [PubMed: 9225406]
31. Phibbs CS, Bronstein JM, Buxton E, Phibbs RH. The effects of patient volume and level of care at the hospital of birth on neonatal mortality. *JAMA : the journal of the American Medical Association*. 1996; 276:1054–9.
32. Moster D, Lie RT, Markestad T. Neonatal mortality rates in communities with small maternity units compared with those having larger maternity units. *Bjog*. 2001; 108:904–9. [PubMed: 11563458]
33. Heller G, Richardson DK, Schnell R, Misselwitz B, Kunzel W, Schmidt S. Are we regionalized enough? Early-neonatal deaths in low-risk births by the size of delivery units in Hesse, Germany 1990–1999. *Int J Epidemiol*. 2002; 31:1061–8. [PubMed: 12435785]

34. ACOG Practice Bulletin: Clinical Management Guidelines for Obstetrician-Gynecologists: Number 38, September 2002. Perinatal care at the threshold of viability. *Obstetrics and gynecology*. 2002; 100:617–24. [PubMed: 12220792]
35. Clark SL, Belfort MA, Hankins GD, Meyers JA, Houser FM. Variation in the rates of operative delivery in the United States. *American journal of obstetrics and gynecology*. 2007; 196:526, e1–5. [PubMed: 17547880]
36. Baicker K, Buckles KS, Chandra A. Geographic variation in the appropriate use of cesarean delivery. *Health Aff (Millwood)*. 2006; 25:w355–67. [PubMed: 16895942]
37. Hanley GE, Janssen PA, Greyson D. Regional variation in the cesarean delivery and assisted vaginal delivery rates. *Obstetrics and gynecology*. 2010; 115:1201–8. [PubMed: 20502291]
38. Yasmeen S, Romano PS, Schembri ME, Keyzer JM, Gilbert WM. Accuracy of obstetric diagnoses and procedures in hospital discharge data. *American journal of obstetrics and gynecology*. 2006; 194:992–1001. [PubMed: 16580288]

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Obstetrical Volume and Postpartum Complications

Women delivering at very low volume hospitals have higher complication rates, as well as modestly higher rates of complications for deliveries at exceedingly high volume hospitals even after accounting for differences in patient demographics, comorbidities, and route of delivery.

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Figure 1.
Patients included in this study

Figure 2.
Unadjusted Composite Morbidity and Mortality by Hospital Decile and Stratified by Route of Delivery

Table 1
Patient Characteristics by Annual Spontaneous Vaginal Deliveries Sorted by Deciles

<u>General Characteristics</u>	<u>Decile 1</u>	<u>Decile 2</u>	<u>Decile 3</u>	<u>Decile 4</u>	<u>Decile 5</u>	<u>Decile 6</u>	<u>Decile 7</u>	<u>Decile 8</u>	<u>Decile 9</u>	<u>Decile 10</u>
Number of Hospitals	N=105	N=104	N=104	N=105	N=104	N=105	N=105	N=104	N=105	N=104
Delivery Volume Range	1 – 99	100 – 307	308 – 551	552 – 788	789 – 1133	1134 – 1567	1568 – 2048	2049 – 2675	2676 – 3724	3725 – 12845
<u>Vaginal Deliveries: Specific Characteristics</u>										
<u>Number of Patients</u>	N=1930	N=13299	N=28507	N=45108	N=63105	N=88305	N=117133	N=150944	N=210723	N=328794
<u>Delivery Volume, mean, (SD)</u>	44.3, (33.2)	165.6, (39.4)	309.8, (48.6)	464.3, (43.0)	643.0, (54.2)	868.6, (81.8)	1139.8, (78.9)	1489.0, (130.7)	2010.8, (186.1)	3231.4, (919.9)
<u>High Risk Volume, mean, (SD)</u>	9.1, (6.6)	33.7, (16.1)	67.1, (29.5)	107.7, (40.2)	155.0, (57.7)	217.6, (77.1)	306.4, (120.7)	400.2, (144.1)	541.0, (194.2)	941.0, (402.0)
<u>Low Risk Volume, mean, (SD)</u>	38.7, (27.6)	131.9, (33.7)	242.7, (43.3)	356.6, (49.3)	488.0, (68.6)	651.1, (88.6)	833.4, (135.2)	1088.8, (153.8)	1469.8, (227.3)	2290.3, (683.7)
<u>Age, mean, (SD)</u>	26.0, (5.6)	25.9, (5.7)	26.0, (5.9)	26.4, (6.0)	26.8, (6.1)	27.2, (6.1)	27.4, (6.2)	27.2, (6.1)	27.3, (6.1)	27.9, (6.2)
<u>Race, n (%)</u>										
White	1445, (74.9)	8807, (66.2)	15707, (55.1)	25333, (56.2)	28628, (45.4)	41419, (46.9)	44652, (38.1)	60716, (40.2)	77926, (37.0)	119403, (36.3)
Hispanic	63, (3.3)	728, (5.5)	3473, (12.2)	5627, (12.5)	14030, (22.2)	19767, (22.4)	33203, (28.4)	41500, (27.5)	64437, (30.6)	96110, (29.2)
Black	59, (3.1)	372, (2.8)	1237, (4.3)	2165, (4.8)	5085, (8.1)	10031, (11.4)	14143, (12.1)	21137, (14.0)	18876, (9.0)	36585, (11.1)
Other	363, (18.8)	3392, (25.5)	8090, (28.4)	11983, (26.6)	15362, (24.3)	17088, (19.4)	25135, (21.5)	27591, (18.3)	49484, (23.5)	76696, (23.3)
<u>Payer, n (%)</u>										
Medicaid	858, (44.5)	6694, (50.3)	14324, (50.3)	21108, (46.7)	28514, (45.2)	36643, (41.5)	54524, (46.6)	66010, (43.7)	93202, (44.2)	142979, (43.5)
Private	862, (44.7)	5734, (43.1)	11682, (41.0)	21482, (47.6)	28885, (45.8)	45110, (51.1)	54512, (46.5)	73341, (48.6)	105493, (50.1)	170092, (51.7)
Medicare	8, (0.4)	36, (0.3)	200, (0.7)	174, (0.4)	255, (0.4)	340, (0.4)	338, (0.3)	549, (0.4)	770, (0.4)	643, (0.2)
Self-pay	164, (8.5)	531, (4.0)	1077, (3.8)	1377, (3.1)	3682, (5.8)	3740, (4.2)	5575, (4.8)	7995, (5.3)	6772, (3.2)	9650, (2.9)
<u>Comorbidities, n (%)</u>										
Advanced Maternal Age	166, (8.6)	1177, (8.9)	2710, (9.5)	4905, (10.9)	7781, (12.3)	11935, (13.5)	16502, (14.1)	20323, (13.5)	28322, (13.4)	52611, (16.0)
Hypertension Disorders	33, (1.7)	277, (1.3)	661, (2.3)	885, (2.0)	1363, (2.2)	1867, (2.1)	2712, (2.3)	3455, (2.3)	4797, (2.3)	9210, (2.8)
Diabetes	22, (1.1)	222, (1.7)	500, (1.8)	891, (2.0)	1436, (2.3)	2016, (2.3)	3114, (2.7)	4043, (2.7)	5814, (2.8)	10126, (3.1)

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<u>General Characteristics</u>	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile10
Obesity	10, (0.5)	94, (0.7)	194, (0.7)	358, (0.8)	476, (0.8)	788, (0.9)	1287, (1.1)	1565, (1.0)	3068, (1.5)	2758, (0.8)
Multiple Gestation	2, (0.1)	11, (0.1)	21, (0.01)	59, (0.1)	72, (0.1)	161, (0.2)	222, (0.2)	306, (0.2)	494, (0.2)	1032, (0.3)
Preterm Gestation	18, (0.9)	185, (1.4)	452, (1.6)	727, (1.6)	1209, (1.9)	1801, (2.0)	2674 (2.3)	3879, (2.6)	5783, (2.7)	10699, (3.3)

Table 2

Patient Characteristics by Annual Cesarean Deliveries Sorted by Deciles

General Characteristics		Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile 10
Number of Hospitals		N=105	N=104	N=104	N=105	N=104	N=105	N=105	N=104	N=105	N=104
Delivery Volume Range		1 – 99	100 – 307	308 – 551	552 – 788	789 – 1133	1134 – 1567	1568 – 2048	2049 – 2675	2676 – 3724	3725 – 12845
Cesarean Deliveries: Specific Characteristics											
Number of Patients		N=922	N=6006	N=14175	N=20779	N=30229	N=45435	N=60659	N=79007	N=102481	N=177080
Cesarean Delivery Volume, mean (SD)		13.2, (11.8)	64.1, (17.3)	135.5 (21.8)	208.1, (19.9)	291.1, (33.9)	422.1, (45.3)	575.2, (45.6)	749.5, (51.0)	999.8, (98.5)	1752.6, (561.4)
High Risk Volume, mean (SD)		5.1, (4.3)	23.1, (12.0)	52.9, (16.0)	83.5, (24.0)	119.0, (33.4)	187.3, (53.0)	253.6, (67.5)	355.1, (88.4)	466.8, (109.0)	891.2, (332.6)
Low Risk Volume, mean (SD)		10.4, (8.8)	41.0, (12.3)	82.6, (19.4)	124.6, (24.0)	172.1, (31.6)	234.7, (56.5)	321.6, (61.4)	394.4, (85.9)	533.0, (119.2)	861.5, (308.8)
Age, mean, (SD)		26.7, (5.7)	27.2, (6.0)	27.4, (6.2)	27.9, (6.2)	28.5, (6.3)	29.0, (6.3)	29.3, (6.4)	29.1, (6.3)	29.3, (6.3)	29.9, (6.3)
Race, n (%)											
White		653, (70.8)	3842, (64.0)	7552, (53.3)	11888, (57.2)	13687, (45.3)	21857, (48.1)	24980, (41.2)	32986, (41.8)	40745, (39.8)	67392, (38.1)
Hispanic		59, (6.4)	418, (7.0)	1938, (13.7)	2635, (12.7)	6940, (23.0)	10554, (23.2)	16155, (26.6)	21102, (26.7)	29559, (28.8)	49018, (27.7)
Black		43, (4.7)	227, (3.8)	775, (5.5)	1093, (5.3)	2748, (9.1)	5606, (12.3)	8000, (13.2)	11851, (15.0)	9687, (9.5)	22147, (12.5)
Other		167, (18.1)	1519, (25.3)	3910, (27.6)	5163, (24.9)	6854, (22.7)	7418, (16.3)	11524, (19.0)	13068, (16.5)	22490, (22.0)	38523, (21.8)
Payer, n (%)											
Medicaid		366, (39.7)	2893, (48.2)	6850, (48.3)	9119, (43.9)	12589, (41.7)	16771, (36.9)	25559, (42.1)	31104, (39.4)	40108, (39.1)	65216, (36.8)
Private		449, (48.7)	2733, (45.5)	6237, (44.0)	10535, (50.7)	15225, (50.4)	25838, (56.9)	31530, (52.0)	42733, (54.1)	56965, (55.6)	104763, (59.2)
Medicare		7, (0.8)	37, (0.6)	138, (0.1)	112, (0.5)	204, (0.7)	208, (0.5)	269, (0.4)	378, (0.5)	455, (0.4)	552, (0.3)
Self-pay		82, (8.9)	225, (3.8)	444, (3.1)	524, (2.5)	1443, (4.8)	1559, (3.4)	2135, (3.5)	3198, (4.1)	2855, (2.8)	3831, (2.2)
Comorbidities, n (%)											
Advanced Maternal Age		93, (10.1)	798, (13.3)	2124, (15.0)	3546, (17.1)	5832, (19.3)	9862, (21.7)	13878, (22.9)	17408, (22.0)	23115, (22.6)	45659, (25.8)
Hypertension Disorders		49, (5.3)	380, (6.3)	995, (7.0)	1386, (6.7)	2123, (7.0)	3019, (6.6)	4288, (7.1)	5922, (7.5)	7731, (7.5)	15330, (8.7)
Diabetes		55, (6.0)	327, (5.4)	886, (6.3)	1424, (6.9)	2240, (7.4)	3165, (7.0)	4564, (7.5)	6204, (7.9)	8633, (8.4)	15335, (8.7)

<u>General Characteristics</u>	Decile 1	Decile 2	Decile 3	Decile 4	Decile 5	Decile 6	Decile 7	Decile 8	Decile 9	Decile 10
Obesity	17, (1.8)	165, (2.8)	331, (2.3)	548, (2.6)	739, (2.4)	1137, (2.5)	1581, (2.6)	2275, (2.9)	3655, (3.6)	4810, (2.7)
Multiple Gestation	5, (0.5)	34, (0.6)	112, (0.8)	179, (0.9)	273, (0.9)	515, (1.1)	774, (1.3)	1158, (1.5)	1915, (1.9)	3720, (2.1)
Preterm Gestation	24, (2.6)	224, (3.7)	537, (3.8)	928, (4.5)	1622, (5.4)	2570, (5.7)	3851, (6.4)	5528, (7.0)	8389, (8.2)	16279, (9.2)

Table 3
Total Population: Unadjusted Percent Complications by Hospital Decile and Route of Delivery

All Deliveries	Decile 1 N = 3011	Decile 2 N = 20678	Decile 3 N = 45446	Decile 4 N = 69869	Decile 5 N = 99654	Decile 6 N = 141844	Decile 7 N = 188227	Decile 8 N = 243475	Decile 9 N = 331801	Decile 10 N = 534804	P-value
Hemorrhage, n (%)	241, (8.0)	1383, (6.7)	2527, (5.6)	3644, (5.2)	4849, (4.9)	6378, (4.5)	8878, (4.7)	12342, (5.1)	17539, (5.3)	26210, (4.9)	<.0001
Infection, n (%)	26, (0.9)	102, (0.5)	212, (0.5)	252, (0.4)	455, (0.5)	693, (0.5)	1178, (0.6)	2061, (0.9)	2450, (0.7)	4709, (0.9)	<.0001
Laceration, n (%)	84, (2.8)	528, (2.6)	927, (2.0)	1508, (2.2)	2152, (2.2)	2859, (2.0)	3404, (1.8)	5005, (2.1)	7161, (2.2)	10910, (2.0)	<.0001
Thrombotic, n (%)	26, (0.9)	252, (1.2)	542, (1.2)	874, (1.3)	1168, (1.2)	1674, (1.2)	2270, (1.2)	2823, (1.2)	4366, (1.3)	7116, (1.3)	<.0001
Operative, n (%)	9, (0.3)	58, (0.3)	121, (0.3)	227, (0.3)	339, (0.3)	426, (0.3)	576, (0.3)	921, (0.4)	1350, (0.4)	2413, (0.5)	<.0001
Mortality, n (%)	1, (0.03)	2, (0.01)	2, (0.00)	5, (0.01)	4, (0.00)	13, (0.01)	17, (0.01)	20, (0.01)	27, (0.01)	56, (0.01)	0.5449
Composite, n (%)	354, (11.8)	2082, (10.1)	3880, (8.5)	5884, (8.4)	8021, (8.1)	10788, (7.6)	14531, (7.7)	20651, (8.5)	29151, (8.8)	45288, (8.5)	<.0001
Vaginal Deliveries	Decile 1 N = 1898	Decile 2 N = 13301	Decile 3 N = 28511	Decile 4 N = 45112	Decile 5 N = 63108	Decile 6 N = 88309	Decile 7 N = 117137	Decile 8 N = 150948	Decile 9 N = 210727	Decile 10 N = 328797	P-value
Hemorrhage, n (%)	136, (7.2)	806, (6.1)	1458, (5.1)	2232, (5.0)	2740, (4.3)	3732, (4.2)	4972, (4.2)	6571, (4.4)	9254, (4.4)	13540, (4.1)	<.0001
Infection, n (%)	13, (0.7)	32, (0.2)	89, (0.3)	121, (0.3)	181, (0.3)	286, (0.3)	472, (0.4)	697, (0.5)	950, (0.5)	1707, (0.5)	<.0001
Laceration, n (%)	50, (2.6)	354, (2.7)	596, (2.1)	1025, (2.3)	1379, (2.2)	1922, (2.2)	2202, (1.9)	3378, (2.2)	4707, (2.2)	7016, (2.1)	<.0001
Thrombotic, n (%)	6, (0.3)	41, (0.3)	93, (0.3)	168, (0.4)	228, (0.4)	312, (0.4)	378, (0.3)	470, (0.3)	692, (0.3)	1063, (0.3)	0.5073
Mortality, n (%)	0, (0.00)	0, (0.00)	0, (0.00)	0, (0.00)	0, (0.00)	4, (0.00)	6, (0.01)	7, (0.00)	3, (0.00)	21, (0.01)	0.0868
Composite, n (%)	194, (10.2)	1150, (8.7)	2123, (7.5)	3379, (7.5)	4283, (6.8)	5935, (6.7)	7617, (6.5)	10551, (7.0)	14771, (7.0)	22126, (6.7)	<.0001
Cesarean Deliveries	Decile 1 N = 922	Decile 2 N = 6006	Decile 3 N = 14175	Decile 4 N = 20779	Decile 5 N = 30229	Decile 6 N = 45435	Decile 7 N = 60659	Decile 8 N = 79007	Decile 9 N = 102481	Decile 10 N = 177080	P-value
Hemorrhage, n (%)	86, (9.3)	438, (7.3)	841, (5.9)	1103, (5.3)	1665, (5.5)	2115, (4.7)	3264, (5.4)	4958, (6.3)	7140, (7.0)	10819, (6.1)	<.0001
Infection, n (%)	12, (1.3)	55, (0.9)	102, (0.7)	111, (0.5)	246, (0.8)	351, (0.8)	633, (1.0)	1231, (1.6)	1360, (1.3)	2779, (1.6)	<.0001
Operative, n (%)	9, (1.0)	58, (1.0)	121, (0.9)	227, (1.1)	339, (1.1)	426, (0.9)	576, (1.0)	921, (1.2)	1350, (1.3)	2413, (1.4)	<.0001
Thrombotic, n (%)	11, (1.2)	70, (1.2)	182, (1.3)	249, (1.2)	363, (1.2)	493, (1.1)	803, (1.3)	1152, (1.5)	1578, (1.5)	2881, (1.6)	<.0001
Mortality, n (%)	1, (0.11)	2, (0.03)	2, (0.01)	3, (0.01)	4, (0.01)	9, (0.02)	11, (0.02)	13, (0.02)	22, (0.02)	34, (0.02)	0.7240
Composite, n (%)	103, (11.2)	535, (8.9)	1043, (7.4)	1412, (6.8)	2166, (7.2)	2809, (6.2)	4342, (7.2)	6810, (8.6)	9378, (9.2)	15304, (8.6)	<.0001

Table 4

Unadjusted and adjusted odds of composite adverse outcome by volume-decile (decile 10 as reference group)

	Lowest Volume	Decile 2 OR (95% CI); p- value	Decile 3 OR (95% CI); p- value	Decile 4 OR (95% CI); p- value	Decile 5 OR (95% CI); p- value	Decile 6 OR (95% CI); p- value	Decile 7 OR (95% CI); p- value	Decile 8 OR (95% CI); p- value	Decile 9 OR (95% CI); p- value	Highest Volume Decile 10
All deliveries										
Unadjusted	1.37 (1.07–1.75) 0.0112	1.17 (0.98–1.39) 0.0901	0.92 (0.78–1.10) 0.3712	0.96 (0.81–1.14) 0.6641	0.87 (0.73–1.03) 0.1046	0.81 (0.68–0.96) 0.0142	0.86 (0.73–1.02) 0.0814	0.96 (0.81–1.14) 0.6643	0.97 (0.82–1.15) 0.7279	REF
Adjusted for demographics ^a	1.38 (1.08–1.76) 0.0100	1.17 (0.98–1.40) 0.0861	0.92 (0.77–1.10) 0.3333	0.96 (0.81–1.14) 0.6481	0.87 (0.73–1.02) 0.0956	0.81 (0.69–0.96) 0.0155	0.86 (0.73–1.02) 0.0819	0.96 (0.81–1.14) 0.6622	0.97 (0.82–1.14) 0.6867	REF
Adjusted for demographics & selected comorbidities ^b	1.43 (1.13–1.82) 0.0035	1.21 (1.02–1.44) 0.0328	0.95 (0.80–1.12) 0.5304	0.99 (0.83–1.17) 0.8652	0.89 (0.75–1.05) 0.1640	0.83 (0.70–0.98) 0.0277	0.87 (0.74–1.03) 0.1112	0.98 (0.83–1.15) 0.7674	0.97 (0.82–1.15) 0.7322	REF
Vaginal										
Unadjusted	1.51 (1.16–1.96) 0.0024	1.28 (1.08–1.53) 0.0055	1.05 (0.88–1.24) 0.6006	1.10 (0.93–1.30) 0.2825	0.94 (0.79–1.11) 0.4364	0.90 (0.76–1.06) 0.1940	0.92 (0.78–1.08) 0.2907	1.00 (0.85–1.17) 0.9625	0.98 (0.83–1.16) 0.8179	REF
Adjusted for demographics ^a	1.57 (1.13–1.92) < .0001	1.32 (1.10–1.57) < .0001	1.05 (0.89–1.24) 0.0002	1.11 (0.94–1.32) < .0001	0.92 (0.78–1.09) 0.9741	0.91 (0.77–1.08) 0.7261	0.92 (0.78–1.08) 0.0066	0.99 (0.84–1.17) 0.0014	0.99 (0.84–1.16) 0.0004	REF
Adjusted for demographics & selected comorbidities ^b	1.60 (1.38–1.86) < .0001	1.33 (1.25–1.42) < .0001	1.12 (1.07–1.17) < .0001	1.13 (1.08–1.17) < .0001	1.02 (0.99–1.06) 0.2401	1.01 (0.98–1.04) 0.3933	0.97 (0.95–1.00) 0.0581	1.05 (1.02–1.07) 0.0002	1.04 (1.02–1.06) 0.0002	REF
Cesarean										
Unadjusted	1.37 (0.96–1.95) 0.0828	1.01 (0.79–1.29) 0.9507	0.79 (0.62–1.00) 0.0469	0.76 (0.60–0.95) 0.0175	0.73 (0.58–0.91) 0.0063	0.65 (0.52–0.82) 0.0002	0.77 (0.62–0.97) 0.0252	0.94 (0.75–1.18) 0.5991	0.94 (0.75–1.18) 0.5986	REF
Adjusted for demographics ^a	1.38 (0.97–1.97) 0.0760	1.02 (0.80–1.31) 0.8841	0.79 (0.62–1.00) 0.0462	0.76 (0.61–0.96) 0.0224	0.73 (0.58–0.91) 0.0062	0.65 (0.52–0.82) 0.0002	0.77 (0.61–0.96) 0.0216	0.93 (0.75–1.17) 0.5482	0.94 (0.75–1.18) 0.6020	REF
Adjusted for demographics & selected comorbidities ^b	1.45 (1.01–2.04) 0.0436	1.06 (0.83–1.36) 0.6286	0.82 (0.65–1.03) 0.0871	0.79 (0.63–0.99) 0.0402	0.75 (0.60–0.94) 0.0129	0.67 (0.53–0.84) 0.0004	0.78 (0.62–0.97) 0.0278	0.95 (0.76–1.18) 0.6250	0.95 (0.76–1.18) 0.6313	REF

^a Adjusted for race, age, payor

^b Adjusted for race, age, payor, plus advanced age, herpes, asthma, cerebral hemorrhage, chorioamnionitis, diabetes, hypertensive disorders, congenital heart disease, liver anomalies, renal anomalies, thyroid disease, mental disorder, multiple gestation, preterm gestation, obesity, pulmonary embolism, uterine rupture