Anesthesia Provider Model, Hospital Resources, and Maternal Outcomes

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Objective. Determine the ability of anesthesia provider model and hospital resources to explain maternal outcome variation.

Data Source/Study Setting. 1,141,641 obstetrical patients from 369 hospitals that reported at least one live birth in 2002 in six representative states.

Study Design. Logistic regression of death, anesthesia complication, nonanesthesia maternal complication, and obstetrical trauma for all patients and those having cesarean deliveries on anesthesia provider model, obstetrical and anesthesia, and patient variables.

Data Collection/Extraction Methods. Data was assembled from information given by hospitals to state agencies and from a 2004 survey of obstetrical organization resources.

Principal Findings. Anesthesia complication rates in anesthesiologist-only hospitals were 0.27 percent compared with 0.23 percent in certified registered nurse anesthetist (CRNA) only hospitals. Rates among other provider models varied from 0.24 to 0.37 percent with none statistically different from the anesthesiologist-only hospitals. A similar pattern was observed for rates of other outcomes. Multivariate analysis found no systematic differences between hospitals with anesthesiologist-only models and models using CRNAs. There was no consistent pattern of association of other hospital or patient characteristics with outcomes.

Conclusion. Hospitals that use only CRNAs, or a combination of CRNAs and anesthesiologists, do not have systematically poorer maternal outcomes compared with hospitals using anesthesiologist-only models.

Key Words. Anesthesia, maternal outcomes, quality of health care, clinical competence

The impact of anesthesia provider credentials on patient outcomes has been a research topic and the subject of policy debates for more than 40 years (Kane and Smith 2004). Although some studies have indicated that credentials (anesthesiologist versus CRNA [certified registered nurse anesthetist]) make a difference to some outcomes, others have not (Abenstein and Warner 1996; Silber et al. 2000; Fleisher and Anderson 2002; Pine, Holt, and Lou 2003;

Simonson, Ahern, and Hendryx 2007). After an extensive literature review, Smith, Kane, and Milne (2004) concluded it is not possible to draw a conclusion regarding outcome differences as a function of anesthesiologist versus CRNA provider type. Among the limitations of the current studies they cite are difficulty in risk adjustment, failure to define precisely how hospital anesthesia providers are utilized, and lack of consideration of resources and processes beyond the anesthesia provider model that may also affect outcomes.

Previous studies, relying on administrative data, have characterized anesthesia as being provided by anesthesiologists, CRNAs under anesthesiologist supervision, or unsupervised CRNAs. This characterization ignores potentially large variations across hospitals in the scope of CRNA practice when both anesthesiologists and CRNAs are present. In a recent survey by the authors of obstetrical anesthesia services, we found there are at least five anesthesia provider models based on providers' procedure initiation privileges (e.g., the initiation of spinal, epidural, and general anesthesia) (Minnick and Needleman 2008). The survey also found systematic variations in anesthesia, nursing, and obstetrical medicine resources across obstetrical anesthesia provider models that raise the possibility that provider model may be a proxy for other clinical resource variables usually left unmeasured in typically used databases.

In this paper, we examine the ability of anesthesia provider model and other hospital resources to explain variations in maternal outcomes using a privilege-based characterization of the anesthesia provider model and accounting for relevant nursing, medical, and anesthesia resources.

We focus on obstetrical care and obstetrical anesthesia. Because the labor, delivery, and postpartum service experience is discrete, maternal outcomes are often directly attributable to perinatal care, and almost all care before, during, and after a delivery is within the domains of three departments (nursing, medicine, and anesthesiology), it is more feasible to draw inferences from a retrospective study in this area of health care than in others. Beyond these design advantages, maternal outcomes deserve examination because, although maternal deaths and long-term disability are relatively rare in the United States, the overall morbidity burden (31 percent) is high (Danel et al.

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2003; Poole and Long 2004). Given that almost 4 million U.S. women give birth annually, determining improvement strategies is important (National Center for Health Statistics 2005).

METHODS

Sample

The study sample included 1,141,641 obstetrical patients from 369 hospitals (995 hospital years) in six states (California, Florida, Kentucky, New York, Texas, Washington, and Wisconsin) that met the following conditions: reported at least one live birth in the 2002 American Hospital Association Annual Survey; provided at least 1 year of discharge data to their state government; and responded to an author-developed 2004 survey on the organization and resources of nursing, anesthesia, and medical obstetrical services. Hospital discharge data for California, Florida, New York, Washington, and Wisconsin for 1999–2001, and Kentucky and Texas for 2000–2001 were obtained and matched to the surveyed hospitals, as was American Hospital Association Annual Survey data for each year. The sample thus included 995 hospital-years of data with 28 percent from 1999, 36 percent from 2000, and 36 percent from 2001.

The survey variables pertaining to resource and anesthesia provider model utilized in this analysis were chosen based on item response rates and variation across models. Details regarding the survey and variables formation may be found in an earlier paper (Minnick and Needleman 2008).

Measures

Outcomes. Four outcomes were coded from the discharge data. Deaths were coded based on patient discharge status. Following Panchal, Arria, and Labhsetwar (2001), we coded anesthesia and other complications based on secondary diagnoses as reported in the abstract based on The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM). Anesthesia complications were classified as pulmonary, cardiac, central nervous system, and other (ICD-9-CM codes 668.0–668.2, 668.8, and 668.9). Other complications included cardiac complications (ICD-9-CM codes 674.8x); obstetrical shock (ICD-9-CM codes 669.1x); cardiac arrest and cerebral anoxia (ICD-9-CM codes 669.4x); other cardiovascular events (ICD-9-CM codes 674.0x, 430.x–432.x, and 436.x); and pulmonary complications including aspiration pneumonia, pulmonary edema, acute respiratory failure,

and acute respiratory distress syndrome (ICD-9-CM codes 507.0, 518.4, 518.5, and 518.8x). The three AHRQ (Agency for Healthcare Research and Quality) Patient Safety Indicators related to obstetrical trauma, were coded into a single indicator variable indicating presence or absence (Agency for Healthcare Research and Quality 2003).

Anesthesia Models. Based upon the survey, hospitals were classified into one of five anesthesia models: anesthesiologist only (ANES-only); CRNA-only; both anesthesiologists and CRNAs practicing at the hospital, with an anesthesiologist required to be present at the initiation of all planned cesarean sections (ANES–CRNA I); both anesthesiologists and CRNAs practicing at the hospital, with an anesthesiologist not required to be present at the initiation of all planned cesarean sections (ANES–CRNA II); and a small group of hospitals in which the anesthesia model differed between labor and delivery and general operating areas (Mixed). Previous work established that this assignment of anesthesia models captured the degree of CRNA supervision more precisely than using a single model designation in institutions where both CRNAs and anesthesiologists practice (Minnick and Needleman 2008).

Other Characteristics of the Obstetrical or Anesthesia Services. Using survey data, we constructed indicator variables that describe the organization of obstetrical services and obstetrical anesthesia. The variables were identified as potentially associated with maternal outcomes as a result of a literature review and deliberations of a panel of experts (Minnick and Needleman 2008). These included the presence of an obstetric anesthesia provider 24 hours per day, facilities to perform a nonemergency cesarean delivery in the labor and delivery area, the proportion of patients reported to labor and deliver in the same room, the number of health care personnel present at a cesarean procedure, minutes to transport a patient for an emergency cesarean delivery from site of labor, and volume (defined as the number of births at the hospital in the year studied divided by 1,000 to make interpretation of the results easier). Other resource variables from the survey were not included in the analysis either because they displayed no variation, were correlated with included variables, or had low response rates. Some variable, such as time to initiate an emergency cesarean delivery were not included because of measurement limitations.

Other Hospital Characteristics. Based upon the American Hospital Association Annual Survey, we constructed measures of metropolitan/nonmetropolitan status, teaching status (based on the presence of approved residency program), membership in the Council of Teaching Hospitals (COTH), and ownership (nonprofit, for-profit, government). Two measures were constructed that might influence the choice of hospital by high risk mothers: the level of obstetrical service as reported on the survey, and the ratio of neonatal intensive care (NICU) beds per thousand births.

Patient Characteristics. Based on the discharge abstract, we constructed categorical variables for age (<20 , $20-34$, $35 \geq$), insurance status (Medicaid, uninsured, private or other insurance), and race/ethnicity where the state reported this information (white non-Hispanic, black non-Hispanic, Hispanic, other). Following Panchal, Arria, and Labhsetwar (2001), we constructed measures of comorbidities related to obstetrical patients (maternal infection, maternal diabetes, maternal obesity, fetal problems affecting mother, grand multiparity, elderly primagravida or multigravida, abnormal fetal heart rate or rhythm, uterine rupture, obstructed labor, long labor, umbilical cord complication, other maternal complications, and insufficient prenatal care) that might affect the need for anesthesia or risk of complication. In addition, a general Charlson score was constructed (Charlson et al. 1987; Romano, Roos, and Jollis 1993). An indicator variable for early onset of labor was also constructed.

Other Variables. Categorical variables for state and year were constructed.

Analysis

We examined descriptive statistics for the hospital and patient samples. Rates for each outcome were estimated for each anesthesia model, and the equality of the rates to that in the ANES-only model were tested using a logistic regression, with standard errors adjusted for clustering within hospitals. We conducted a logistic regression of each of the four outcome measures on a full model that included the anesthesia model, other hospital characteristics, and patient characteristics, with standard errors adjusted for clustering within hospitals. Because anesthesia and other complications were more prevalent in patients undergoing cesarean deliveries and because these patients might be more sensitive to the anesthesia model in use and other factors, we also con-

ducted a logistic regression of the full model for each outcome restricted to cesarean patients.

Selection may play a substantial role in the choice of hospital by women with high-risk pregnancies, which in turn might be associated with a higher risk of anesthesia or other complications. Propensity analysis has been used as a method for adjusting for selection, although there is no consensus on the appropriate method and simulations show differences in results across methods (Rosenbaum and Rubin 1983; D'Agostino 1998; Kurth et al. 2006). We conducted propensity analyses using inverse probability-weighted regression (Robins, Hernan, and Brumback 2000), and nearest-neighbor matching and stratified methods (Becker and Ichino 2002). Three sets of analyses were constructed: CRNA-only compared with ANES-only, CRNA I compared with ANES-only, and CRNA II compared with ANES-only. Estimated adjusted rates and odds ratios differ in the two-model analyses from those in analyses including all five models, and the two-model estimates are presented as part of the propensity analysis.

RESULTS

Rates of Complications

The rate of death (0.007 percent) is low, and anesthesia complications (0.269 percent) and anesthesia or other complications (0.787 percent) occurred in less than 1 percent of the sample. Nearly 7 percent of patients (6.692 percent) experienced obstetrical trauma as defined by AHRQ.

Patient Characteristics

Three-quarters of the patients giving birth in this sample were between 20 and 34 years of age, a distribution consistent with national statistics. Twelve percent were less than 20, and 14 percent were age 35 and older. Nearly 40 percent were insured by Medicaid, with only 3 percent uninsured and the remainder reporting other payers. One-third of the sample was Hispanic, reflecting the substantial Hispanic presence in California, Texas, and Florida. In comparison, based on NCHS statistics for the nation, 22 percent of births are to women of Hispanic origin (National Center for Health Statistics 2005). Whites (44 percent) were slightly underrepresented in the sample. African Americans and others were represented consistent with national statistics. Thirteen percent were reported as "other" or not coded.

The most common comorbidities were umbilical cord complications (19.2 percent), abnormal fetal heart rate or rhythm (9.2 percent), fetal problems affecting the mother (9.1 percent), obstructed labor (6.0 percent), and grand multiparity or elderly primagravida (5.8 percent). Maternal infection (0.03 percent), maternal diabetes (0.54 percent), maternal obesity (0.59 percent), uterine rupture (0.08 percent), long labor (1.2 percent), and insufficient prenatal care (2.1 percent) occurred less often. All other maternal comorbidities occurred in 4.4 percent of births. The overall Charlson score was 0.017, reflecting the general health of the child-bearing population. The most common comorbidity observed was respiratory, probably associated with asthma. Early onset of labor occurred in 6.1 percent of the births.

Hospital Characteristics

The hospitals were overwhelmingly metropolitan (67 percent), nonteaching (83 percent), and nonprofit (69 percent). Fourteen percent were for profit and 17 percent were under government auspices. The sample somewhat over-represented metropolitan hospitals (56 percent of all U.S. hospitals reporting a birth are in metropolitan areas) but was consistent with national ownership (65 percent nonprofit, 22 percent government) and teaching hospital (81 percent nonteaching) distributions. One reason for the metropolitan dominance is that although rural hospitals completed the survey at equal or greater rates than urban hospitals, in some states their outcomes data were not available due to regulatory rules. The average number of births per year was 1,165 (standard deviation [SD] 1,209). Four percent of hospitals reported membership in the COTHs, 13 percent reported they were nonmembers but were involved in medical education.

California provided the most hospitals (27 percent) in the sample followed by Wisconsin (19 percent), New York (14 percent), Texas (13 percent), Washington (13 percent), Florida (9 percent), and Kentucky (5 percent).

Anesthesia Models

Thirty-nine percent of the hospitals had an ANES-only model, with 23 percent using a CRNA-only model. The next most common model was ANES–CRNA II (22 percent) followed by ANES–CRNA I (13 percent), and Mixed (3 percent). Hospitals using ANES-only models had more births than average across this sample, and CRNA-only hospitals had fewer, and 49 percent of births were in ANES-only hospitals, 7.5 percent in CRNA-only hospitals,

19 percent in CRNA I, 20 percent in CRNA II, and 3.8 percent in Mixed model hospitals.

Hospital Resources

An obstetric anesthesia service provider was present physically at all times in one-quarter of the hospitals. This does not mean the provider was present on a single obstetric unit at all times given that in some hospitals obstetric anesthesia is provided in labor units, delivery areas, and in separate operating rooms. The number of persons present at a planned cesarean delivery averaged 4.8, but the SD, 2.0, reflects substantial variation. The mean number of minutes for transport from labor site to an emergency cesarean delivery was 5.4 (SD 8.0), but this was inflated by the small number of hospitals reporting more than 20 minutes. More than 75 percent of the sample reported transport times of 5 minutes or less. Sixty percent of hospitals in the sample provided nonemergency cesarean deliveries in the labor and delivery area. Twenty-two percent of hospitals were level 2 obstetrical providers, 8 percent level 3. The mean number of NICU beds per thousand births was 1.6, with an average of 6.9 in the 24 percent of the sample reporting any NICU beds.

Risk of Death and Anesthesia Model

Death rates were highest in hospitals with ANES-only models, although the differences were not statistically significant (Table 1). In the logistic regression of deaths in the full sample (Table 2) and cesarean samples (Table 3), the pattern was similar, with no model's experience statistically significantly different from that in ANES-only hospitals. In the propensity analyses, the weighted regression approaches estimate statistically significantly lower rates in the CRNA-only hospitals compared with, and for ANES/CRNA I hospitals, in the base-adjusted models as well as the propensity-weighted models. The results from the other propensity models, while not statistically significant, are comparable in magnitude and direction of effect (Table 4).

Risk of Anesthesia and Other Complications and Anesthesia Model

Anesthesia complication rates in ANES-only hospitals were 0.27 percent, compared with 0.23 percent in CRNA-only hospitals. Rates in the other hospitals varied from 0.24 to 0.37 percent, with none statistically significantly different from the ANES-only hospitals. A similar pattern is observed for the combined rate of anesthesia and other complications (Table 1).

Table 1: Rates of Adverse Outcomes by Anesthesia Model

<i>Model</i>	<i>Rate (%)</i>	<i>p (ANES only)</i>
Deaths (<i>n</i> = 1,141,641)		
ANES only	0.0089	Reference
CRNA only	0.0047	.070
ANES/CRNA I: ANES at all cesareans	0.0055	.086
ANES/CRNA II: ANES not at all cesareans	0.0069	.351
Mixed	0.0069	.453
Total	0.0074	
Any anesthesia complication (<i>n</i> = 1,141,641)		
ANES only	0.27	Reference
CRNA only	0.23	.233
ANES/CRNA I: ANES at all cesareans	0.24	.302
ANES/CRNA II: ANES not at all cesareans	0.29	.629
Mixed	0.37	.082
Total	0.27	
Anesthesia or other complication (<i>n</i> = 1,141,641)		
ANES only	0.81	Reference
CRNA only	0.60	.063
ANES/CRNA I: ANES at all cesareans	0.80	.949
ANES/CRNA II: ANES not at all cesareans	0.75	.619
Mixed	0.95	.523
Total	0.79	
AHRQ obstetric trauma indicator (<i>n</i> = 1,136,590)		
ANES only	6.21	Reference
CRNA only	6.71	.431
ANES/CRNA I: ANES at all cesareans	7.52	.044
ANES/CRNA II: ANES not at all cesareans	6.84	.248
Mixed	7.96	.174
Total	6.69	

The *p*-values adjusted for clustering within hospitals.
ANES, anesthesiologist; CRNA, certified registered nurse anesthetist.

In the multivariate regression analysis of the entire obstetrical sample (Table 2), the odds ratios for anesthesia complications are as follows: CRNA-only, 0.764; ANES–CRNA I, 0.908; ANES–CRNA II, 1.055; Mixed, 1.297; none statistically significantly different from one. The nearest-neighbor propensity analysis for the CRNA-only model is statistically significant, as are the nearest-neighbor and block-stratified propensity analyses for the ANES–CRNA I model, with the rates calculated via these propensity analyses lower than for the ANES-only model hospitals (Table 4).

When the multivariate analysis is restricted to cesarean deliveries (Table 3), the results are comparable. The odds ratios for anesthesia complications are

Table 2: Logit for Full Sample of Patients of Selected Complications on Anesthesia Model and Other Hospital and Patient Variables

<i>Anesthesia Model</i>	<i>Odds Ratio</i>	<i>95% Confidence Interval</i>	<i>p</i>
Mortality (<i>n</i> = 1,102,661)			
CRNA only	0.650	0.247–1.707	.381
ANES/CRNA I: ANES at all cesareans	0.529	0.256–1.094	.086
ANES/CRNA II: ANES not at all cesareans	0.604	0.273–1.337	.214
Mixed	0.597	0.229–1.557	.292
Anesthesia complication (<i>n</i> = 1,141,641)			
CRNA only	0.764	0.561–1.039	.086
ANES/CRNA I: ANES at all cesareans	0.908	0.663–1.244	.548
ANES/CRNA II: ANES not at all cesareans	1.055	0.774–1.438	.735
Mixed	1.297	0.864–1.945	.209
Anesthesia or other complication (<i>n</i> = 1,141,641)			
CRNA only	0.737	0.529–1.027	.072
ANES/CRNA I: ANES at all cesareans	1.076	0.814–1.423	.606
ANES/CRNA II: ANES not at all cesareans	0.837	0.626–1.117	.227
Mixed	1.347	1.000–1.814	.050
AHRQ obstetric trauma indicator (<i>n</i> = 1,136,590)			
CRNA only	1.030	0.66–1.224	.738
ANES/CRNA I: ANES at all cesareans	1.179	0.973–1.428	.094
ANES/CRNA II: ANES not at all cesareans	0.943	0.766–1.160	.579
Mixed	1.236	0.898–1.702	.193

Reference (excluded) category—ANES only. Full regression includes hospital variables for whether anesthesia continuously available in hospital; labor, delivery, and recovery in same room; whether nonemergency cesarean deliveries in labor and delivery area, number of persons at a planned cesarean delivery, minutes to transport for an emergency cesarean delivery, number of births at the hospital in a year; obstetric unit care level, number of neonatal intensive care beds per thousand births; metropolitan/nonmetropolitan location; ownership; teaching status; state; year; and patient variables for patient age; payer; ethnicity; maternal Charlson score; categorical variables for 13 obstetrical comorbidities, whether there was early onset of labor. Standard errors adjusted for clustering of patients within hospitals.

ANES, anesthesiologist; CRNA, certified registered nurse anesthetist; AHRQ, Agency for Healthcare Research and Quality.

as follows: CRNA-only model, 0.731; ANES-CNRA I, 0.832; ANES-CRNA II, 0.923; Mixed, 1.100; none statistically significantly different from one. The propensity analysis results are consistent with those in the multivariate analysis, with two statistically significant results for the ANES-CRNA I models, both for lower rates than in ANES-only hospitals (Table 4).

When complications are expanded to include nonanesthesia complications, the results are similar in the full sample. For the CRNA-only hospitals compared with ANES-only hospitals, the odds ratio in the full regression for the full sample is <1 and rates are lower, although these differences are not

Table 3: Logit for Patients Having Cesarean Delivery of Selected Complications on Anesthesia Model and Other Hospital and Patient Variables

<i>Anesthesia Model</i>	<i>Odds Ratio</i>	<i>95% Confidence Interval</i>	<i>p</i>
Mortality (<i>n</i> = 271,350)			
CRNA only	0.531	0.136–2.073	.363
ANES/CRNA I: ANES at all cesareans	0.697	0.273–1.780	.450
ANES/CRNA II: ANES not at all cesareans	0.708	0.257–1.951	.505
Mixed	0.561	0.105–2.982	.497
Anesthesia complication (<i>n</i> = 279,420)			
CRNA only	0.731	0.520–1.027	.071
ANES/CRNA I: ANES at all cesareans	0.832	0.585–1.183	.306
ANES/CRNA II: ANES not at all cesareans	0.923	0.647–1.317	.657
Mixed	1.100	0.735–1.645	.643
Anesthesia or other complications (<i>n</i> = 279,420)			
CRNA only	0.723	0.542–0.965	.028
ANES/CRNA I: ANES at all cesareans	0.956	0.758–1.206	.703
ANES/CRNA II: ANES not at all cesareans	0.773	0.600–0.997	.047
Mixed	0.998	0.732–1.361	.989
AHRQ Obstetric Trauma Indicator (<i>n</i> = 278,757)			
CRNA only	0.884	0.626–1.248	.483
ANES/CRNA I: ANES at all cesareans	1.481	1.130–1.939	.004
ANES/CRNA II: ANES not at all cesareans	0.917	0.702–1.197	.523
Mixed	2.317	1.428–3.758	.001

Reference (excluded) category—ANES only. Full regression includes hospital variables for whether anesthesia continuously available in hospital; labor, delivery, and recovery in same room; whether nonemergency cesarean deliveries in labor and delivery area, number of persons at a planned cesarean delivery, minutes to transport for an emergency cesarean delivery, number of births at the hospital in a year; obstetric unit care level, number of neonatal intensive care beds per thousand births; metropolitan/nonmetropolitan location; ownership; teaching status; state; year; and patient variables for patient age; payer; ethnicity; maternal Charlson score; categorical variables for each condition comprising maternal Charlson score, whether there was early onset of labor. Standard errors adjusted for clustering of patients within hospitals.

ANES, anesthesiologist; CRNA, certified registered nurse anesthetist; AHRQ, Agency for Healthcare Research and Quality.

statistically significant. Estimates of lower rates in the CRNA-only hospitals are statistically significant in the nearest-neighbor and block-stratified propensity analyses. This same pattern is observed for hospitals using the ANES–CRNA II model (Table 4).

In the analysis of the cesarean section sample, the odds ratio for the full multivariate analysis are statistically significant and < 1 for the CRNA-only model hospitals (0.723, $CI_{95} = 0.542\text{--}0.965$, $p = .028$) and the ANES–CRNA II model hospitals (0.773, $CI_{95} = 0.600\text{--}0.997$, $p = .047$) (Table 3). In the two-way comparisons in the propensity analysis, none of the CRNA-only differ-

Table 4: Propensity Analysis

Comparison	Outcome			
	Mortality	Anesthesia Complication	Anesthesia or Other Complication	AHRQ Obstetric Trauma Indicator
<i>Full sample</i>				
CRNA-only compared with ANES-only				
Odds ratio (full regression)	0.519	0.849	0.873	0.988
Odds ratio (propensity-weighted regression)	0.208*	1.031	1.082	0.916
Unadjusted difference in rates (%)	−0.0042	−0.05	−0.20	0.49
Adjusted difference in rates (%)	−0.0029	−0.04	−0.08	−0.03
Adjusted difference in rates (propensity-weighted regression) (%)	−0.0054*	0.01	0.06	−0.48
Nearest neighbor difference in rates (%)	−0.0067	−0.02*	−0.13*	0.47**
Block-stratified difference in rates (%)	−0.0043	−0.01	−0.07*	0.51***
ANES/CRNA I: ANES at all sections compared with ANES-only				
Odds ratio (full regression)	0.376*	1.009	0.973	1.299*
Odds ratio (propensity-weighted regression)	0.225***	0.982	0.941	1.380***
Unadjusted difference in rates (%)	−0.0034	−0.04	−0.01	1.31*
Adjusted difference in rates (%)	−0.0064*	0.01	0.03	1.63*
Adjusted difference in rates (propensity-weighted regression) (%)	−0.0101**	0.00	−0.02	2.07**
Nearest neighbor difference in rates (%)	−0.0056	−0.07***	−0.11	0.73***
Block-stratified difference in rates (%)	−0.0057	−0.07***	−0.09	0.92***
ANES/CRNA II: ANES not at all sections compared with ANES-only				
Odds ratio (full regression)	0.849	1.226	0.892	1.039
Odds ratio (propensity-weighted regression)	0.867	1.206	0.933	0.919
Unadjusted difference in rates (%)	−0.0020	0.02	−0.05	0.63
Adjusted difference in rates (%)	−0.0011	0.06	−0.06	0.12
Adjusted difference in rates (propensity-weighted regression) (%)	0.0005	0.07	0.02	−0.69
Nearest neighbor difference in rates (%)	−0.0040	−0.01	−0.19***	−0.24*
Block-stratified difference in rates (%)	−0.0018	−0.02	−0.15***	−0.13
<i>Cesarean-section patients</i>				
CRNA-only compared with ANES-only				
Odds ratio (full regression)	0.371	0.880	0.852	0.863
Odds ratio (propensity-weighted regression)	0.148*	0.921	0.804	0.633**
Unadjusted difference in rates (%)	−0.0145	−0.06	−0.35	−0.09
Adjusted difference in rates (%)	−0.0155	−0.07	−0.25	−0.05
Adjusted difference in rates (propensity-weighted regression) (%)	−0.0208*	−0.02	−0.20	−0.17*

continued

Table 4. *Continued*

<i>Comparison</i>	<i>Outcome</i>			
	<i>Mortality</i>	<i>Anesthesia Complication</i>	<i>Anesthesia or Other Complication</i>	<i>AHRQ Obstetric Trauma Indicator</i>
Nearest neighbor difference in rates (%)	− 0.0081	0.15	− 0.18	− 0.21
Block-stratified difference in rates (%)	− 0.0186	0.08	0.08	− 0.08
ANES/CRNA I: ANES at all sections compared with ANES-only				
Odds ratio (full regression)	0.498	0.937	0.973	<i>1.592*</i>
Odds ratio (propensity-weighted regression)	0.306	0.944	0.920	1.336
Unadjusted difference in rates (%)	− 0.0054	− 0.11	− 0.07	0.10
Adjusted difference in rates (%)	− 0.0151	− 0.01	− 0.04	0.31
Adjusted difference in rates (propensity-weighted regression) (%)	− 0.0250*	− 0.01	− 0.12	0.16
Nearest neighbor difference in rates (%)	− 0.0042	− 0.16**	0.01	<i>0.17***</i>
Block-stratified difference in rates (%)	− 0.0054	− 0.15**	− 0.07	<i>0.10*</i>
ANES/CRNA II: ANES not at all sections compared with ANES-only				
Odds ratio (full regression)	0.923	0.984	0.764	0.865
Odds ratio (propensity-weighted regression)	1.081	1.012	0.822	0.795
Unadjusted difference in rates (%)	− 0.0061	0.02	− 0.09	− 0.09
Adjusted difference in rates (%)	− 0.0116	0.00	− 0.39	− 0.02
Adjusted difference in rates (propensity-weighted regression) (%)	− 0.0030	0.08	− 0.30	− 0.08
Nearest neighbor difference in rates (%)	0.0032	0.02	− 0.24*	− 0.15**
Block-stratified difference in rates (%)	− 0.0056	− 0.06	− 0.26**	− 0.05

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

Italicized results are those for which estimate for the CRNA-only, ANES/CRNA I, or ANES/CRNA II model of care is statistically significant and above that of the ANES-only model. Propensity models for choice of hospital include variables for patient age; payer; ethnicity; maternal Charlson score; categorical variables for each condition comprising maternal Charlson score, whether there was early onset of labor, and metropolitan location variable. Logistic regressions for odds ratios and OLS regressions for adjusted rates include hospital variables for whether anesthesia continuously available in hospital; labor, delivery, and recovery in same room; whether nonemergency cesarean deliveries in labor and delivery area, number of persons at a planned cesarean delivery, minutes to transport for an emergency cesarean delivery, number of births at the hospital in a year; obstetric unit care level, number of neonatal intensive care beds per thousand births; metropolitan/nonmetropolitan location; ownership; teaching status; state; year; and patient variables for patient age; payer; ethnicity; maternal Charlson score; categorical variables for each condition comprising maternal Charlson score, whether there was early onset of labor. Standard errors adjusted for clustering of patients within hospitals.

ANES, anesthesiologist; CRNA, certified registered nurse anesthetist; AHRQ, Agency for Healthcare Research and Quality.

ences are significant, and the lower rates of complications for the ANES–CRNA II model are only significant in the nearest-neighbor and block-stratified propensity analyses (Table 4). For the ANES–CRNA I and Mixed models, the lower estimated differences in anesthesia or other complications are not significant in any analysis.

Risk of Obstetrical Trauma and Anesthesia Model

Obstetrical trauma rates were lowest (6.21 percent) in the ANES-only hospitals, although the differences were not statistically significantly different for any group except the ANES–CRNA I hospitals (7.52 percent, $p = .044$). The Mixed model hospitals also had a relatively high rate, 7.96 percent, although the difference from ANES-only hospitals was not significant (Table 1). In the multivariate regression of the full sample, the odds ratios vary from 0.943 for the ANES–CRNA II to 1.236 in the Mixed models, none statistically significant (Table 2). In the propensity analysis for the full sample, the estimated differences in obstetrical trauma rates are higher and statistically significant for the CRNA-only hospitals for the nearest-neighbor and block-stratified analyses, and for all analyses (propensity and nonpropensity) for the ANES–CRNA I model hospitals (Table 4).

In the cesarean sample, the odds ratio are high and differ significantly from those in the ANES-only hospitals for ANES–CRNA I (odds ratio 1.481, $CI_{95} = 1.130\text{--}1.939$, $p = .004$) and the Mixed model hospitals (odds ratio 2.317, $CI_{95} = 1.428\text{--}3.758$, $p = .001$) (Table 3). The odds ratio for the CRNA-only (0.884) and ANES–CRNA II (0.917) hospitals are not significantly different from one. The results are comparable for the ANES–CRNA I model hospitals in the propensity analyses, with statistically significant differences observed in the multivariate analysis, and nearest-neighbor and block-stratified propensity analyses. The propensity-weighted regressions comparing CRNA-only and ANES-only hospitals estimate statistically significant and lower rates for obstetrical trauma in the CRNA-only hospitals (Table 4).

Association of Other Variables with Risks of Complication

There is no consistent pattern of association of other hospital or patient characteristics with the complications studied. With respect to hospital variables, more births at a hospital are associated with lower rates of anesthesia complications and obstetrical trauma in the full sample, but only with obstetrical trauma in the cesarean sample. Having a level 2 obstetrical unit was associated

with lower rates of the combined anesthesia and other complications in the cesarean sample, and having a level 3 obstetrical unit was associated with lower levels of anesthesia complications in the full sample. Having higher ratios of NICU beds to births was associated with higher rates of complications and obstetrical trauma in both full and cesarean section samples. Longer times to initiate emergency cesarean sections are associated with lower rates of obstetrical trauma in both samples and lower rates of anesthesia or other complications in the full patient sample.

With respect to patient characteristics, the odds ratios for death are higher for blacks and Hispanics in both the full sample and cesarean sample, but statistically significant only in the full sample (blacks: odds ratio 3.006, $CI_{95} = 1.347-6.710$, $p = .007$; Hispanics: odds ratio 2.167, $CI_{95} = 1.109-4.232$, $p = .024$). In the full sample, patients who are age 35 and older are more likely to experience death (odds ratio 2.067, $CI_{95} = 1.205-3.546$, $p = .008$) and anesthesia or other complications (odds ratio 1.407, $CI_{95} = 1.3112-1.510$, $p < .001$), but lower rates of obstetrical trauma (odds ratio 0.693, $CI_{95} = 0.662-0.725$, $p < .001$). Patients who are age 35 and older, and undergoing cesarean sections, however, are more likely to experience obstetrical trauma (odds ratio 1.311, $CI_{95} = 1.096-1.567$, $p = .003$). Medicaid and uninsured patients are less likely to experience anesthesia complications, anesthesia or other complications, or obstetrical trauma in both samples, although the results are statistically significant only for the Medicaid patients and obstetrical trauma in the cesarean sample.

The Charlson score and individual obstetrical comorbidities are statistically significant for many outcomes in the full and cesarean samples but the results are not consistent for individual comorbidities across the two samples or across outcomes.

DISCUSSION

Although obstetrical care is generally safe, high cesarean delivery rates and the extensive use of epidural pain relief make anesthesia an important component of obstetrical care. In this study, with a geographically broad sample of hospitals with approximately 10 percent of the births in U.S. hospitals in 1999–2001, we examined the role of anesthesia provider and anesthesia care model on deaths, anesthesia complication, other complications, and obstetrical trauma. We find no evidence that, compared with anesthesia models relying exclusively on anesthesiologists, hospitals that use only CRNAs or have an

anesthesia model involving both CRNAs and anesthesiologists have systematically higher rates of these complications. This is the case whether or not we introduce substantial controls for other dimensions of the hospital's obstetrical care or patient characteristics or comorbidities, or propensity methods to control for selection. Only for the ANES-CRNA I model did we observe a consistent pattern of statistically significant estimate of higher rates for a complication, i.e., obstetrical trauma, a complication in which anesthesia provider is unlikely to be involved operationally. This is a reassuring finding, given the large number of births that currently take place in hospitals in which hospitals' CRNAs are the sole obstetrical anesthesia provider or have broad privileges.

It is not feasible to construct prospective studies of patient outcomes using random assignment of patients, making retrospective quasi-experimental designs continued strategies for comparing the experience of patients. It is, however, feasible to improve the accuracy of these study results if more detail regarding practice privileges and clinically relevant resources becomes part of general databases. The approach we use here, involving detailed information on provider practice patterns and resources that may influence patient outcomes, should be used in further investigations of provider type influence in other areas of anesthesia practice. It is also relevant for other large sample studies of differences in hospital quality that use administrative data.

There are several study limitations. The study results are limited only to the outcomes and the anesthesia models studied. In this regard, we note that this is a study of maternal outcomes. Many of the important outcomes associated with anesthesia provision in obstetrics will be those that relate to the health of the child. Further studies of anesthesia provision and neonatal outcomes are encouraged.

Different results might be obtained if outcomes in areas outside of obstetrics were studied. For example, infant outcomes could be studied. Such studies would require determination of anesthesia privilege patterns and the clinical resources that produce the overall outcome. For example, the 24-hour presence of an obstetric CRNA might make a difference in providing the rapid interventions needed by neonates when compared with institutions that do not provide 24-hour obstetrical anesthesia coverage. The resource variables that could be utilized in this study were limited; perhaps others found to be significant in future studies would suggest more avenues for quality improvement. Ideally, we would also have included the type of anesthesia and anesthetic used, but this was not reliably available in our data sources.

It may also be the case that models of anesthesia organization have changed since 2004, although informal inquiries among knowledgeable observers suggest this is not the case. The dynamic nature of practice organization underscores the importance of establishing regular mechanisms for collecting information on practice, procedures, and resources that are not currently available from the AHA, CMS or other surveys, and hospital financial and statistical reports.

The study is also constrained by the usual limitations of retrospective design and the attendant need to make severity and comorbidity adjustments. In this study, we used standard techniques to code a substantial number of patient risk factors that might have been expected to influence maternal outcomes. Thus, comparisons across studies that use the same risk adjustment techniques are possible.

The covariates and propensity models may not have fully controlled for selection of high-risk patients with greater potential for complications to hospitals with additional resources, such as high-level obstetrical care, teaching programs, or NICU beds. To address this, in analysis not shown, we re-ran our analysis omitting from the sample hospitals that were most likely to be referral centers: major teaching hospitals, those with the highest level of obstetrical care and large numbers of NICU beds, and high birth volume. Our results were unchanged, and we do not believe selection explains our findings.

This study does not examine the reasons why hospitals adopt specific anesthesia models or the relative cost of alternative models, and the implications for regulation and payment. Further study and analysis of these issues is warranted. The findings do suggest that at least in the area of obstetrical services, there may be no gain in anesthesia safety from restricting which licensed providers can provide these services. The use of CRNAs may make it possible to provide obstetric anesthesia coverage where anesthesiologists are not available because of cost or other factors pertaining to regulation and payment.

There are other paths that may augment safety, however. As training with simulators that educate both anesthesiologists and CRNAs to use standardized protocols becomes the norm, it is time to consider research designs that involve simulations of standard and emergency delivery situations if further improvements are to be made for maternity patients. Increasing standardization of all providers' practice make it likely that improving outcomes will result from improving training algorithms and standardizing the experiences of all providers rather than in legislating a specific educational credential.

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Appendix SA1: Author Matrix.

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