ANESTHESIOLOGY

Adverse Events and Factors Associated with Potentially Avoidable Use of General Anesthesia in Cesarean Deliveries

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Neuraxial anesthesia is recommended in lieu of general anesthesia for cesarean deliveries
- The association of general anesthesia without a clinical indication with adverse events in cesarean deliveries remains poorly understood

What This Article Tells Us That Is New

- In New York State, 5.7% of cesarean sections without a clinical indication for general anesthesia are performed with general anesthesia
- The use of potentially avoidable general anesthesia in these patients is associated with an increased risk of anesthesia-related complications, surgical site infection, and venous thromboembolism, but not death or cardiac arrest

ABSTRACT

Background: Compared with neuraxial anesthesia, general anesthesia for cesarean delivery is associated with increased risk of maternal adverse events. Reducing avoidable general anesthetics for cesarean delivery may improve safety of obstetric anesthesia care. This study examined adverse events, trends, and factors associated with potentially avoidable general anesthetics for cesarean delivery.

Methods: This retrospective study analyzed cesarean delivery cases without a recorded indication for general anesthesia or contraindication to neuraxial anesthesia in New York State hospitals, 2003 to 2014. Adverse events included anesthesia complications (systemic, neuraxial-related, and drug-related), surgical site infection, venous thromboembolism, and the composite of death or cardiac arrest. Anesthesia complications were defined as severe if associated with death, organ failure, or prolonged hospital stay.

Results: During the study period, 466,014 cesarean deliveries without a recorded indication for general anesthesia or contraindication to neuraxial anesthesia were analyzed; 26,431 were completed with general anesthesia (5.7%). The proportion of avoidable general anesthetics decreased from 5.6% in 2003 to 2004 to 4.8% in 2013 to 2014 (14% reduction; $P < 0.001$). Avoidable general anesthetics were associated with significantly increased risk of anesthesia complications (adjusted odds ratio, 1.6; 95% CI, 1.4 to 1.9), severe complications (adjusted odds ratio, 2.9; 95% CI, 1.6 to 5.2), surgical site infection (adjusted odds ratio, 1.7; 95% CI, 1.5 to 2.1), and venous thromboembolism (adjusted odds ratio, 1.9; 95% CI, 1.3 to 3.0), but not of death or cardiac arrest. Labor neuraxial analgesia rate was one of the most actionable hospital-level factors associated with avoidable general anesthetics. Relative to hospitals with a rate greater than or equal to 75%, the adjusted odds ratio of avoidable general anesthetics increased to 1.3 (95% CI, 1.2 to 1.4), 1.6 (95% CI, 1.5 to 1.7), and 3.2 (95% CI, 3.0 to 3.5) as the rate decreased to 50 to 74.9%, 25 to 49.9%, and less than 25%, respectively.

Conclusions: Compared with neuraxial anesthesia, avoidable general anesthetics are associated with increased risk of adverse maternal outcomes.

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Compared with neuraxial anesthesia, general anesthesia for cesarean delivery is associated with significantly increased risks of maternal adverse events. These include death, cardiac arrest, anesthesia-related complications, or surgical site infection.[1–4] Increased risk of deep venous thrombosis and pulmonary embolism is also suggested.[5] These higher risks of maternal adverse events were taken into consideration in the 2007 and 2016 American Society of Anesthesiologists Practice Guidelines for Obstetric Anesthesia, hence the statements "neuraxial techniques are preferred to general anesthesia for most cesarean deliveries" and "consider selecting neuraxial techniques in preference to general anesthesia for most cesarean deliveries."[6,7]

Use of general anesthesia for cesarean delivery has consequently markedly decreased during the last decade.[8] This decrease was associated with a parallel decrease in anesthesia-related morbidity.[1,8] The current general anesthesia rate for cesarean delivery is estimated around 5.5%.[9,10] Further reduction in this rate could be a potential area for clinical interventions to improve the safety and quality of obstetric anesthesia care and reduce anesthesia-related morbidity.

This article is accompanied by an editorial on p. 864. This article has been selected for the Anesthesiology CME Program. Learning objectives and disclosure and ordering information can be found in the CME section at the front of this issue. Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are available in both the HTML and PDF versions of this article. Links to the digital files are provided in the HTML text of this article on the Journal's Web site (www.anesthesiology.org).

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However, use of general anesthesia for cesarean delivery may be clinically indicated in women with specific preexisting or pregnancy-associated conditions (*e.g.*, severe heart valve stenosis), in high-risk obstetrical situations (*e.g.*, morbidly adherent placenta), or in women with contraindications to neuraxial techniques (*e.g.*, coagulation factor deficit). In these situations, the risk–benefit balance may favor general anesthesia, and the additional risk associated with general anesthesia compared with neuraxial anesthesia can be deemed acceptable. On the contrary, additional risks associated with general anesthesia without a clinical condition precluding use of neuraxial anesthesia could be deemed as unnecessary because exposure to general anesthesia-associated risks is avoidable. To date, most of the research on general anesthesia for cesarean delivery has examined general anesthesia as a whole without individualizing situations in which general anesthesia was not clinically indicated.[8,9,11] Characterizing patient- and hospital-level factors associated with general anesthesia without a recorded clinical indication or characterizing groups of patients and hospitals with potentially avoidable use of general anesthesia use could help identify targets for quality assurance programs.

This study examined risks of maternal adverse events, temporal trends, and patient- and hospital-level risk factors for potentially avoidable general anesthesia in cesarean deliveries.

Materials and Methods

The study protocol was reviewed by the Institutional Review Board of Columbia University Medical Center, New York, New York, and was granted exemption under 45 Code of Federal Regulation 46 (not human subjects research). The Strengthening The Reporting of OBservational studies in Epidemiology (STROBE) and the Reporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statements were followed.

The initial study protocol was not publicly registered. The currently presented analysis plan was based upon the initial plan combined with peer review process requested changes.

Study Samples and Definition of Exposure

The study sample included all records of discharges after cesarean delivery performed in New York State hospitals between January 1, 2003, and December 31, 2014, without a recorded clinical indication for general anesthesia. Clinical indications for general anesthesia were categorized into three groups (table 1 and Supplemental Digital Content Table 1, http://links.lww.com/ALN/B862): obstetrical indications (*e.g.*, placenta accreta), maternal indications (*e.g.*, pulmonary hypertension), and contraindications to neuraxial techniques (*e.g.*, coagulation factor deficit). Cesarean delivery cases without a recorded clinical indication for general anesthesia may indicate situations where general anesthesia was potentially avoidable.

Table 1. Clinical Indications for General Anesthesia

1. Obstetrical indications
   - Abnormal fetal heart rhythm
   - Fetal distress
   - Severe postpartum hemorrhage (***i.e.***, hemorrhage associated with blood transfusion, hysterectomy, or disseminated intravascular coagulation)
   - Abruptio placenta, placenta praevia, or placenta accreta
   - Uterine rupture
   - Umbilical cord prolapse
   - Amniotic fluid embolism
2. Maternal indications
   - Comorbidity index for obstetric patients ≥ 3
   - Charlson comorbidity index ≥ 2
3. Contraindications to neuraxial techniques
   - Coagulation factor deficit, von Willebrand disease, or thrombocytopenia
   - Sepsis and septic shock
   - Maternal pyrexia or generalized infection during labor
   - Chorioamnionitis

Hospital discharge records of the State Inpatient Database for New York were analyzed. State Inpatient Databases are part of the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality (Rockville, Maryland). They capture all inpatient discharges from nonfederal acute care community hospitals, including tertiary and academic centers. For each discharge, the New York State Inpatient Database indicates the type of anesthesia provided, one hospital identifier, patients characteristics, and procedures performed using the International Classification of Diseases, Ninth Revision–Clinical Modification (ICD-9-CM). Hospital characteristics were calculated from the State Inpatient Database or obtained from the American Hospital Association Annual Survey Database.

Cesarean deliveries were identified with a combination of ICD-9-CM diagnosis and procedure codes as previously described.[12] Discharges were excluded if information on the type of anesthesia provided was missing, the hospital identifier was missing, or a clinical indication for general anesthesia was recorded.

The New York State Inpatient Database is the only Healthcare Cost and Utilization Project participating state providing information on anesthesia care. Anesthesia type is reported as a categorical variable with values corresponding to general, regional, other, local, none, and missing. Each discharge record contains a maximum of one value for anesthesia type. For the purpose of the study, the variable was categorized as general anesthesia, regional (neuraxial) anesthesia, and missing. In this data set, anesthetics are coded hierarchically. For example, a woman who received general anesthesia for cesarean delivery because of a failed epidural catheter would be coded as general anesthesia. To take into account the experience of the anesthesia providers within each hospital in performing and managing neuraxial analgesia/anesthesia to obstetric patients, the annual proportion of women delivering with neuraxial analgesia/anesthesia during labor and vaginal

deliveries (the labor epidural analgesia rate) was calculated for each hospital using State Inpatient Database data.

Adverse Events

Five adverse events were analyzed: (1) the composite outcome of death or cardiac arrest, (2) anesthesia-related complications, (3) severe anesthesia-related complications, (4) surgical site infections, and (5) venous thromboembolic events (Supplemental Digital Content Table 2, http://links.lww.com/ALN/B862). Death was directly recorded from the State Inpatient Database.

Anesthesia-related complications were divided into three groups: (1) systemic complications, (2) complications related to neuraxial techniques, and (3) complications related to anesthetic drugs. Severe anesthesia-related complications were defined as complications associated with death, cardiac arrest, severe organ dysfunction, or hospital stay greater than the ninety-ninth percentile (7 days; Supplemental Digital Content Table 3, http://links.lww.com/ALN/B862). Organ dysfunction variables used to define severe complications reflect concurrent coding in individual cases, and do not establish a causal relationship between anesthesia and organ dysfunctions. Venous thromboembolic events included deep venous thrombosis and pulmonary embolism. Analysis of adverse events was limited to the index hospitalization and did not analyze readmissions.

Patient- and Hospital-level Factors

The following patient-level factors were recorded directly from the State Inpatient Database: age, race and ethnicity, insurance type, admission type (elective or nonelective), and admission for delivery during weekend. In the State Inpatient Databases, Hispanic ethnicity is considered as a distinct racial group. The comorbidity index for obstetric patients and the Charlson comorbidity index were calculated using previously described ICD-9-CM algorithms.[13–15] Preexisting maternal conditions and pregnancy-associated conditions were identified with ICD-9-CM diagnostic codes (Supplemental Digital Content Table 4, http://links.lww.com/ALN/B862).

The following hospital-level factors were calculated from the State Inpatient Database: annual proportion of neuraxial techniques during labor and vaginal deliveries, annual volume of delivery, annual proportion of admission during weekend, annual proportion of high-risk pregnancy, and annual intensity of coding. High-risk pregnancies were defined as a comorbidity index for obstetrics patients at or above 2.[15] Intensity of coding was the mean number of diagnosis and procedure codes reported per discharge.[3,16]

The following hospital-level factors were obtained from the American Hospital Association Annual Survey Database: hospital location (rural or urban), teaching status, and neonatal level-of-care designation (1, 2, or 3). Rural hospital location included micropolitan or rural areas based on the Core-Based Statistical Areas. A micropolitan area corresponds to at least one urban cluster that has a population of at least 10,000 but less than 50,000. A teaching hospital had an affiliation to a medical school or residency training accreditation. Neonatal level-of-care 1 hospitals provide basic neonatal level of care, level 2 specialty neonatal care (*e.g.*, care of preterm infants with birth weight at or above 1,500 g), and level 3 subspecialty neonatal intensive care (*e.g.*, mechanical ventilation of 24 h or more).

In the final study sample, patient- and hospital-level factors with a count less than 10 in the general anesthesia group or in the neuraxial anesthesia group were excluded from the analysis.

Statistical Analysis

Statistical analysis was performed with R version 3.4.1 (R Foundation for Statistical Computing, Austria) and specific packages (mice for multiple imputations and lme4 for mixed-effect models). Results are expressed as mean ± SD or count (percent or per 10,000).

Comparison of continuous variables used Student's *t* test and comparison of categorical variables chi-square test. Missing values were estimated using multiple imputations (Supplemental Digital Content Table 5, http://links.lww.com/ALN/B862).

Risk of Serious Adverse Events Associated with General Anesthesia

Unadjusted odds ratios for the five adverse events associated with general anesthesia were calculated using univariate logistic regression. Adjusted odds ratios were calculated using an inverse probability of treatment weighting approach.[17,18] Because we examined five adverse events, we used a Bonferroni correction with a *P* value threshold for statistical significance of $0.05/5 = 0.01$.

The probability of treatment (*i.e.*, general anesthesia) was calculated using a mixed-effect logistic regression model. In this model, the random effect was the hospital identifier (normally distributed intercept and constant slope); the fixed-effects were the year of delivery and patient and hospital characteristics described in the Supplemental Digital Content Table 6, http://links.lww.com/ALN/B862. Both the fixed and random effects were used to calculate the individual probability of receiving general anesthesia (*i.e.*, the propensity score).

Inverse probability weights were calculated using the propensity score. Using weights aims to create a synthetic sample in which the distribution of measured baseline covariates is independent of treatment assignment (*i.e.*, general anesthesia). This approach is similar to the use of survey sampling weights that are used to weight survey samples so that they are representative of specific populations. Inverse weights were stabilized and truncated at 1 and 99%. Inverse stabilized weights for women who received general anesthesia were calculated as $P(Z = 1) / P(Z = 1 \mid X)$, where

$P(Z = 1)$ is the probability of general anesthesia in the study sample (*i.e.*, prevalence) and $P(Z = 1 \mid X)$ the individual probability of general anesthesia conditional of the set of predictors (*i.e.*, propensity score). Inverse stabilized weights for women who did not receive general anesthesia were calculated as $1 - P(Z = 1) / (1 - P(Z = 1 \mid X))$.

The likelihood of serious adverse event associated with general anesthesia was quantified with the odds ratio from a mixed-effect logistic regression. In this model, the outcome was the examined adverse event, the random effect was the hospital identifier, the fixed effect was the exposure to general anesthesia, and the weight was the inverse stabilized weight.

We reestimated the adjusted odds ratio for the five adverse outcomes examined in two sensitivity analyses after limitation of the study sample to (1) women with a Charlson comorbidity index at or above 1 and a comorbidity index for obstetric patients at or below 1 (with all other inclusion criteria unchanged) and (2) women with a Charlson comorbidity index equals 0 and a comorbidity index for obstetric patients equals 0 (with all other inclusion criteria unchanged).

Temporal Trends in the Use of General Anesthesia

General anesthesia rate was calculated for each 2-year interval of the 12-year study period. The percent change for rates over the study period was calculated as the difference between the rate in 2013 to 2014 and the rate in 2003 to 2004 divided by the rate in 2003 to 2004. The 95% CI for the percent change was calculated. The Cochran–Armitage test for trends was used to assess the statistical significance of changes of rate over time. Trends were assessed overall, according to three hospital characteristics (rural or urban location, teaching status, and annual volume of deliveries) and according to two patients characteristics (Medicaid/Medicare status and race).

Risk Factors for General Anesthesia

To take into consideration the nested nature of patients within hospitals, identification of patient- and hospital-level factors associated with general anesthesia used a mixed-effect logistic regression. In this model, the patient- and hospital-level factors with a P value less than 0.2 in the univariate analysis were included as fixed effects, along with the year of delivery and the intensity of coding. The random effect was the hospital identifier with the assumption of a normally distributed intercept and a constant slope. The selection of variables used a backward procedure with a P threshold of 0.05 for exclusion of variables. Discrimination of the model was assessed with the C index.

The relationship between continuous variables and the probability of general anesthesia use was examined using the relationship between the continuous variable and the logarithm of the probability of receiving general anesthesia. Continuous predictors with a nonlinear relationship with the outcome were categorized; predictors with linear relationship were kept continuous or categorized according to clinically relevant thresholds.

Results

During the study period, 864,058 cesarean delivery discharges were identified; of them, 60,502 (7.00%) were completed with general anesthesia (fig. 1). After excluding 398,044 cases with accepted indications for general anesthesia, the final study sample consisted of 466,014 cesarean deliveries, including 26,431 cases (5.67%) completed with general anesthesia without a recorded clinical indication.

Comparing the excluded cases (those with a clinical indication for general anesthesia) with cases without a recorded clinical indication, the rate of general anesthesia was higher in discharges with a clinical indication for general anesthesia (8.56% *vs.* 5.67%; $P < 0.001$). The rates of adverse events in discharges with a clinical indication for general anesthesia were also significantly higher than in discharges without a clinical indication for general anesthesia (table 2). General anesthesia cases without an indication accounted for 43.69% of all general anesthesia cases (with and without and indication).

Risk of Serious Adverse Events Associated with General Anesthesia

The risk of serious adverse events associated with general anesthesia without a recorded clinical indication before and after adjustment is presented in table 3. After adjustment, general anesthesia was associated with a significant increase in the risk of anesthesia-related complications (overall and severe), surgical site infection, and venous thromboembolic events. It was not associated with an increased risk of the composite outcome of death or cardiac arrest. Results were unchanged in the two sensitivity analyses examining various cutoffs values for the comorbidity index for obstetric patients and the Charlson comorbidity index (Supplemental Digital Content Table 7, http://links.lww.com/ALN/B862).

Temporal Trends in the Use of General Anesthesia

The rate of general anesthesia for cesarean delivery without a recorded clinical indication decreased from 5.6% in 2003 to 2004 to 4.8% in 2013 to 2014 (14% decrease; 95% CI, 10 to 18; $P < 0.001$). A statistically significant decrease was observed in all subgroup analyses according to patient and hospital characteristics except for high-delivery-volume hospitals and minority patients (Supplemental Digital Content Table 8, http://links.lww.com/ALN/B862). In hospitals with more than 2,500 annual deliveries, no change in the utilization of general anesthesia without a recorded clinical indication was observed. In minority women, the utilization of general anesthesia increased from 5.4% in 2003 to 2004 to 6.0% in 2013 to 2014 (11% increase; 95% CI, 4 to 18; $P < 0.001$).

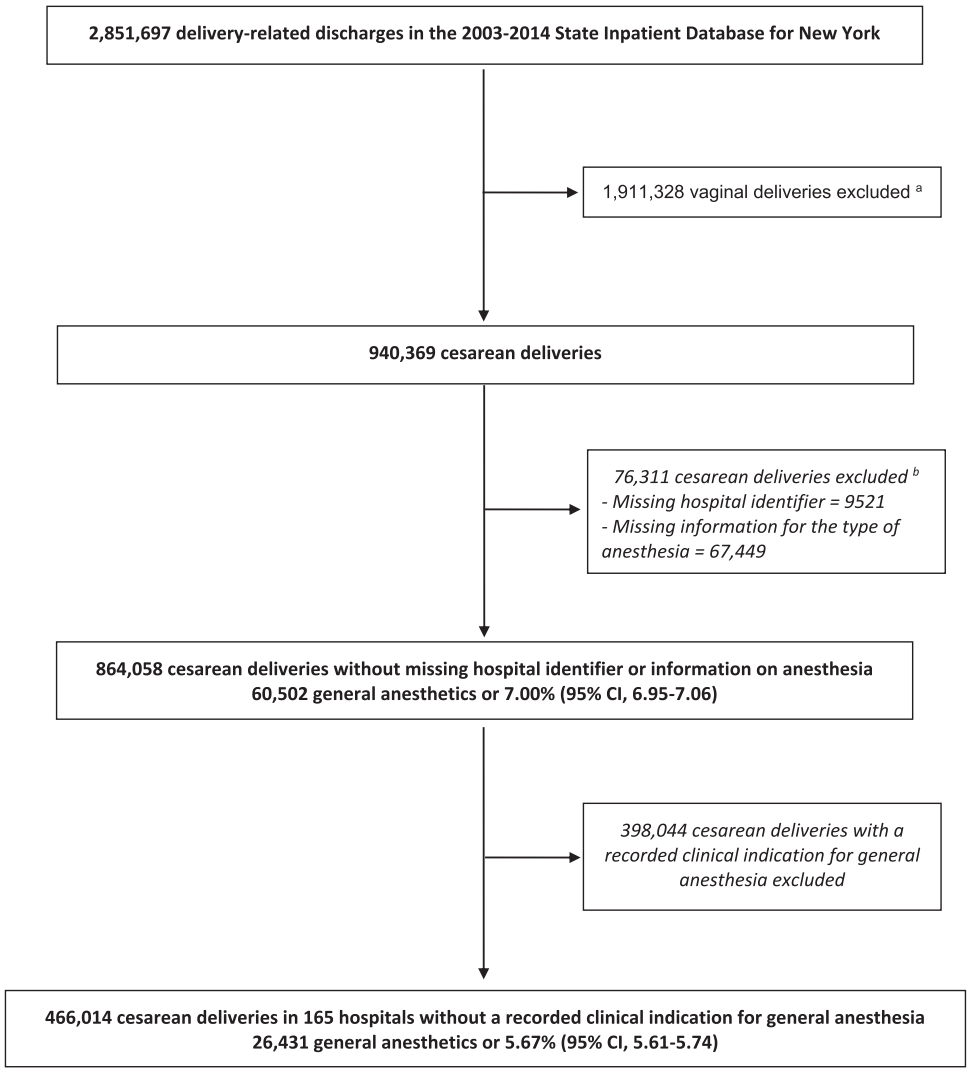

Fig. 1. Flowchart of the study. [a]The hospital annual proportion of women who received neuraxial techniques during labor and vaginal deliveries and the temporal trends in the utilization of neuraxial techniques during labor and vaginal deliveries were calculated in these discharges. [b]Does not round up.

During the study period, the utilization of neuraxial technique during labor and vaginal deliveries increased significantly across racial groups and hospitals (Supplemental Digital Content Table 9, http://links.lww.com/ALN/B862).

Risk Factors for General Anesthesia Use

The univariable comparisons of cesarean deliveries with general or neuraxial anesthesia are presented in table 4. In the final multilevel model (table 5), the following patient-level factors were associated with a significantly increased likelihood of potentially avoidable general anesthesia: age less than 19 yr, racial or ethnic minority, Medicaid or Medicare beneficiaries, preexisting or pregnancy-associated conditions, nonelective admission, and admission during weekend. Hospital-level factors associated with a significantly increased odds of general anesthesia were the following: teaching hospital, neonatal level-of-care designation 1 or 3, lower use of neuraxial techniques during labor and vaginal deliveries, higher annual volume of deliveries, and higher proportion of women with a comorbidity index greater than 2. Relative to hospitals with labor neuraxial analgesia rate greater than or equal to 75%, the adjusted odds ratios of potentially avoidable general anesthesia increased to 1.35, 1.60, and 3.24 as the labor neuraxial analgesia rate decreased to 50 to 74.9%, 25 to 49.9%, and less than 25%, respectively.

Discussion

In this 12-year study, we analyzed risks, time trends, and risk factors for potentially avoidable general anesthesia for cesarean delivery. The major findings were the following: (1) a

Table 2. Comparison of Cesarean Delivery Discharges with and without a Recorded Clinical Indication for General Anesthesia

	Recorded Clinical Indication for General Anesthesia (N = 398,044)	No Recorded Clinical Indication for General Anesthesia (N = 466,014)	*P* Value*
Exposure			
General anesthesia	34,071 (8.56%)	26,431 (5.67%)	< 0.001
Adverse events			
Death or cardiac arrest (missing = 4)	261 (6.6 per 10,000)	31 (0.7 per 10,000)	< 0.001
Anesthesia-related complications	2,345 (58.9 per 10,000)	2,757 (59.2 per 10,000)	0.89
Severe anesthesia-related complications (missing = 4)†	341 (8.6 per 10,000)	117 (2.5 per 10,000)	< 0.001
Surgical site infection	4,226 (106.2 per 10,000)	3,154 (67.7 per 10,000)	< 0.001
Venous thromboembolic events	710 (17.8 per 10,000)	342 (7.3 per 10,000)	< 0.001

Results are expressed as count (% or per 10,000 of discharges with or without a clinical indication for general anesthesia).

*The *P* value for statistical significance for adverse events is 0.01. †Complications associated with death, cardiac arrest, severe organ dysfunction, or hospital stay at or above the ninety-ninth percentile (7 days).

Table 3. Adverse Events in the 466,014 Cesarean Deliveries without a Recorded Clinical Indication for General Anesthesia in the State Inpatient Database for New York 2003–2014

	Neuraxial Anesthesia (N = 439,583)	General Anesthesia (N = 26,431)	Crude OR (95% CI)	*P* Value*	Adjusted OR† (95% CI)	*P* Value*
Death or cardiac arrest (missing = 2)	27 (0.6 per 10,000)	—‡	—‡	0.096	2.44 (0.67–8.93)	0.18
Anesthesia-related complications	2,540 (57.8 per 10,000)	217 (82.1 per 10,000)	1.42 (1.24–1.64)	< 0.001	1.62 (1.37–1.92)	< 0.001
Severe anesthesia-related complications§ (missing = 2)	118 (2.7 per 10,000)	18 (6.8 per 10,000)	2.54 (1.55–4.17)	< 0.001	2.86 (1.58–5.19)	< 0.001
Surgical site infections	2,812 (64.0 per 10,000)	342 (129.4 per 10,000)	2.04 (1.82–2.28)	< 0.001	1.74 (1.47–2.06)	< 0.001
Venous thromboembolic events	311 (7.1 per 10,000)	31 (11.7 per 10,000)	1.66 (1.15–2.40)	0.009	1.92 (1.23–2.97)	0.004

Results are expressed as count (per 10,000 of discharges with neuraxial or general anesthesia).

*The *P* value for statistical significance is 0.01. †Adjustment using propensity score weighting. ‡Because of Healthcare Cost and Utilization Project data use agreement restrictions on small cell size, the number of observed cases and exact proportions are not presented. §Complications associated with death, cardiac arrest, severe organ dysfunction, or hospital stay at or above the ninety-ninth percentile (7 days). OR, odds ratio.

high proportion of potentially avoidable general anesthesia among all general anesthesia cases (44%); (2) a decrease over time in potentially avoidable general anesthesia cases except in minority women and in high-volume hospitals; (3) a significant increase in the risk of serious adverse events when cesarean delivery was performed with general anesthesia compared with neuraxial anesthesia; and (4) several patient- and hospital-level factors associated with potentially avoidable general anesthesia, with some of them directly actionable.

Risk of Adverse Events Associated with General Anesthesia

Contrary to previous research, we did not observe an increased risk of death or cardiac arrest associated with general anesthesia compared with neuraxial anesthesia.[1,2] This apparent discrepancy can be explained by the exclusion in our analysis of discharges recording severe comorbidities and high-risk obstetrical situations (Charlson comorbidity index at or above 2 or comorbidity index for obstetric patients at or above 3), which are strongly associated with the risk of near-miss maternal morbidity or mortality.[19] However, we observed a significantly increased risk of anesthesia-related complications (overall and severe) and surgical site infections. It confirms previous research on the risks associated with general anesthesia for cesarean delivery and extends it to cases of potentially avoidable general anesthesia.[3,4]

Increased risk of surgical infection associated with general anesthesia has also been reported in planned orthopedic surgery. The increased risk associated with general anesthesia in cesarean delivery may not only be related to the urgency of the procedure. Several mechanisms have been suggested to account for the decreased risk of surgical infection associated with neuraxial techniques.[20] They include an attenuated inflammatory response to surgery, an improvement in tissue oxygenation through the vasodilation induced by

Table 4. Univariable Analysis of Risk Factors for the Use of General Anesthesia in the 466,014 Cesarean Deliveries without a Recorded Clinical Indication for General Anesthesia in the State Inpatient Databases for New York 2003–2014

	Neuraxial Anesthesia (N = 439,583)	General Anesthesia (N = 26,431)	Crude OR (95% CI)	*P* Value
General characteristics				
Age, y				< 0.001
≤ 19	15,021 (3.4%)	951 (3.6%)	Reference	
20–29	180,211 (41.0%)	9,320 (35.3%)	0.82 (0.76–0.88)	
30–39	234,875 (53.4%)	15,291 (57.9%)	1.03 (0.96–1.10)	
≥ 40	9,476 (2.2%)	869 (3.3%)	1.45 (1.32–1.59)	
Race and ethnicity (missing = 12,362)				< 0.001
White	227,379 (53.2%)	12,245 (46.8%)	Reference	
Black	57,178 (13.4%)	2,692 (10.3%)	0.87 (0.84–0.91)	
Hispanic	73,928 (17.3%)	4,733 (18.1%)	1.19 (1.15–1.23)	
Asian and Pacific Islander	26,901 (6.3%)	4,017 (15.4%)	2.77 (2.67–2.88)	
Other	42,109 (9.9%)	2,470 (9.4%)	1.09 (1.04–1.14)	
Insurance				< 0.001
Medicare and Medicaid	161,531 (36.7%)	10,504 (39.7%)	Reference	
Private insurance	253,970 (57.8%)	15,441 (58.4%)	0.93 (0.91–0.96)	
Self-pay	14,874 (3.4%)	255 (1.0%)	0.26 (0.23–0.30)	
Other	9,208 (2.1%)	231 (0.9%)	0.39 (0.34–0.44)	
Admission				
Elective admission (missing = 1,094)	285,608 (65.1%)	19,738 (74.9%)	1.60 (1.55–1.65)	< 0.001
Admission during weekend	53,687 (12.2%)	4,044 (15.3%)	1.30 (1.25–1.34)	< 0.001
Preexisting maternal conditions				
Mental retardation	91 (0.02%)	14 (0.05%)	2.56 (1.46–4.49)	0.001
Depression	6,210 (1.4%)	424 (1.6%)	1.14 (1.03–1.26)	0.011
Schizophrenia	186 (0.04%)	15 (0.06%)	1.34 (0.79–2.27)	0.34
Bipolar disorders	1,648 (0.4%)	109 (0.4%)	1.10 (0.91–1.34)	0.36
Drug use	241 (0.1%)	16 (0.1%)	1.10 (0.67–1.83)	0.80
Smoking	6,945 (1.6%)	437 (1.7%)	1.05 (0.95–1.15)	0.37
Preexisting hypertension	2,091 (0.5%)	122 (0.5%)	0.97 (0.81–1.17)	0.78
Heart valve disease	734 (0.2%)	67 (0.3%)	1.52 (1.18–1.95)	0.001
Cardiac arrhythmias	237 (0.05%)	13 (0.05%)	0.91 (0.52–1.59)	0.85
Cardiac conduction disorders	1,800 (0.4%)	135 (0.5%)	1.25 (1.05–1.49)	0.015
Obesity	15,567 (3.5%)	652 (2.5%)	0.69 (0.64–0.75)	< 0.001
Lupus	278 (0.06%)	31 (0.12%)	1.86 (1.28–2.69)	0.001
HIV infection	632 (0.1%)	33 (0.1%)	0.87 (0.61–1.23)	0.48
Asthma	2,024 (0.4%)	119 (0.4%)	0.98 (0.81–1.18)	0.84
Chronic kidney disease	256 (0.1%)	16 (0.1%)	1.04 (0.63–1.72)	0.98
Chronic hepatitis	170 (0.04%)	21 (0.08%)	2.06 (1.31–3.23)	0.002
Pregnancy-associated conditions				
Gestational hypertension	6,444 (1.5%)	407 (1.5%)	1.05 (0.95–1.16)	0.34
Preeclampsia and eclampsia	8,227 (1.9%)	440 (1.7%)	0.89 (0.81–0.98)	0.017
Previous cesarean delivery	224,273 (51.0%)	11,567 (43.8%)	0.75 (0.73–0.77)	< 0.001
Uterine scar	3,619 (0.8%)	359 (1.4%)	1.66 (1.49–1.8)	< 0.001
Pregnancy resulting from ART	885 (0.2%)	213 (0.8%)	4.03 (3.47–4.68)	< 0.001
Multiple gestation	1,608 (0.4%)	112 (0.4%)	1.16 (0.96–1.40)	0.14
Abnormal presentation	89,654 (20.4%)	6,079 (23.0%)	1.17 (1.13–1.20)	< 0.001
Fetal macrosomia	31,231 (7.1%)	1,243 (4.7%)	0.65 (0.61–0.68)	< 0.001
Hospital				
Urban hospital (missing = 1,894)	412,275 (94.2%)	25,013 (94.8%)	1.12 (1.06–1.18)	< 0.001
Teaching hospital (missing = 1,894)	425,829 (97.3%)	25,922 (98.2%)	1.54 (1.40–1.69)	< 0.001
Neonatal level-of-care designation (missing = 91,819)				< 0.001
1	91,293 (25.8%)	3,991 (19.9%)	3.02 (2.82–3.24)	
2	70,567 (19.9%)	1,020 (5.1%)	Reference	
3	192,292 (54.3%)	15,032 (75.0%)	5.41 (5.07–5.77)	
Neuraxial use during labor and vaginal deliveries (missing = 10)				< 0.001
≥ 75%	141,008 (32.1%)	3,882 (14.7%)	Reference	
50 to 74.9%	106,695 (24.3%)	3,716 (14.1%)	1.27 (1.21–1.32)	
25 to 49.9%	42,432 (9.7%)	2,487 (9.2%)	2.13 (2.02–2.24)	
≤ 24.9%	149,441 (34.0%)	16,343 (61.8%)	3.97 (3.83–4.12)	
Volume of delivery < 0.001				
≤ 500	24,782 (5.6%)	1,664 (6.3%)	2.48 (2.35–2.62)	
501–2,499	218,865 (49.8%)	5,921 (22.4%)	Reference	
≥ 2,500	195,936 (44.6%)	18,846 (71.3%)	3.56 (3.45–3.66)	
Percent admission during weekend ≥ 20%	236,963 (53.9%)	21,699 (82.1%)	3.92 (3.80–4.05)	< 0.001
Percent comorbidity index in deliveries ≥ 2				< 0.001
≤ 15%	52,206 (11.9%)	6,070 (23.0%)	3.66 (3.53–3.78)	
15.1–24.9%	268,684 (61.1%)	8,546 (32.3%)	Reference	
≥ 25%	118,693 (27.0%)	11,815 (44.7%)	3.13 (3.04–3.22)	
Coding intensity*	6.6 ± 1.1	6.9 ± 1.2	1.33 (1.32–1.34)	< 0.001

Results are expressed as mean ± SD or count (%).
*The mean number of diagnosis and procedure codes reported per discharge.
ART, assisted reproductive technology; HIV, human immunodeficiency virus; OR, odds ratio.

Table 5. Multivariable Analysis of Risk Factors for the Use of General Anesthesia in the 466,014 Cesarean Deliveries without a Recorded Clinical Indication for General Anesthesia in the State Inpatient Database for New York 2003–2014

	Adjusted OR (95% CI)	*P* Value
General characteristics		
Age (yr)		
≤ 19	Reference	Reference
20–29	0.79 (0.73–0.85)	< 0.001
30–39	0.78 (0.72–0.85)	< 0.001
≥ 40	0.74 (0.65–0.86)	< 0.001
Race and ethnicity		
White	Reference	Reference
Black	1.27 (1.20–1.35)	< 0.001
Hispanic	1.15 (1.08–1.21)	< 0.001
Asian and Pacific Islander	1.04 (0.97–1.12)	0.27
Other	1.10 (1.03–1.18)	0.007
Insurance		
Medicare and Medicaid	Reference	Reference
Private insurance	0.85 (0.81–0.89)	< 0.001
Self-pay	1.06 (0.90–1.24)	0.48
Other	0.73 (0.63–0.84)	< 0.001
Preexisting conditions		
Mental retardation	3.69 (1.96–6.97)	< 0.001
Depression	1.32 (1.15–1.50)	< 0.001
Heart valve disease	1.59 (1.11–2.28)	0.011
Cardiac conduction disorders	1.67 (1.33–2.10)	< 0.001
Obesity	1.18 (1.07–1.29)	< 0.001
Chronic hepatitis	3.64 (2.05–6.46)	< 0.001
Pregnancy-associated conditions		
Preeclampsia and eclampsia	1.14 (1.02–1.29)	0.025
Previous cesarean delivery	0.77 (0.74–0.80)	< 0.001
Pregnancy resulting from ART	1.59 (1.14–2.21)	0.006
Fetal macrosomia	0.77 (0.72–0.84)	< 0.001
Admission		
Elective admission	0.83 (0.79–0.88)	< 0.001
Admission during weekend	1.06 (1.01–1.11)	0.034
Hospital		
Teaching hospital	1.29 (1.11–1.50)	< 0.001
Neonatal level of care		
1	1.35 (1.24–1.48)	< 0.001
2	Reference	Reference
3	1.92 (1.75–2.11)	< 0.001
Volume of delivery		
≤ 500	1.15 (0.98–1.35)	0.10
501–2,499	Reference	Reference
≥ 2,500	1.34 (1.22–1.47)	< 0.001
Neuraxial use during vaginal deliveries		
≥ 75%	Reference	Reference
50 to 74.9%	1.35 (1.27–1.44)	< 0.001
25 to 49.9%	1.60 (1.49–1.73)	< 0.001
≤ 24.9%	3.24 (3.03–3.48)	< 0.001
Percent comorbidity index in deliveries ≥ 2		
≤ 15%	0.85 (0.80–0.91)	< 0.001
15.1–24.9%	Reference	Reference
≥ 25%	1.16 (1.06–1.26)	< 0.001

The C index of the model is 0.909 (95% CI, 0.907 to 0.911). The year of delivery and intensity of coding were also included in the model.

ART, assisted reproductive technology; OR, odds ratio.

neuraxial techniques, and an enhanced postoperative analgesia with a decrease in pain-associated autonomic response and subsequent vasoconstriction. In addition, we extend the previously reported association between neuraxial techniques and decreased risk of venous thromboembolic events to cesarean deliveries.[21] This decreased risk is thought to be related to improved blood flow through the legs secondary to sympathectomy-induced vasodilatation. Venous thromboembolic disease is a leading cause of maternal morbidity and mortality in the United States and one of the three priority conditions targeted by the National Partnership for Maternal Safety to decrease maternal morbidity and mortality.[22,23]

Whereas increased risks of anesthesia-related complications, surgical site infection, and venous thromboembolic events associated with general anesthesia could be considered acceptable when general anesthesia was clinically indicated and could not have been avoided, risks would be less acceptable when general anesthesia was potentially avoidable. In other words, efforts to reduce the use of general anesthesia for cesarean delivery should probably target cases without a recorded clinical indication.

Temporal Trends

We observed a 14% decrease in the occurrence of potentially avoidable use of general anesthesia for cesarean delivery. This indicates that obstetric anesthesia providers have increasingly favored neuraxial over general anesthesia for cesarean delivery, as recommended by the successive American Society of Anesthesiologists Practice Guidelines for Obstetric Anesthesia.[6,7] However, we observed an increase in the utilization of general anesthesia in minority women and no change in high-volume hospitals.

Using 1999 to 2002 data, Butwick *et al.*[11] reported racial disparities in the use of general anesthesia for cesarean delivery with a higher use of general anesthesia in African American women. Similarly, a lower use of neuraxial labor analgesia in minority women has been repeatedly reported.[24] In this study, we observed that racial disparities in anesthesia care are increasing over time. One hypothesis for this finding is a lower increase in the use of labor neuraxial analgesia in minority women compared with nonminority women. However, in the current study, we observed an increase in the use of labor neuraxial analgesia for both minority and nonminority women, suggesting that the increased utilization of general anesthesia observed in minority patients is related to other mechanisms.

Contrasting with a decreased utilization of general anesthesia in low- and intermediate-volume hospitals, we observed no change in high-volume hospitals. This trend was also observed for cesarean deliveries with a recorded indication for general anesthesia (Supplemental Digital Content Table 10, http://links.lww.com/ALN/B862). It may reflect the redistribution of high-risk patients (*i.e.*, women with severe comorbidities) or high-risk deliveries (*e.g.*, previous cesarean delivery) to high-volume centers (regionalization of care).

Patient-level Factors Associated with General Anesthesia

We confirm previous research on patient-level factors that identified higher odds of general anesthesia in younger women, minority women, Medicaid beneficiaries, women with preexisting or pregnancy-associated conditions, women admitted during weekend, and women with a nonelective admission.[9,11,25,26] Although many of these factors do not seem easily amenable, some of them could indicate areas for possible actions such as younger maternal age and admission during weekend.

Previous studies suggests that younger patients spontaneously tend to favor general anesthesia for a surgical procedure, especially younger patients.[27,28] Lower anticipated and actual use of neuraxial analgesia during labor is also reported in younger women.[29] Provision of antenatal information about the benefits and risks of neuraxial analgesia intrapartum and neuraxial *versus* general anesthesia for cesarean delivery may help reduce the general anesthesia use in this population.

Increased use of general anesthesia in women admitted during weekend could be related to the commonly called "weekend effect" or worse outcomes in patients admitted on Saturday or Sunday.[30] Possible mechanisms accounting for this weekend effect include difference in patient case mix and suboptimal quality of care resulting from reduction in staffing or presence of less experienced providers.[31] A 2015 survey of obstetric anesthesia directors in academic center reports that up to 60% hospitals do not have an in-house dedicated team for the labor and delivery unit during weekends, indicating a change in staffing composition and likely experience.[32] Because our multilevel model adjusts for case mix, we suggest that increased use of general anesthesia during weekend may be related to understaffing or provision of care by less experienced physicians.[33,34]

Hospital-level Factors Associated with General Anesthesia

Hospital-level factors associated with the use of general anesthesia have not previously been thoroughly evaluated, with only one recent study indicating a higher proportion of general anesthesia in university hospitals.[9] In the current study, we confirm a higher use of general anesthesia in university hospitals and identified higher annual volume of delivery, higher proportion of high-risk pregnancy, lower labor neuraxial analgesia rate, and neonatal level-of-care designations 1 or 3 as new risk factors. Similar to patient-level factors, many of the hospital-level factors associated with general anesthesia are beyond the control of the anesthesiologists except for the utilization of neuraxial techniques during labor.

We found that in hospitals with a lower labor epidural analgesia rate, the general anesthesia rate for cesarean delivery was significantly higher. The exact mechanisms accounting for a low labor neuraxial analgesia rate in some hospitals are difficult to determine using administrative data. One explanation is that, with a low epidural analgesia rate, the experience and expertise of anesthesia providers may be limited, which results in their preference to perform general anesthesia for cesarean deliveries. Another explanation is the lack of availability of a dedicated anesthesia team for obstetric anesthesia care, and the low epidural analgesia rate is a surrogate marker for lack of 24/7 anesthesia services, which increases the likelihood of general anesthesia for urgent or even less urgent cesarean deliveries. In other words, labor epidural analgesia rate could be less a measure of clinician experience but rather physical presence and involvement on the labor and delivery unit and intensity of services.[35] Because general anesthesia without a clinical indication was associated with a higher risk of adverse events, this finding should be viewed as a strong incentive to target quality assurance programs to hospitals with a low use of neuraxial techniques such as developing dedicated staffing for the labor and delivery unit. Free from duties outside of this unit, dedicated teams could improve the intensity of services.

Limitations of the Study

We acknowledge several limitations to our study. First, we had to apply ICD-9-CM codes and not individual chart review for the definition of exposure and the lack of or presence of a clinical indication for general anesthesia for cesarean delivery. It is therefore possible that a case may have had a clinical indication that was not captured by ICD-9-CM coding (either by missing code or a clinical circumstance not recorded appropriately). Furthermore, some factors associated with the use of general anesthesia are not available in administrative data, such as (1) patients' request for general anesthesia (or refusal of neuraxial anesthesia) and (2) a nonfunctional epidural catheter for intrapartum cesarean delivery or a general anesthetic being needed for rescue of a failed neuraxial anesthetic. Therefore, a proportion of general anesthesia cases may have been attributable to patient refusal of neuraxial analgesia/anesthesia, or rescue general anesthesia if neuraxial anesthesia was not adequate for cesarean delivery (either because of emergent intrapartum cesarean delivery or simply because of a failed neuraxial anesthetic). Several studies suggest that patient refusal represents a small proportion of general anesthesia for cesarean delivery cases.[10,26] For example, in a series of 98 cases of general anesthesia for cesarean delivery in an academic hospital, Palanisamy *et al.*[26] report that patient refusal of neuraxial technique accounted for only 1% of the cases. However, the incidence of failed epidural catheter is much higher and up to 12% in a recent study.[36] Another limitation is that our analysis is limited to practice in New York State because it is the only Healthcare Cost and Utilization Project participating state that provides information on anesthesia care; therefore, our findings may not be generalizable because of marked variations in anesthesia care between states. Indeed,

Butwick *et al.*[37] reported the current overall labor neuraxial analgesia rate in the United States to be 73%, but with a minimum of 37% in the state of Maine and a maximum of 80% in the state of Utah. From an analytical standpoint, although we limited our study sample to women without a recorded clinical indication for general anesthesia, adjusted for a large set of confounders using propensity score weighting, and conducted sensitivity analyses to test the robustness of our main analysis, we cannot exclude some residual confounding in the estimate of the adjusted odds of adverse events associated with general anesthesia compared with neuraxial anesthesia. Last, we cannot report on the influence of the anesthesia provider on general anesthesia use without a recorded clinical indication; nonobstetric anesthesiologist care has been associated with an increased use of general anesthesia for cesarean delivery through failed intrapartum conversion of labor epidural analgesia into surgical anesthesia..[34,38,39] Unfortunately, we do not have any information about anesthesia providers' characteristics.

Conclusions

In this cohort, we identified that 44% of general anesthesia cases for cesarean delivery were potentially avoidable, which was associated with an increased risk of maternal adverse events, including venous thromboembolic events. A low hospital-level use of neuraxial techniques during labor was one of the strongest predictors of potentially avoidable use of general anesthesia for cesarean delivery.

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Competing Interests

The authors declare no competing interests.

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