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Obstetric Anesthesia Practice Significantly Evolved: A Field for Cesarean Delivery Parturient for the Provision of Safe Anesthesia in Urgent Circumstances

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Abstract

General anesthesia and Obstetric Anesthesia is the gold standard for a cesarean section but there are some cases where general anesthesia is unavoidable. The use of general anesthesia for cesarean delivery has decreased in recent years due to the widespread use of neuraxial techniques. The choice of anesthesia techniques for cesarean delivery depends on several factors, including the patient's psychology and the attending physician's experience. It is chosen because of its safety profile and its benefits to the mother and fetus. It may be indicated due to emergency, maternal refusal of regional techniques, or regional contraindications. Major complications include failed intubation, gastric content aspiration, and increased bleeding risk. This study aims to evaluate the impact of a newly launched team on obstetric anesthesia practice.

Keywords

General Anesthesia, Cesarean Delivery, Intubation, Maternal Refusal, Obstetric Anesthetists

1. Introduction

The World Health Organization considers that the ideal rate of cesarean section is between 10% and 15% of the total number of deliveries [1]. Despite global approaches to reducing the rate of cesarean delivery worldwide, there has been an increase in the rate of cesarean delivery to over 50% [1]. The choice between regional or general anesthesia is made according to the patient's clinical condition. The use of appropriate and effective anesthesia for cesarean section is important not only to reduce the incidence of maternal and fetal complications but also to reduce the incidence of intraoperative maternal awareness. The most common indications for general anesthesia are emergency, maternal refusal of regional anesthesia including coagulation or spinal anomalies. Obstetric indications such as placenta previa were considered absolute indications for general anesthesia [2]. Currently, all recommendations point to neuraxial anesthesia as the reference technique rather than general anesthesia for most patients undergoing cesarean section [3], since the mortality rate of cesarean section under general anesthesia is 16.7 times higher than under regional anesthesia [4]. With the widespread use of general anesthesia, the risks associated with it have decreased over time, namely maternal mortality and morbidity related to anesthesia, thanks to the use of new devices, monitors, and medications [5]. Among the advantages of general anesthesia include maintenance of patent airway, controlled ventilation, and less cardiovascular depression [6]. However, it leads to several complications such as intubation failure, ventilation failure, aspiration of gastric contents, consciousness, pain, and fetal depression [7]. These higher risks of maternal complications were considered in the American Society of Anesthesiologists (ASA) 2007 and 2016 practice guidelines for obstetric anesthesia, resulting in the 2 (**Figure 1**). Ease of Use (Heading 2) statements "neuraxial techniques are effective with less risk compared with general anesthesia for most cesarean deliveries" and "consider choosing neuraxial techniques in preference to general anesthesia for most cesarean deliveries" [8].

2. Materials & Methods

This retrospective study analyzed cesarean deliveries without a recorded indication for general anesthesia or contraindication to neuraxial anesthesia in New York State hospitals from 2003 to 2014. Adverse events included anesthesia complications (systemic, neuraxial anesthesia-related, and drugrelated), surgical site infection, venous thromboembolism, and a composite of death or cardiac arrest [9].

Study Samples

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 3 groups (**Table 1**): obstetrical indications (placenta accreta), maternal indications (pulmonary hypertension),

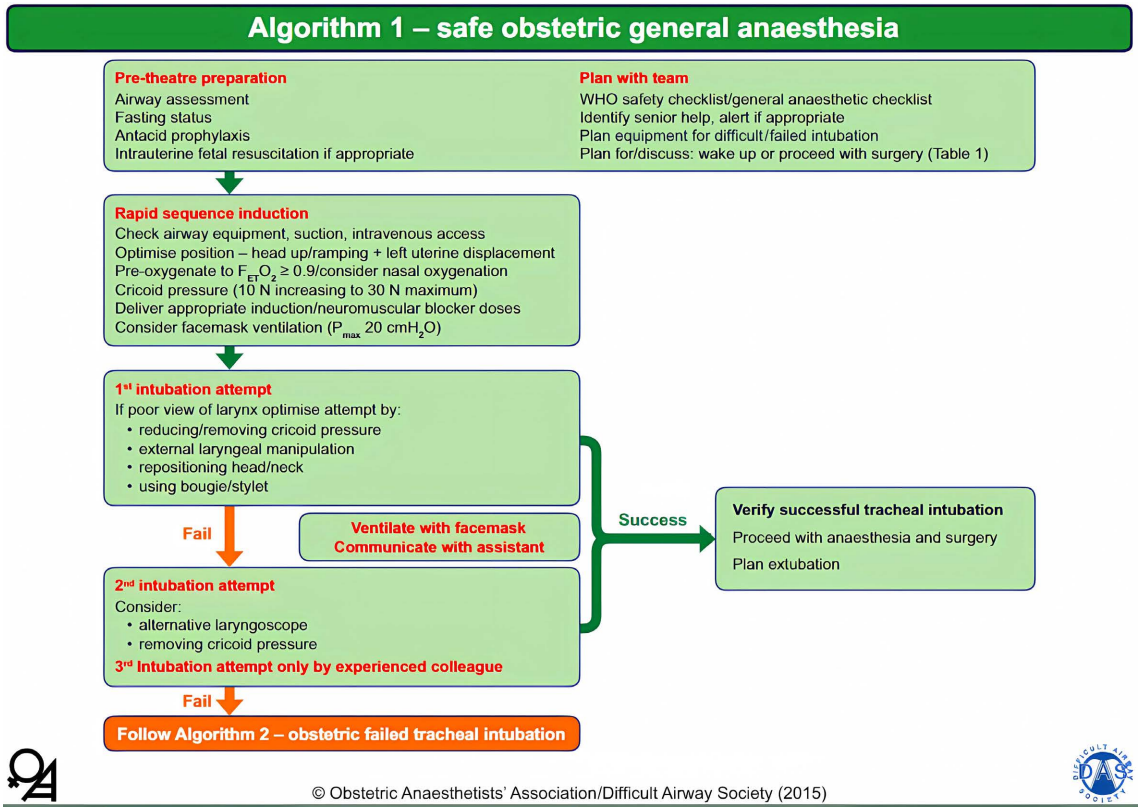

Figure 1. OAA/DAS obstetric airway guidelines, algorithm 1: safe obstetric general anesthesia. Reproduced from Mushambi and colleagues, with permission from the obstetric anaesthetists' association and difficult airway society.

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 accrete
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

and contraindications to neuraxial techniques (coagulation factor deficit). Cesarean deliveries cases without a recorded clinical indication for general anesthesia may indicate situations where general anesthesia was potentially avoidable. Cesarean deliveries were identified with a combination of ICD-9-CM diagnosis and procedure codes. Discharges were excluded if information on the type of anesthesia provided was missing, hospital identifier was missing, or if a clinical indication for general anesthesia was recorded.

3. 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; 5) Venous thromboembolic events. Anesthesia-related complications were divided into 3 groups: 1) Systemic complications; 2) Complications related to neuraxial techniques; 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 99th percentile (7 days). Organ dysfunction variables used to define severe complications reflects 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. Choice of Anesthesia for Cesarean Delivery: An Analysis of the National Anesthesia Clinical Outcomes Registry [10].

3.1. Abbreviations and Acronyms

They analyzed CD records submitted to NACOR with current procedural terminology codes (CPT) 59510, 59514, 59515, 59618, 59620, or 59622 that occurred between January 1, 2010, and March 31, 2015. All CD cases were stratified by the American Society of Anesthesiologists (ASA) physical status (PS) and the presence of status E, indicating emergency surgery. Noting that the ASA effectively eliminated the ASA I class for obstetric anesthesia in 2014, but the majority of NACOR data predate this policy change. Additional case elements analyzed separately by all DCs included patient age, trial of labor after DC, year of surgery, time of surgery as defined by time of start of anesthesia, day of week, region of the United States, facility volume (1000 or fewer DCs versus more than 1000 DCs per year), setting (urban versus rural), and facility type. A retrospective review of 10-year trends in general anesthesia for cesarean delivery at a university hospital: the impact of a newly launched team on obstetric anesthesia practice. A clinical database regarding the care and management of obstetric anesthesia was retrospectively analyzed for 10 calendar years, from January 1, 2010, to December 31, 2019. Medical records of all parturients who received GA to determine indications for cesarean section requiring GA, whether elective, urgent, or emergency were selected Urgent cases in the present study were defined as corresponding to a category 1 cesarean

section described in the National Institute for Health and Clinical Excellence guidelines. An interrupted time series analysis was used to assess the impact of our obstetric anesthesia team launch on our practice after 2015. Quarterly trends in the proportion of GA cases were analyzed to ensure an adequate number of points in time before and after the procedure. Residual autocorrelation was tested using the Durbin-Watson test. The two-sided P value < 0.05 was determined to be statistically significant.

3.2. Study Population

This prospective cohort study was conducted at the Clinic of Gynecology and Obstetrics, Clinical Center "Dragisa Misovic-Dedinje", Belgrade, Serbia. Each patient gave informed consent before surgery. Full-term patients (37 - 42 weeks of gestation), with ASA II score (American Society of Anesthesiologists score—a subjective assessment of a patient's general health ranging from I to V), who delivered by cesarean section, were included in the study. The type of anesthesia used for cesarean delivery was determined based on the anesthesiologist's judgment or patient preference. Both scheduled and urgent cesarean sections were included in the study.

3.3. Anesthetics Protocols

The anesthesiologist monitored non-invasive blood pressure, electrocardiogram, and pulse oximetry for all patients during the procedure. Before the induction of anesthesia, every patient received Ringer lactate solution (500 mL).

GEA protocol: After the adequate preoperative preparation for the cesarean section, and before the induction in GEA, patients were adequately positioned to avoid aortocaval compression and its effect on hemodynamics. We placed a high-flow peripheral line and, in case of potential massive bleeding, several venous lines. Non-invasive basic monitoring included blood pressure measurement, ECG monitoring, pulse oximetry, and capnography. We performed preoxygenation to increase the oxygen reserve in the lungs during apnea (inhalation of 100% oxygen for two minutes, which provides more than 95% complete preoxygenation in pregnant women). After preoxygenation, we started administering the induction drug propofol in a dose of 2.3 mg/kg intravenously. As a muscle relaxant for induction, we used succinylcholine (a depolarizing muscle relaxant for rapid induction in a dose of 1.5 mg/kg). Laryngoscopy was performed using direct laryngoscopes or video laryngoscopes. Smaller diameter tubes with inner diameter of 6 - 7 mm were placed. After induction and intubation, anesthesia was maintained with a mixture of inhalational anesthetic gases and oxygen. Nitric oxide, which serves to maintain GEA, was made up 50% of the pre-extraction mixture and 67% of mixture after the baby was extracted. In cases of emergencies and fetal endangerment, 100% oxygen mixed with sevoflurane was applied until the moment of extraction. Sevoflurane was applied in dose of 0.6 MAC-A so that it would have no effect on the relaxation of the uterus and the occurrence

of atony. Fentanyl 3 μ/kg and rocuronium 0.5 mg/kg were applied after baby extraction and umbilical cord clamping for placenta extraction. After surgery, the neuromuscular block reversal was performed with a mixture of prostigmine and atropine. We did not use sugammadex in any patient. After careful planning and preparation, extubation was performed in a fully awake patient who responded to voice commands, maintained adequate blood oxygen saturation, and had satisfactory respiratory volume and protective reflexes. Postoperative monitoring was mandatory. Ø Spinal anesthesia (SA) protocol: The spinal anesthetic (SA) was induced by hyperbaric bupivacaine 12 mg and fentanyl 0.01 mg. After the spinal injection, blood pressure was measured every minute for the first 10 min and then every 3 min until the end of the procedure. By protocol, any reduction in systolic pressure by at least 10% from preoperative pressure or below 100 mmHg would be treated with intravenous ephedrine (3 - 6 mg). Ø Epidural anesthesia (EA) protocol: After the insertion of the epidural catheter and the application of the test dose, isobaric bupivacaine 0.5% (0.5 mg per 10 cm height) and fentanyl 0.05 mg were injected. Removal of the epidural catheter was performed 24 h after its placement. Epidural catheter was used only in patients where cesarean section was performed under EA and a combined SA-EA approach was not used. In the recovery room, the patients stayed for an hour after the cesarean section. A non-invasive blood pressure, heart rate, and pulse oximetry measurement was taken every 15 min for the first hour, and every 30 min for the second hour, within the postoperative observation area. Details regarding noninvasive measurements have been described in detail elsewhere. Postoperative pain therapy was managed by multimodal approach using intravenous analgesics. All patients received 1 mg/kg of diclofenac every 8 h for 24 h after surgery. In addition, intravenous diclofenac was available upon request without a time limit if patients reported inadequate analgesia via epidural catheter; however, there was a restriction on the total dose, as recommended by the manufacturer. GEA patients received Tramadol 100 mg and, in addition, Acetaminophen 1 gr optionally every 8 h for 24 h after surgery. Tramadol was received by 98% of GEA patients (280/284), and Acetaminophen was received by 78.5% of GEA patients (223/284), in contrast to no RA patients who received Tramadol/Acetaminophen (0/249).

4. Results

During the study period, 864,058 cases of cesarean delivery were identified; of these, 60,502 (7.00%) were completed under general anesthesia (**Figure 2**). After excluding 398,044 cases with accepted indications for general anesthesia, the final study population consisted of 466,014 cesarean deliveries, of which 26,431 cases (5.67%) were completed under general anesthesia with no recorded clinical indication.

The hospital annual proportion of women who received neuraxial techniques during labor and vaginal deliveries and the temporal trends in the utilization of

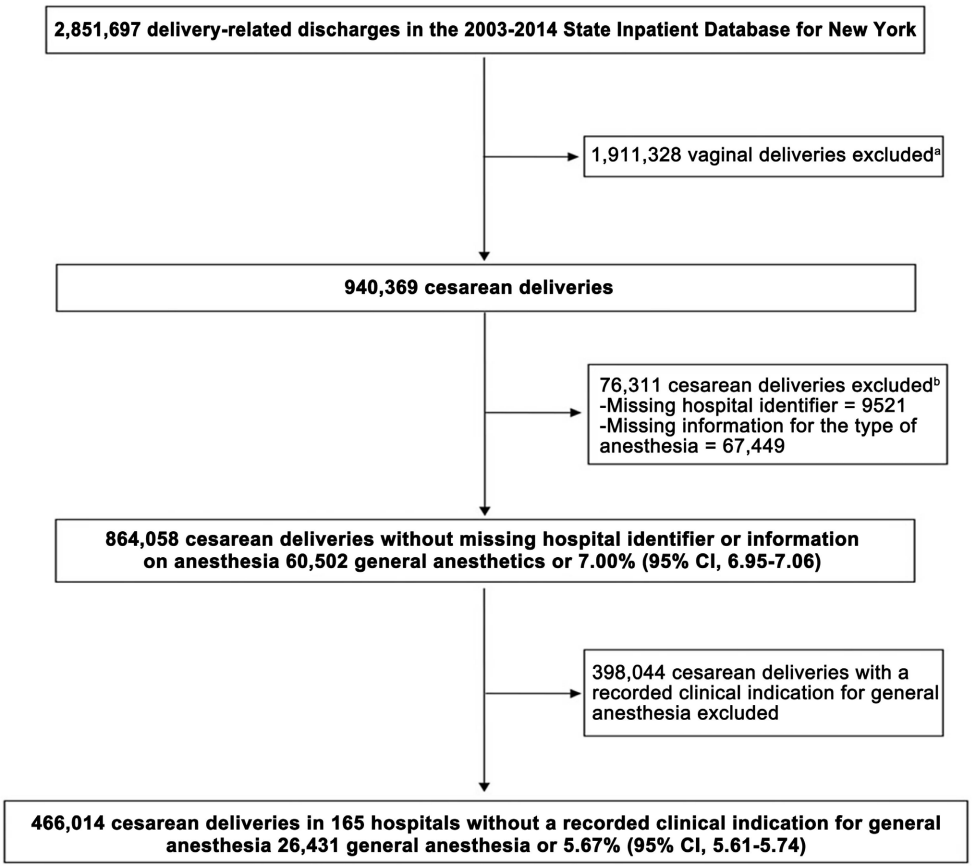

Figure 2. Flowchart of the study.

neuraxial techniques during labor and vaginal deliveries were calculated in these discharges b Does not round up

When comparing excluded cases (Patients with clinical indication for general anesthesia) with cases without a recorded clinical indication, the rate of general anesthesia was higher in discharges with clinical indication for general anesthesia (8.56% versus 5.67%; $P < 0.001$). Adverse event rates 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 indication) (Table 2), comparison of cesarean delivery discharges with and without a recorded clinical indication for general anesthesia.

4.1. Risk of Serious Adverse Events Associated with General Anesthesia

H The serious adverse complications associated with general anesthesia without clinical indication recorded before and after adjustment is presented in Table 3. After adjustment, general anesthesia was associated with a significant increased risk of anesthesia-related complications (overall and severe), surgical site infection, and venous thromboembolic events. It was not associated with an increased

Table 2. Adverse event rates in discharges with and without a 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[a]
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	2345 (58.9 per 10,000)	2757 (59.2 per 10,000)	0.89
Severe anesthesia-related complications (missing = 4)[b]	341 (8.6 per 10,000)	117 (2.5 per 10,000)	<0.001
Surgical site infection	4226 (106.2 per 10,000)	3154 (67.7 per 10,000)	<0.001
Venous thromboembolic events	710 (17.8 per 10,000)	342 (7.3 per 10,000)	<0.001

Table 3. Adverse complications associated with general anesthesia without clinical indication recorded before and after adjustment.

	Neuraxial anesthesia (N = 439,583)	General anesthesia (N = 26,431)	Crude OR (95% CI)	P-value[a]	Adjusted OR[b] (95% CI)	P-value[a]
Death or cardiac arrest (missing = 2)	27 (0.6 per 10,000)	--[c]	--[c]	0.096	2.44 (0.67 - 8.93)	0.18
Anesthesia-related complications	2540 (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[d] (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	2812 (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

Abbreviations: CI: confidence interval; OR: odds ratio. Results are expressed as count (per 10,000 of discharges with neuraxial or general anesthesia). [a]The P-value for statistical significance is 0.01. [b]Adjustment using propensity score weighting. [c]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. [d]Complications associated with death, cardiac arrest, severe organ dysfunction, or hospital stay ≥ 99th percentile (7 days).

risk of mortality or cardiac arrest. The results were unchanged in the 2 sensitivity analyses examining various cutoff values for the comorbidity index for obstetric patients and the Charlson comorbidity index.

4.2. Risk Factors for General Anesthesia Use

The following patient-level factors were associated with a significantly increased likelihood of potentially avoidable general anesthesia: age less than 19 years, racial or ethnic minority, Medicaid or Medicare recipients, preexisting or pregnancy-associated conditions, nonelective admission, and weekend admission.

Hospital factors associated with a significantly increased likelihood of general anesthesia were: 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. Compared with hospitals with a rate of neuraxial labor analgesia ≥ 75%, the adjusted odds ratios of potentially avoidable general anesthesia increased to 1.35, 1.60, and 3. NACOR provided 287,127 CDs from a total of 26,568,734 patients from January 2010 to March 2015. After excluding CD cases with unknown primary anesthesia type, the sample size was 218,285, with 205,671 (94.2%) cases performed under NA and 12,614 (5.8%) cases performed under GA. A total of 308 different hospital facilities contributed cases to this cohort, with a range of 1 to 14,385 cases reported per facility. A total of 15,282 emerging CD cases were identified, of which 13,046 (85.4%) cases were performed under NA and 2,236 (14.6%) cases under GA. The temporal and total use of GA is represented in Figure 3.

Patient and Facility Characteristics Presented by NA or GA Selection for All CDs (Table 4 and Table 5).

The annual number of cesarean deliveries increased during 2010-2019 at this institution, in parallel with the increase in the total number of deliveries (Figure 4). The proportion of cesarean deliveries remained relatively high throughout the years covered by the study, ranging from 29.2% to 34.9% with a gradual increase over time.

4.3. General Anesthesia for Cesarean Delivery

In 2014, more than about 10% of cesarean deliveries were performed under GA, with an annual number of 27 - 39 cases, peaking in 2011 at 39 cases. Since 2015,

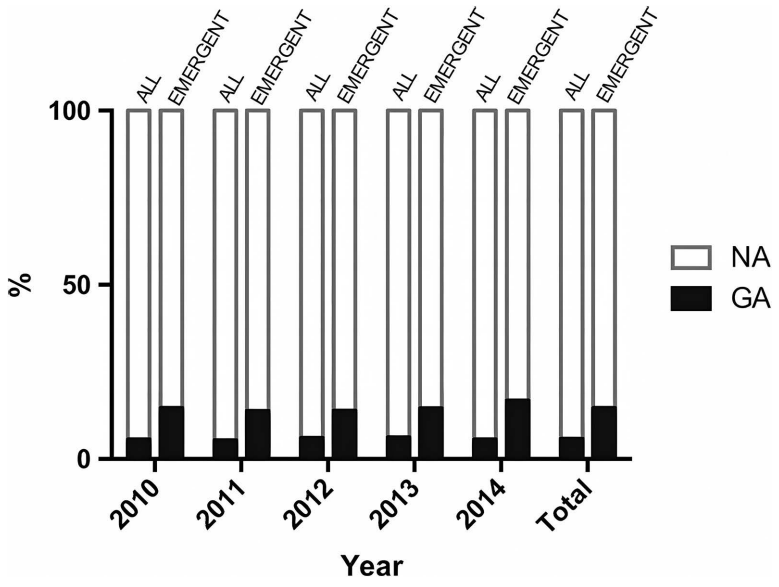

Figure 3. Percentage of all cesarean deliveries and emergent cesarean deliveries performed under general anesthesia versus those performed under neuraxial anesthesia by year.

Table 4. Results of a univariate and multivariate logistic regression model determining association of patient and facility factors with the use of NA versus GA as primary anesthetic for all CDs.

	NA		GA	
	N	**%**	**N**	%
Total	205,671	94.22	12,614	5.78
Age				
Mean age (±SD)	30.02 ± 5.95		29.26 ± 6.30	
≤18 years	3319	1.61	366	2.90
19 - 34 years	154,092	74.92	9502	75.33
≥35 years	48,260	23.46	2746	21.77
ASA PS class				
ASA I-II	176,836	85.98	8983	71.21
ASA III-V	28,835	14.02	3631	28.79
Time of day				
Day shift (7:00 AM - 5:00 PM)	141,901	68.99	7177	56.90
After hours (5:01 PM - 6:59 AM)	63,770	31.01	5437	43.10
Time of week				
Weekday	176,812	85.97	10,230	81.10
Weekend	28,859	14.03	2384	18.90
Urban versus rural				
Urban	73,948	35.95	4229	33.53
Rural	114,278	55.56	7030	55.73
Unknown	17,445	8.48	1355	10.74
Facility type				
University hospital	18,088	8.79	1685	13.36
Large community	45,204	21.98	2196	17.41
Medium-sized				
Community	81,514	39.63	5543	43.94
Other facility	46,980	22.84	2690	21.33
Unknown facility	13,885	6.75	500	3.96
United States region				
Northeast	42,729	20.78	2515	19.94
Midwest	40,729	19.80	2628	20.83
South	81,869	39.81	5802	46.00
West	26,406	12.84	1169	9.27
Unknown region	13,938	6.78	500	3.96
CD volume per year				
Volume ≤ 1000	149,312	72.60	9301	73.74

Continued

Volume > 1000	56,359	27.40	3313	26.26
Emergency status				
Not emergency	192,625	93.66	10,378	82.27
Emergency	13,046	6.34	2236	17.73
TOLAC				
Not TOLAC	204,342	99.35	12,588	99.79
TOLAC	1329	0.65	26	0.21
Year of CD				
2010	26,397	12.83	1668	13.22
2011	32,728	15.91	1965	15.58
2012	44,516	21.64	2912	23.09
2013	40,028	19.46	2618	20.75
2014	55,162	26.82	3127	24.79
2015	6840	3.33	324	2.57

Abbreviations: ASA PS, American Society of Anesthesiologists Physical "Status; CD, cesarean deliveries; GA, general anesthesia; NA, neuraxial anesthesia; TOLAC, Trial of Labor after Cesarean Delivery".

Table 5. Results of a univariate and multivariate logistic regression model determining association of patient and facility factors with the use of NA versus GA as primary anesthetic for all CDs.

	Univariable Analysis		Multivariable Analysis	
All Cesarean Deliveries	**OR (95% Cl)**	**P Value**	**OR (95% Cl)**	**P Value**
Age				
≤18 years old	1.79 (1.60 - 2.00)	<0.0001	1.62 (1.45 - 1.82)	<0.0001
19 - 34 years old	Reference		Reference	
≥35 years old	0.92 (0.88 - 0.96)	0.0003	0.91 (0.87 - 0.95)	<0.0001
ASA PS class				
ASA I - II	Reference		Reference	
ASA I - V	2.48 (2.38 - 2.58)	<0.0001	2.34 (2.24 - 2.43)	<0.0001
Time of day				
Day shift (07:00 - 17:00)	Reference		Reference	
After hours (17:01 - 06:59)	1.69 (1.63 - 1.75)	<0.0001	1.42 (1.37 - 1.48)	<0.0001
Day of week				
Weekday	Reference		Reference	
Weekend	1.43 (1.36 - 1.50)	<0.0001	1.24 (1.19 - 1.31)	<0.0001
Urban versus rural				
Urban	Reference		-	
Rura	1.08 (1.03 - 1.12)	0.0003		
Unknown	1.36 (1.27 - 1.45)	<0.0001		

Continued

Facility type				
University hospital	Reference		Reference	
Large community	0.52 (0.49 - 0.56)	<0.0001	0.49 (0.46 - 0.53)	<0.0001
Medium-sized community	0.73 (0.69 - 0.77)	<0.0001	0.76 (0.72 - 0.81)	<0.0001
Other facility	0.61 (0.58 - 0.65)	<0.0001	0.67 (0.63 - 0.72)	<0.0001
Unknown facility	0.39 (0.35 - 0.43)	<0.0001	0 (0 to ∞)	0.85
US region				
Northeast	Reference		Reference	
Midwest	1.10 (1.04 - 1.16)	0.0014	1.25 (1.17 - 1.33)	<0.0001
South	1.20 (1.15 - 1.26)	<0.0001	1.34 (1.27 - 1.41	<0.0001
West	0.75 (0.70 - 0.81)	<0.0001	0.77 (0.71 - 0.83)	<0.0001
Unknown region	0.61 (0.55 - 0.67)	<0.0001	0 (0 to ∞)	0.84
CD volume per year				
Volume ≤ 1000	Reference			-
Volume > 1000	0.94 (0.91 - 0.98)	0.0054	-	-
Emergency status				
Not emergency	Reference		Reference	
Emergency	3.18 (3.03 - 3.34)	<0.0001	2.96 (2.81 - 3.12)	<0.0001
TOLAC				
Not TOLAC	Reference		Reference	
TOLAC	0.32 (0.22 - 0.47)	<0.0001	0.31 (0.21 - 0.46)	<0.0001
Year of CD				
2010	Reference		Reference	
2011	0.95 (0.88 - 1.02)	0.1360	0.92 (0.86 - 0.99	0.02
2012	1.04 (0.97 - 1.10)	0.2700	1.00 (0.94 - 1.06)	0.96
2013	1.04 (0.97 - 1.10)	0.2900	0.99 (0.93 - 1.06	0.82
2014	0.90 (0.84 - 0.95)	0.0005	0.88 (0.82 - 0.94)	<0.0001
2015	0.75 (0.66 - 0.85)	<0.0001	0.74 (0.65 - 0.84)	<0.0001

ORs with associated 95% Cls are provided for each category with associated reference variable, noted under the Reference column. An OR with 95% Cl not including 1.00 is considered statistically significant. P values are a result of x^2 analysis for categorical variables, and Student t test for continuous variables. P < 0.0001 is considered statistically significant. Abbreviations: ASA PS, American Society of Anesthesiologists Physical Status; CD, cesarean delivery; Cl, confidence interval; OR, odds ratio; TOLAC, trial of labor after cesarean delivery; US, United States.

however, there has been a steady decline in the number of cesarean sections requiring GA to 15 in 2019. As a percentage, GA administration peaked at 14.5% in 2012 but has trended downward, decreasing to less than 5% in 2019 (**Figure 5**). Elective and urgent cesarean deliveries accounted for the majority of all GA cases until recently.

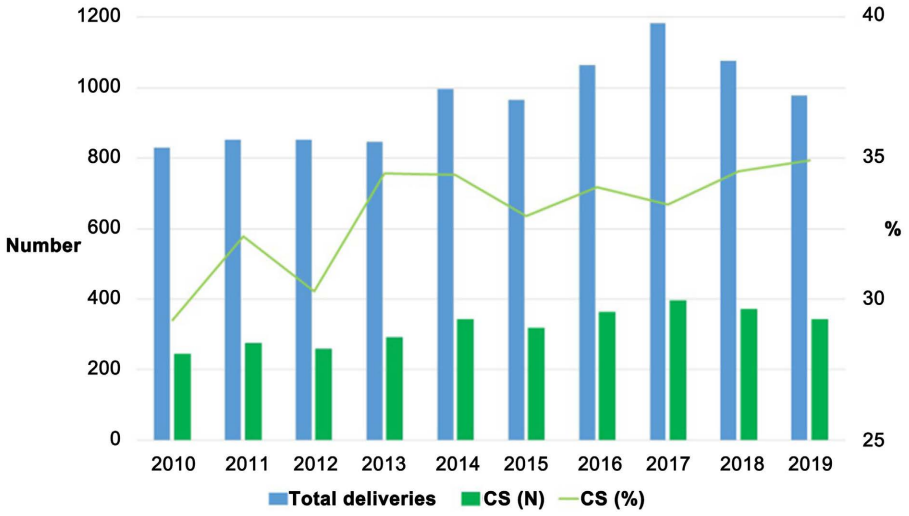

Figure 4. Yearly change in the total number of all deliveries and cesarean deliveries (%) in the years from 2010 to 2019.

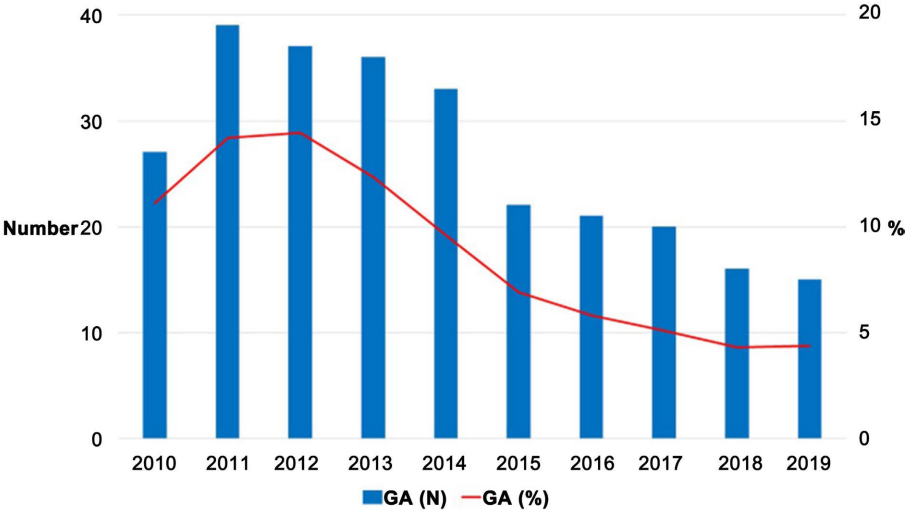

Figure 5. Yearly change in the number and percentage of cesarean deliveries that required general anesthesia.

There has been an upward trend in the number of women with placental anomalies at our institution, exceeding 20 per year. GA was chosen for pregnancies with placenta previa in the years 2010-2014, at a time when placenta previa was the main indication for elective and urgent cesarean sections, with proportions ranging from 47.2% to 78.3%. However, the annual number of parturients with placenta previa who received GA for elective or urgent cesarean section was declining (**Figure 6**), representing 28.6% of elective and emergent cases in 2019. During the study period, the median blood loss in cesarean deliveries for placenta previa was 1920 ml with an interquartile range (IQR) of 1423 to 2896 ml, although there were 9 sporadic cases with blood loss greater than 4000 ml (**Figure 7**). Despite these cases of massive hemorrhage, the use of obstetric GA has been declining in recent years.

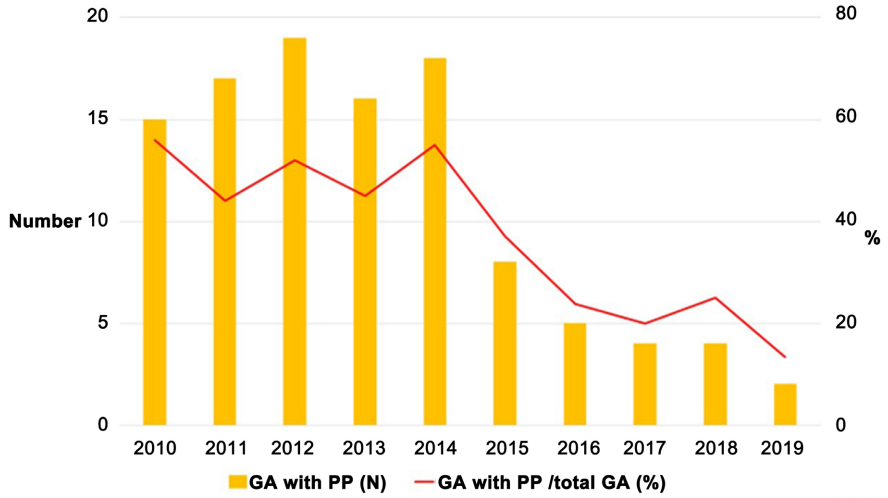

Figure 6. The number and percentage of parturients with placenta previa who received general anesthesia for elective or emergent cesarean delivery in 2010-2019.

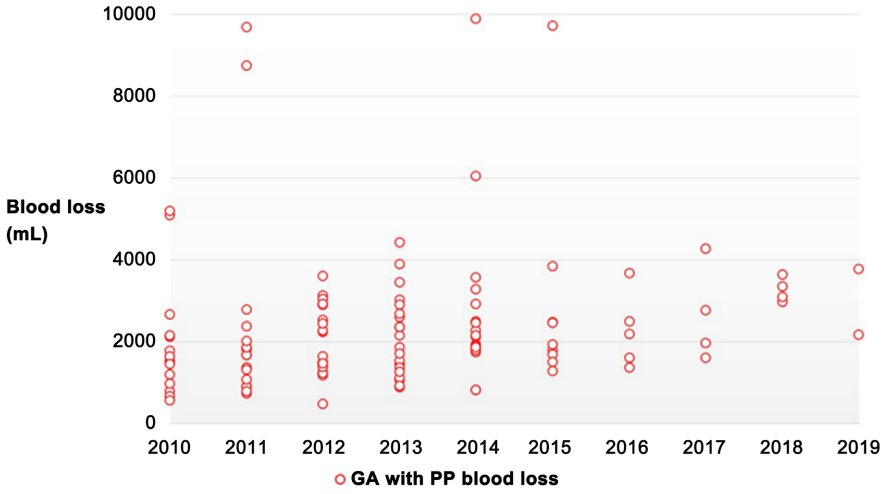

Figure 7. Blood loss during cesarean delivery under general anesthesia in parturients with placenta previa.

4.4. Urgent Cesarean Delivery

In contrast to the substantial decrease in elective and urgent cases, we experienced a somewhat variable but not decreasing number of urgent caesarean sections each year (Figure 8). Overall, the non-reassuring fetal condition was responsible for many urgent cases. The decision-to-delivery interval (DDI) was different depending on the case, with a median value of 19 min (IQR 15 - 25 min) in the years 2010-2019.

4.5. Neuraxial Anesthesia for Pregnancy with Placenta Previa

Recently, we have adopted the use of neuraxial anesthesia over GA for pregnancy with placenta previa. A total of 75 women with placenta previa without suspected placenta accreta (63 elective and 12 emergent) received neuraxial anesthesia for cesarean delivery in 2016-2018. The use of combined spinal-epidural

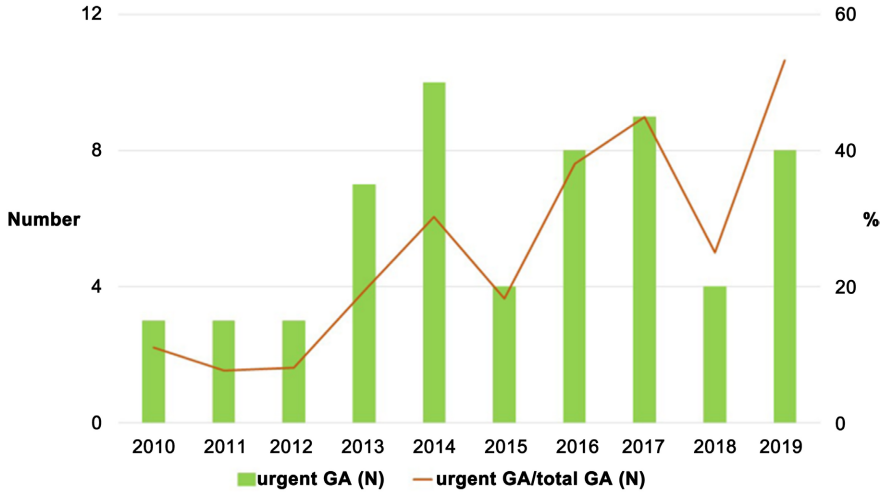

Figure 8. The number and percentage of urgent cesarean deliveries that required general anesthesia in 2010-2019.

anesthesia comprised the majority of these cases (88.0%). Internal iliac artery balloon catheters were placed in 6 cases prior to elective cesarean delivery.

During the same period, GA was administered in 13 women with placenta previa (9 elective and 4 emergent). The 9 parturients scheduled for elective cesarean delivery had preoperative placement of internal iliac artery balloon catheters. Total hysterectomy was additionally performed in 5 of the 13 cases. The average amount of intraoperative blood loss was 1729 ± 686 mL in 75 cases performed under neuraxial anesthesia, and 2682 ± 878 mL in 13 cases performed under GA.

4.6. Mortality and Morbidity

We observed no anesthesia-related mortality during the entire study period. There was one case of amniotic fluid embolism associated with disseminated intravascular coagulation, which was followed by intraoperative massive hemorrhage. This case required emergent use of extracorporeal membrane oxygenation during the surgery. No case of difficult intubation was identified in which more than three attempts at laryngoscopy were made. We recorded 19 cases where the lowest oxygen saturation (SpO_2) was below 90% following the rapid sequence induction of GA, but the total duration of desaturation was less than 1 min in every case. During the 10-year period, the parturients who received GA for cesarean delivery, including the one with amniotic fluid embolism, were discharged without any anesthesia-related morbidity.

This study included 533 patients who delivered by cesarean section. GEA was performed for 284 deliveries, whereas RA was performed for 249 (SA for 162 and EA for 87). The mean age in the GEA group was 32.4 ± 4.5, whereas in the RA group the mean age was 31.7 ± 4.8. Patients who underwent cesarean section under GEA had a gestational age of 38.4 ± 1.23 compared with 38.5 ± 1.35 in the RA group. Caesarean section was classified as an emergency in 56 patients

(19.7%) in the GEA group versus 57 (22.9%) in the RA group. Age, gestational age, education level, and type of cesarean section did not differ between the groups.

As measured by Cronbach's alpha, the SF-MPQ showed excellent reliability in all three measures, 0.943, 0.905, and 0.915 at 2, 12, and 24 h, respectively. The Cronbach's alpha of the entire scale was 0.863, indicating the reliability of the scale. Significant differences were found in the sensory and affective characteristics of postoperative pain between the two types of anesthesia in intervals of 2, 12, and 24 h after cesarean section ($p < 0.001$ for all respective intervals), with the GEA group having higher postoperative sensory and affective pain levels. Pain characteristics represented by the VAS scale showed significant differences regarding the type of anesthesia in all intervals assessed after cesarean section ($p < 0.001$ for all respective intervals), with the GEA group having higher postoperative VAS pain levels. A Pearson correlation coefficient greater than 0.8 showed a strong correlation between the SF-MPQ and VAS for all three measures. The two groups differed on the intensity of the pain attributes scale, with the GEA group having higher postoperative pain levels in intervals of 2, 12, and 24 h after cesarean section ($p < 0.001$).

In the GEA group, 86.3% of women established lactation 36 to 48 h after cesarean delivery, in contrast to the RA group, where 56.2% and 28.9% of women established lactation after 18 and 24 h, respectively. In the GEA group, 95.8% of women had their first peroral intake 24 to 36 h after birth, in contrast to the RA group, where 86.7% of women had a peroral intake after 18 h. In addition, the GEA application allowed 85.9% of women to take their first independent mobilization 24 to 48 h after surgery, in contrast to the RA group, where 29.7% of patients established their first independent mobilization after 12 h, and 50.6% of them after 18 h (**Figure 9**).

5. Discussion

In this 12-year study, the risks, temporal trends, and risk factors for potentially avoidable general anesthesia in cesarean delivery were analyzed. The main findings were as follows: 1) A high proportion of potentially avoidable general anesthesia among all cases of general anesthesia (44%); 2) A decrease over time in cases of potentially avoidable general anesthesia, except among minority women and in high-volume hospitals; 3) A significant increase in the risk of serious adverse events when cesarean section was performed under general anesthesia compared to neuraxial anesthesia; 4) Several patient and hospital-level factors associated with potentially avoidable general anesthesia, some of which are directly actionable.

Contrary to previous studies, we did not find evidence of an elevated risk of death or cardiac arrest associated with general anesthesia compared to neuraxial anesthesia [11]. This apparent discrepancy can be explained by our exclusion criteria, which removed cases with severe comorbidities and high-risk obstetric

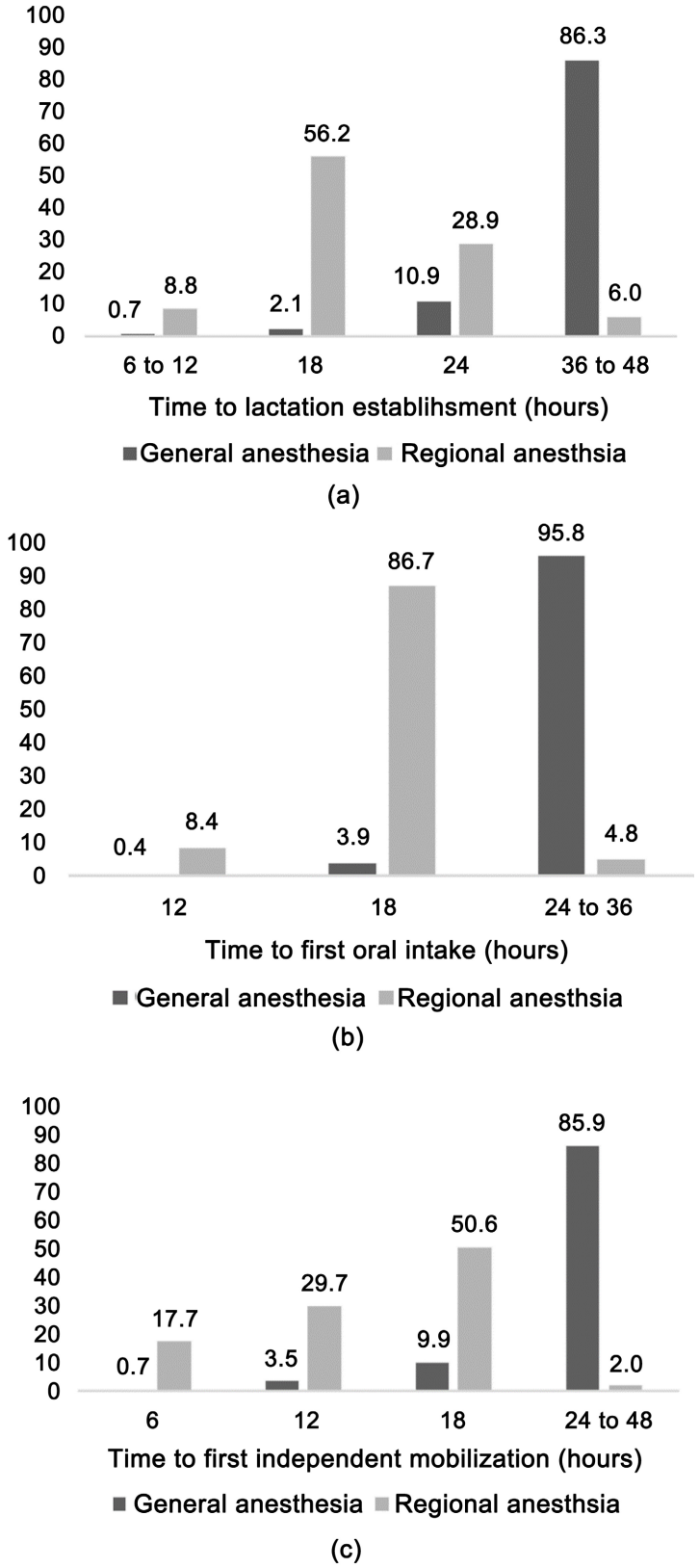

Figure 9. (a) Time to lactation establishment in hours according to anesthesia type; (b) Time to first oral intake in hours according to anesthesia type; (c) Time to first independent mobilization in hours according to anesthesia type.

situations (Charlson comorbidity index ≥ 2 or comorbidity index for obstetric patients ≥ 3). These conditions are strongly linked to the risk of near-miss maternal morbidity or mortality [12]. However, we did observe a significantly higher risk of anesthesia-related complications (both overall and severe) and surgical site infections. This supports previous research highlighting the risks associated with general anesthesia for cesarean delivery and expands the findings to include cases of potentially avoidable general anesthesia.

There are several suggested mechanisms that explain the lower risk of surgical site infections associated with neuraxial techniques. These mechanisms include a reduced inflammatory response to surgery, improved tissue oxygenation resulting from vasodilation induced by neuraxial techniques, and enhanced postoperative analgesia leading to a decrease in pain-related autonomic response and subsequent vasoconstriction. Additionally, our study extends previous findings by demonstrating an association between neuraxial techniques and a decreased risk of venous thromboembolic events in cesarean deliveries [13].

5.1. Patient-Level Factors Associated with General Anesthesia

Our findings support previous studies regarding patient-level factors that are associated with a higher likelihood of general anesthesia. These factors include younger age, belonging to a minority group, being a Medicaid beneficiary, having preexisting or pregnancy-associated conditions, being admitted during weekends, and having a non-elective admission. While addressing some of these factors may pose challenges, there are potential areas for intervention, such as focusing on younger maternal age and addressing the issue of weekend admissions [10]. These findings suggest that targeted actions in these areas could contribute to reducing the use of general anesthesia in cesarean deliveries.

The increased use of general anesthesia in women admitted during the weekend may be attributed to the phenomenon known as the "weekend effect", where patients admitted on Saturdays or Sundays experience worse outcomes. This effect could be influenced by differences in patient case-mix and suboptimal quality of care resulting from reduced staffing or the presence of less experienced providers [14]. A 2015 survey of obstetric anesthesia directors in academic centers revealed that up to 60% of hospitals lack an in-house dedicated team for the labor and delivery unit during weekends, indicating changes in staffing composition and potential differences in experience levels [15].

5.2. Hospital-Level Factors Associated with General Anesthesia

Our study revealed a significant association between lower rates of labor epidural analgesia and higher rates of general anesthesia for cesarean delivery in certain hospitals. However, determining the exact mechanisms behind this relationship using administrative data alone is challenging. There are a couple of possible explanations that could shed light on this observation.

One explanation is that in hospitals with lower rates of labor epidural analgesia, anesthesia providers may have limited experience and expertise in administering epidurals. Consequently, they may prefer to opt for general anesthesia for cesarean deliveries. Another explanation could be the lack of availability of a dedicated anesthesia team specifically for obstetric anesthesia care. The low epidural analgesia rate could be a surrogate marker indicating the absence of 24/7 anesthesia services, which increases the likelihood of general anesthesia being chosen for both urgent and less urgent cesarean deliveries. In other words, the labor epidural analgesia rate might reflect not only clinician experience but also the physical presence and involvement of anesthesia providers on the labor and delivery unit, as well as the intensity of services provided [16].

Since the use of general anesthesia without a clinical indication was associated with a higher risk of adverse events, this finding emphasizes the importance of targeting quality assurance programs towards hospitals with low utilization of neuraxial techniques. One potential intervention could involve developing dedicated staffing for the labor and delivery unit. By being free from duties outside of this unit, dedicated anesthesia teams could enhance the intensity and quality of services provided, potentially leading to increased utilization of neuraxial techniques and a reduction in the need for general anesthesia during cesarean deliveries.

The overall rate of general anesthesia (GA) usage for cesarean deliveries (CDs) across the nation constituted a small proportion (5.8%) of the total anesthesia procedures. Among different types of facilities, university hospitals had the highest rate of GA usage (8.5%), which was unexpected considering previous publications from a single university hospital reported rates ranging from 0.4% to 1% between 2000 and 2005 [17].

The rate of GA usage during emergent CDs reported in the NACOR dataset was 14.5%, which aligns with more recent findings from the obstetric anesthesia workforce survey 2. Notably, the 30-year update from the workforce survey indicated a slight increase in emergent GA use from 15% to 19%. However, the statistical significance of this rate increase was not discussed in that particular article.

Although NACOR aims to capture basic data from approximately 25% of all anesthesia cases in the United States in 2015, the number of cesarean delivery (CD) cases included in the study (287,127) seems to represent a small fraction of the estimated total CD cases performed in the country during the same period (6.8 million) [18]. The annual number of CD cases in NACOR more than doubled between 2010 and 2014, indicating evolving reporting practices. These observations suggest that while the NACOR data provide insights into subsets of data elements associated with higher rates of general anesthesia (GA) usage, the statistical analysis can only be considered illustrative, as the sample collected by NACOR continues to expand. However, one reassuring observation is that the derived rate of emergent GA in the NACOR dataset is consistent with findings

from the obstetric anesthesia workforce survey conducted in the previous decade [19].

There are several methodological limitations that should be discussed. Firstly, the NACOR database does not allow us to differentiate between cases where general anesthesia (GA) is used due to the failure of neuraxial anesthesia (NA), which can vary significantly between institutions (ranging from 2% to 20%) [20]. Additionally, NACOR does not provide information on whether neuraxial anesthesia initially placed for vaginal deliveries that were subsequently converted to cesarean deliveries is distinguished from de novo placement of neuraxial anesthesia for cesarean deliveries. As a result, the relationship between institutional characteristics and the use of GA may be confounded by the relative contributions of elective cesarean deliveries and unplanned cesarean deliveries at each institution.

5.3. Main Findings

During our review of obstetric anesthesia practice at our institution from 2010 to 2019, we observed a significant decline in the use of general anesthesia (GA) for cesarean deliveries, particularly in the most recent five years. This reduction in GA usage was accompanied by a decrease in the number of parturients with placenta previa who required GA for cesarean delivery. However, it is important to note that there were still situations where the use of urgent GA for cesarean delivery was unavoidable in unplanned scenarios. This highlights the continued importance of GA throughout the study period, despite the overall decrease in its utilization.

5.4. Impact of the Launch of Our Obstetric Anesthesia Team on Clinical Practice

In 2011, the establishment of the Perinatal Center marked a significant milestone in our institution. Two years later, in 2013, one of our staff anesthesiologists began specializing in obstetric anesthesia. Subsequently, in 2015, our obstetric anesthesia team was launched, serving as a catalyst for collaborative discussions with obstetricians and opening up opportunities for practice improvement.

Through these initiatives, we successfully identified pregnant women with specific risk factors prior to cesarean delivery, leading to a reevaluation of the indications for general anesthesia (GA) in obstetric practice. We shifted our approach to reserving GA primarily for parturients with placenta accreta, a condition associated with a high risk of massive hemorrhage, prolonged operating times, and the need for complex surgical procedures. This strategic change played a significant role in the reduction of GA administration for cases of pregnancy with placenta previa.

Overall, there has been a declining trend in the use of GA in obstetric practice as neuraxial anesthesia for cesarean delivery has gained popularity. However, controversies and variations among institutions still exist regarding the pre-

ferred anesthetic technique for cesarean delivery complicated by placenta previa [21]. To optimize patient care and minimize GA-related complications, our current clinical practice promotes the use of neuraxial techniques for parturients without abnormally invasive placentation, aligning with evidence demonstrating the feasibility of neuraxial anesthesia in cases of placenta previa [22] [23].

In contrast to the past, when GA was almost the sole option for pregnancies with placenta previa, we now reserve GA for parturients with a high risk of hemorrhage, who have been prenatally diagnosed with placenta accreta with a high level of certainty. This change in strategy is supported by findings indicating higher intraoperative blood loss in GA cases. Our refined approach significantly contributes to optimizing the selection of cesarean deliveries that warrant the use of GA.

5.5. Activities of the Obstetric Anesthesia Team

Since its establishment in 2015, our obstetric anesthesia team has played a crucial role as a communication bridge between the departments of anesthesiology and obstetrics. The team comprises a dedicated leader and multiple members who rotate their presence in the obstetric ward on weekdays, providing assistance to obstetricians in administering epidural anesthesia for labor and delivery. Additionally, the team members participate in a weekly multidisciplinary conference alongside obstetricians and neonatologists. During these meetings, detailed information on parturients with comorbidities is shared, including the current physical status of the individual, the preferred method and timing of delivery, and the appropriate choice of anesthetic technique, taking into consideration both maternal and neonatal outcomes. This regular exchange of information ensures that team members are updated on the latest medical conditions of high-risk parturients.

In close collaboration with the department of obstetrics, the team leader takes part in clinical assessments for all women undergoing elective cesarean delivery. Obstetricians are encouraged to consult with the leader regarding parturients scheduled for vaginal delivery with maternal or fetal complications, should they require support from the obstetric anesthesia team. Through discussions with the parturient and obstetricians in outpatient settings, the team leader establishes clear guidelines in advance regarding the preferred type of anesthetic technique for scheduled cesarean deliveries. This newly implemented system has proven beneficial, even in cases of emergency cesarean deliveries, as it facilitates a rapid understanding of the parturient's medical condition and challenges.

5.6. Current Trends and Future Concerns

Throughout the duration of the study, instances of difficult intubation were not frequent among the 267 parturients who received general anesthesia. In 19 cases, the minimum peripheral oxygen saturation (SpO_2) dropped below 90%, but there were no prolonged periods of oxygen desaturation following the induction

of general anesthesia. It is worth noting that our institution is committed to medical residency education, and as part of the training process, the first attempt at laryngoscopy was performed by a resident anesthesiologist.

However, ensuring sufficient opportunities for training in obstetric general anesthesia remains a concern. Some studies have highlighted the limited clinical experience that trainee anesthesiologists may have with administering general anesthesia for cesarean delivery, as the use of general anesthesia in obstetric practice has been largely replaced by the widespread adoption of neuraxial techniques [24]. The observed decline in the number of cesarean deliveries performed under general anesthesia could potentially lead to a lack of exposure to obstetric general anesthesia during residency training. This situation becomes even more critical considering that anesthesia providers at our institution are regularly faced with unpredictable cases that require the urgent administration of general anesthesia. It is crucial to raise awareness about the importance of maintaining skills in obstetric airway management.

In this study, the effects of regional anesthesia (RA) and general epidural anesthesia (GEA) were compared in terms of postoperative analgesic requirements and pain relief in women undergoing cesarean section. The findings indicated that GEA resulted in higher levels of postoperative pain as assessed by various pain scales, including the Short-Form McGill Pain Questionnaire (SF-MPQ) and visual analog scale (VAS). On the other hand, RA was associated with faster first independent mobilization and establishment of lactation.

Cesarean section, although not classified as a major procedure, is ranked ninth among various surgical procedures in terms of postoperative pain intensity [25]. The choice of anesthesia plays a significant role in the patient's perception of postoperative pain, recovery time, and care for the newborn. Given the high frequency of cesarean sections, there has been increasing interest in optimizing postoperative pain relief. RA, particularly spinal anesthesia (SA), is the most commonly used type of anesthesia for cesarean sections due to its ease of administration and lower complication rates. Hypotension is the most common complication, which is more frequently observed with SA compared to epidural anesthesia (EA). RA allows the mother to present during the birth of her child and establish immediate contact with the newborn, making it a preferable option.

Previous studies have reported comparable postoperative pain scores between GEA and spinal anesthesia, with some studies showing lower pain scores in the GEA group initially, but the trend reversed in favor of spinal anesthesia after 48 hours [26]. However, our study demonstrated significantly lower pain scores for RA across all assessed time intervals (2 hours, 12 hours, 24 hours). These discrepancies may be attributed to the inclusion of epidural anesthesia in the RA group and variations in the multimodal approaches used for post-cesarean pain relief. Another study also found that GEA and longer procedure durations were independent predictors of higher post-cesarean pain intensity [27].

The use of GEA for cesarean sections has declined significantly in recent years, corresponding to a reduction in anesthesia-related maternal mortality. Certain risk factors, such as severe heart valve stenosis, morbidly adherent placenta, or coagulation factor deficits, necessitate the use of GEA 4. GEA is also preferred for urgent cesarean sections due to its rapid and predictable effects [28]. Urgent conditions, such as placental abruption or umbilical cord prolapse, can increase the rate of GEA in cesarean sections. In our study, urgent cesarean sections accounted for 19.7% of GEA and 22.9% of RA administrations. There is an increasing trend in the use of RA, particularly SA, for emergency cesarean sections, as supported by studies from Italy and the United Kingdom [9]. However, it is recommended that the percentage of general anesthesia for cesarean sections should be kept below 5% according to the Society for Obstetric Anesthesia and Perinatology (SOAP) and the Royal College of Anaesthetists [9].

Effective pain relief after cesarean section is crucial for promoting early recovery and facilitating the mother's ability to care for her newborn. Postpartum pain involves sensory, affective, cognitive, and behavioral components, and adequate pain relief is still inadequate in many cases. Pain after cesarean section often remains under-treated and underestimated due to concerns about potential side effects. Therefore, continuous research is necessary to prioritize maternal and newborn safety and accelerate postoperative recovery and functional activities.

The establishment of lactation after cesarean delivery is a vital aspect of the early postpartum period. Cesarean delivery has been identified as a factor contributing to shorter exclusive breastfeeding duration. The effect of anesthesia type on breastfeeding is unclear, but pain following the procedure is known to impact breastfeeding. Studies have shown that women who underwent cesarean section under GEA experienced more breastfeeding problems compared to those under RA. Opioids administered during GEA can affect the newborn's neurobehavior and hinder the mother's ability to position for breastfeeding [29] [30].

Recent meta-analyses have indicated that early oral feeding after cesarean section is not associated with an increased risk of postoperative complications and supports the return to normal bowel function. Our study showed that women in the GEA group had their first oral intake 24 - 36 hours after birth, while the RA group had peroral intake after 18 hours. Moreover, mobilization was established earlier in the RA group (12 - 18 hours) compared to the GEA group (24 - 48 hours). Early mobilization aims to prevent thrombophlebitis, and systemic complications, and improve blood supply to tissues. Previous studies have also demonstrated better pain management, mobility, and faster recovery in women who underwent cesarean section under RA [31].

6. Conclusion

Understanding the clinical scenario leading to cesarean delivery is crucial for providing safe and effective anesthesia. Several factors contribute to the use of

general anesthesia in cesarean delivery, including patient-specific, obstetric, anesthesia, and provider-related factors.

Patient-specific factors, such as ethnic and socioeconomic disparities, can influence the choice of anesthesia. These factors may impact access to prenatal care, health literacy, and patient preferences. Addressing these disparities through education, improved access to care, and patient-centered communication can help reduce avoidable general anesthesia.

Obstetric factors, including the urgency of the cesarean delivery and preterm birth, may necessitate the use of general anesthesia. Urgent cesarean deliveries require rapid interventions, and in some cases, general anesthesia may be the most appropriate option. Preterm births pose unique challenges, and general anesthesia may be chosen for specific indications or when regional anesthesia is contraindicated.

Anesthesia factors, such as dysfunctional intrapartum neuraxial analgesia, can contribute to the need for general anesthesia. In some cases, complications or limitations of neuraxial analgesia techniques may require a switch to general anesthesia. Ensuring proper training and skills among anesthesiologists, along with continuous education, can help optimize the use of regional anesthesia techniques and reduce the need for general anesthesia.

Provider-specific factors, such as the presence of non-obstetric anesthesiologists, can also influence the choice of anesthesia. Collaborative and effective communication between obstetricians, nurses, and anesthesiologists is crucial to ensure optimal care and decision-making. Incorporating the mother's preferences and involving her in the decision-making process can contribute to a safe and positive childbirth experience.

To improve maternal and neonatal outcomes associated with unavoidable general anesthesia in cesarean delivery, it is essential to focus on ongoing education and training of anesthesiologists to maintain proficiency in obstetric anesthesia. Access to devices and equipment specifically designed for airway management in the obstetric population can facilitate safe anesthesia administration. Optimal communication and teamwork among all providers involved in the care of the mother and baby are vital to ensure a comprehensive and patient-centered approach. By addressing these factors and promoting a multidisciplinary approach, efforts can be made to reduce the need for avoidable general anesthesia and improve overall outcomes in cesarean delivery.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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