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ORIGINAL ARTICLE

Anesthetic and obstetric predictors of general anesthesia in urgent or emergent Cesarean delivery: a retrospective case–control study

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Abstract

Purpose While regional anesthesia (RA) is considered preferable to general anesthesia (GA) for Cesarean delivery (CD), certain situations necessitate GA. This study reviewed the practice patterns around the use of GA for CD to identify modifiable predictors of GA with the goal of reducing GA rates.

Methods This was a retrospective, case–control study. Patients undergoing urgent/emergent CD over a 3-year period were identified, from which 102 patients undergoing GA and 102 patients undergoing RA were randomly selected. The data included patient characteristics, obstetrical indications for CD, type/indication of anesthetic, characteristics of airway management (GA group)/neuraxial anesthesia (RA group), and neonatal outcomes.

Results Abnormal fetal heart rate (aFHR) was the most common obstetrical indication for urgent/emergent CD amongst the cases (39%) and controls (39%). GA administration was most commonly due to "limited time due to maternal/fetal compromise" (56%), followed by "maternal contraindication to RA" (25%) and "inadequate RA" (17%). The most frequent modifiable anesthetic indication for GA was inadequate neuraxial anesthesia (17%). Anesthetic and obstetric predictors for GA included ASA classification [OR 0.11 (0.06–0.21)], emergency code activation [OR 13.55 (1.73–106.40)], failure to progress [OR 0.15 ((0.06–0.36)], labor in a patient scheduled for CD [OR 0.16 (0.05–0.57)], pregnancy-related illness [OR 8.63 (1.06–70.38)], cord/fetal prolapse [14.85(1.90–115.94)], and gestational age (OR 0.86 (0.81–0.92)).

Conclusion Abnormal fetal heart rate, specifically bradycardia, was the most common obstetrical indication of GA for urgent/emergent CD, while inadequate neuraxial anesthesia was the most modifiable anesthetic indication. Our data suggest aFHR and cord/fetal prolapse as potentially modifiable risk factors for GA in certain situations.

Keywords Cesarean delivery · General anesthesia · Predictors

Introduction

It is commonly accepted that neuraxial anesthesia is preferable to general anesthesia (GA) for Cesarean delivery (CD) [1]. As a result of the physiologic changes of pregnancy, induction of GA in the pregnant patient is associated with increased maternal morbidity and mortality [2–8]. General anesthesia has also been associated with lower Apgar scores, greater need for neonatal respiratory support, and neonatal intensive care unit admission [9–11]. Fortunately, the overall rates of anesthesia-related morbidity in childbirth has declined in the past 40 years, likely related to increased utilization of regional anesthesia [2]. The American Society of Anesthesiologists (ASA) and the Society for Obstetric Anesthesia and Perinatology (SOAP) recommend "selecting neuraxial techniques in preference to GA for most CD." Nonetheless, their guidelines recognize that the anesthetic technique should be "individualized based on anesthetic, obstetric, or fetal risk factors" and that "GA may be the most appropriate choice in some circumstances" [1]. Such circumstances may occur in either elective situations, such as when a contraindication to neuraxial technique exists, or

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in urgent or emergent situations, in which delivery needs to be expedited due to maternal or fetal concerns. Furthermore, some studies have identified factors that may be associated with a greater propensity for general anesthesia for CD, such as patient race or ethnicity, socioeconomic status, time of day of CD, and care provided by a non-obstetric anesthesiologist. [12–14]

Although the overall trend in the use of GA for CD has declined over the past few decades, the rates of GA continue to vary by geographic location. The SOAP's benchmark metric for the target overall rate of GA for CD is lower than 5%. Data from the National Anesthesiology Clinical Outcomes Registry (USA, 2010–2015) and the SOAP Serious Complication Repository Project (USA, 2004–2009) identified a GA rate of 5.8% and 5.6%, respectively, and a more recent study from New York State reported a 7.0% GA rate [5, 15, 16]. In the United Kingdom, the National Obstetric Anaesthetic database reported a 8.75% rate of GA administration (2020) [17]. At a large, university-affiliated center in Tokyo, Japan, the rate of GA for CD was approximately 10% in 2014, however, decreased to less than 5% following the institution of an obstetric anesthesia program [18]. These numbers are in contrast to a five-year retrospective analysis at a tertiary care university hospital (2000–2005, Boston MA) with a reported 0.4–1% rate of CD under GA. [13]

Our study sought to better understand the clinical indications of GA for CD at our large tertiary care center. While previous studies suggest certain patient factors associated with GA for CD, anesthetic or obstetric factors associated with GA for CD have yet to be determined. The purpose of this study was to identify independent risk factors for GA by performing a retrospective observational study, with the goal of reducing our GA administration rate.

Methods

Ethics approval was obtained from the MSH Research Ethics Board (MSH REB: 18–0073-C, 19–05-2018 Toronto Canada) for this retrospective case–control study. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement. All patients undergoing urgent or emergent CD at Mount Sinai Hospital (MSH) from January 1, 2015 to December 31, 2017 were identified within our electronic medical record system. Patients were categorized according to the type of anesthetic administered: general or regional anesthesia (RA; spinal, epidural, or combined spinal/epidural). It was expected that there would be no more than 10 predictors of GA, therefore according to the one in ten rule, approximately 100 cases and controls were required. Thus, of all patients who received GA for emergent or urgent CD, 102 were selected at random, stratified by the admission year (34 for each year). Similarly, 102 patients were randomly selected, stratified by the admission year (34 for each year), amongst those who had undergone emergent or urgent CD under RA. The simple random sampling method stratified by admission year was applied for the selection using the statistical software SAS 9.4. As this was a retrospective chart review, the study design minimized the potential for recall and information bias, as data were recorded contemporaneously during patient care, rather than relying on patient recall.

Data collection included patient characteristics and pre-existing comorbidities, primary obstetrical indication for CD, timing of events around delivery, post-partum complications, and neonatal outcomes. Specific anesthetic data included type of anesthetic administered, indication for specific anesthetic, and characteristics of airway management (GA group) or epidural analgesia in situ versus de novo RA if applicable (RA controls). For patients with fetuses exhibiting abnormal fetal heart rates, charts were reviewed by an obstetrician (WW) to elicit further information about the type of heart rate abnormality, according to the definitions set out by the Society of Obstetricians and Gynecologists of Canada (SOGC).

Statistical methods

The study population was summarized descriptively. The prevalence of GA was estimated based on the three years data. To examine the risk factors of GA, anesthetic and obstetric characteristics were compared between the GA and RA groups using Chi-square or Fisher exact test for categorical variables and student t test or Wilcoxon rank sum test as appropriate for continuous variables. The odds ratio of GA (95% CI) for the characteristics were also estimated based on the univariable logistic regression models. The final multivariable logistic regression model derived by backward variable selection procedure was used to further determine the risk factors of GA. The variables included in the full model were those identified as significantly associated ($p < 0.05$) with GA in the univariable analysis. The adjusted odds ratios of GA (AOR) with 95% CIs based on the final logistic regression model were reported. The data management and all statistical analyses were performed using SAS 9.4 (SAS institute Inc). A two-sided p-value of < 0.05 was considered as statistical significance.

Results

During the study period, there was a total of 20,519 deliveries and a CD rate of 35.5% (Table 1). The overall rate of GA for CD during the three-year period for all CD performed

Table 1 Total number of deliveries, Cesarean deliveries (CD), CD requiring general anesthesia (GA), number of urgent/emergent (U/E) CD, and number of U/E CD requiring GA

Year	Total Deliveries	CD	CD under GA	U/E CD	U/E CD under GA
2015	7012	2407	92 (3.8%)	1222	81 (6.6%)
2016	6715	2417	99 (4.1%)	1228	87 (7.1%)
2017	6792	2458	107 (4.4%)	1231	86 (7.0%)

(elective and urgent/emergent) was 4.1%. CDs that were classified as urgent or emergent accounted for 50.5% of all CD, of which 6.9% were performed with GA.

In both the GA and RA groups, five patients were not included in the study as they were incorrectly identified as belonging to their group, thus 97 patients in each group were reviewed. Patient characteristics of the GA and RA group are shown in Table 2. There was no statistical difference in patient age or weight/BMI. Although more deliveries occurred on weekends/evenings ("afterhours") in the GA group than in the RA group, the difference was not statistically significant. In the GA group, there were more patients with lower gestational age, with 59% of patients delivering preterm (< 37 weeks). There were more primiparous patients in the RA group (77%) compared to the GA group (63%). Seventy three percent of the patients were classified as ASA ≥ 3 in the GA group versus 23% in the RA group.

Anesthetic indications for CD under GA in urgent/emergent cases are presented in Table 3. Amongst the cases, the most common indication for GA was "limited time due to maternal/fetal compromise" (56%), followed by "maternal contraindication to RA" (25%). Abnormal FHR accounted

Table 2 Characteristics of patients who had GA versus regional anesthesia (RA) for CD

Variables	General anesthesia	Regional anesthesia	*p*-value
Maternal characteristics			
Age (year), mean (sd)	32.9 (5.2)	34.3 (5.2)	0.07
GA (week), median (IQ range)	36 (29, 39.1)	39 (37.3, 40.3)	< 0.0001
Weight (kg), mean (sd)	78.1 (15.6)	78.9 (15.8)	0.72
BMI, mean (sd)	28.6 (7.9)	29.2 (7.6)	0.62
Primigravida (gravida = 1), % (n/N)	38.1 (37/97)	58.8 (57/97)	0.028
ASA, %(n/N)			
2	26.8 (26/97)	77.32 (75/97)	< 0.0001
3	69.07 (67/97)	22.68 (22/97)	
4	4.12 (4/97)	0 (0/97)	
Epidural in situ, % (n/N)	32.99 (32/97)	63.92 (62/97)	< 0.0001
Delivery timing			
Delivery on weekend, % (n/N)	24.74 (24/97)	18.56 (18/97)	0.29
Delivery time of day, % (n/N)			0.76
08:00–17:00	30.93 (30/97)	32.99 (32/97)	
17:00–08:00	69.07 (67/97)	67.01 (65/97)	
Anesthetic characteristics			
Obstetric characteristics			
Limited time due to fetal/maternal compromise, % (n/N)	55.67 (54/97)	1.03 (1/97)	< 0.0001
Emergency code activation, % (n/N)	12.37 (12/97)	1.03 (1/97)	0.0016
Failure to progress, % (n/N)	7.22 (7/97)	34.02 (33/97)	< 0.0001
Labor in a patient booked for elective CD, % (n/N)	3.09 (3/97)	16.49 (16/97)	0.0017
Maternal			
Pregnancy related maternal illness, % (n/N)	8.25 (8/97)	1.03 (1/97)	0.035
Antepartum hemorrhage, % (n/N)	7.22 (7/97)	3.09 (3/97)	0.19
Chorioamnionitis/sepsis, % (n/N)	2.06 (2/97)	0 (0/97)	0.49
Maternal hemodynamic compromise, % (n/N)	1.03 (1/97)	0 (0/97)	0.99
Abnormal placentation, % (n/N)	1.03 (1/97)	0 (0/97)	0.99
Fetal			
Cord/fetal prolapse, % (n/N)	13.4 (13/97)	1.03 (1/97)	0.0009
Fetal IUGR, % (n/N)	1.03 (1/97)	2.06 (2/97)	0.99
Abnormal fetal heart rate, % (n/N)	55.67 (54/97)	40.21 (39/97)	0.03

Table 3 Anesthetic indications of GA for CD

Limited time due to maternal/fetal compromise	**54**
Abnormal fetal heart rate:	38
Sudden onset bradycardia/recurrent decelerations ($n=30$)	
Immediately following labor epidural placement ($n=3$)	
During fetal intrauterine transfusion ($n=3$)	
During attempted external cephalic version ($n=2$)	
Cord/fetal prolapse	14
Placental abruption	2
Maternal contraindication to neuraxial anesthesia	**24**
Pregnancy-related contraindication	19
Thrombocytopenia ($n=9$)	
Anticoagulant given as in-patient ($n=5$)	
Obstetrical hemorrhage (n = 4)	
Sepsis ($n=1$)	
Pre-pregnancy related contraindication	5
Immune thrombocytopenic purpura ($n=1$)	
Von Willebrand disease ($n=1$)	
Hereditary dysfibrinogenemia ($n=1$)	
Dilated cardiomyopathy/pulmonary hypertension/CHF ($n=1$)	
Previous spine surgery and SCS in situ ($n=1$)	
Inadequate neuraxial anesthesia	**17**
Failure of in-situ epidural top-up:	14
Effective labor epidural with no top-ups in labor ($n=6$)	
CD within 1 h of epidural placement ($n=3$)	
Epidural requiring ≥ 3 top-ups during labor ($n=2$)	
Parturient with 3 resited epidurals ($n=1$)	
Class 3 Obesity (BMI 51) ($n=1$)	
5/10 pain score documented 30 min prior to CD ($n=1$)	
Failure of neuraxial anesthesia initiated in the OR:	3
Attempted spinal insertion unsuccessful ($n=1$)	
Inadequate block noted after skin/fascia opened ($n=1$)	
Excess muscle tension interfering with surgical closure ($n=1$)	
Need for intraoperative conversion to GA	**2**
Invasive placenta	2

CD = Cesarean delivery; CHF = congestive heart failure; SCS = spinal cord stimulator; BMI = body mass index

for the most common obstetrical indication resulting in urgent/emergent CD under GA (39%) and was also the most common indication for CD under RA (39%). "Inadequate RA" accounted for 17% of the GA cases, of which inadequate in situ neuraxial anesthesia for surgery accounted for 14%.

Amongst the GA cases, the majority of abnormal FHRs were fetal bradycardia ($n=31$) (Table 4). In the RA group, recurrent complex variable decelerations ($n=15$), fetal tachycardia ($n=8$), recurrent late decelerations ($n=6$), and recovered bradycardia ($n=4$) accounted for most of the abnormal FHRs.

With respect to airway management, 89% of the cases were intubated with direct laryngoscopy while 11% were intubated using video laryngoscopy. During intubation, 72% of the patients exhibited a Cormack–Lehane grade 1 view, 23% exhibited a grade 2 view, and 5% exhibited a grade 3 view. There was no morbidity related to airway management.

Many neonatal outcomes including need for resuscitation and NICU admission were significantly higher for patients with GA compared to RA and are presented in Table 5. There were eight sets of twins in the GA group ($n=105$), and three sets of twins and one set of triplets in the RA group ($n=102$). There were six "Infant Emergency" activations in the GA group compared to two "Infant Emergency" activations in the deliveries under RA.

The univariate analysis results are shown in Table 2 and Table 6. It showed that the potential risk factors/predictors of GA included primigravida patients, ASA classification, presence of epidural in situ, maternal/fetal emergency code activation, failure to progress in labor, labor in a patient scheduled for a CD, pregnancy-related illness, cord/fetal prolapse, and gestational age. We also conducted multivariate analysis to further determine the risk factors/predictors of GA. The predictors identified in univariate analysis but with too few cases (e.g., emergency code activation, pregnancy-related illness, cord/fetal prolapse) were not included in the multivariate analysis. The results showed that the ASA class ≤ 2, failure to progress in labor, labor in a patient scheduled for CD, and increased gestational age were negatively associated with GA (AOR < 1). For example,

Table 4 Classification of abnormal fetal heart rates resulting in CD

Type of abnormal fetal heart rate	General anesthesia ($n=38$)	Regional anesthesia ($n=38$)
Bradycardia	31	2
Bradycardia with recovery to normal FHR	0	4
Tachycardia	1	8
Recurrent late deceleration	4	6
Recurrent complex variable deceleration	2	15
Abnormal fetal heart rate—unspecified	0	3

Table 5 Comparison of neonatal outcomes between General and Regional Anesthesia groups

Neonatal variable	General Anesthesia ($N=102$)	Regional Anesthesia ($N=105$)	p-value
Apgar score < 7 at 1 min, % (n/N)	61.54 (64/104)	17.82 (18/102)	< 0.001
Apgar score < 7 at 5 min, % (n/N)	29.81 (31/105)	5.94 (6/102)	< 0.001
Neonatal resuscitation, % (n/N)	63.81 (67/105)	25.49 (26/102)	< 0.001
NICU admission, % (n/N)	60.0 (63/105)	25.49 (26/102)	< 0.001
Infant Emergency called, % (n/N)	6.67 (7/105)	1.96 (2/102)	0.17
Mortality, % (n/N)	3.81 (4/105)	0.98 (1/102)	0.37

Table 6 Proposed anesthetic and obstetric risk factors of GA for CD

Covariate	Univariate analysis		Multivariate analysis	
	Odds Ratio (95%CI) GA vs RA	p-value	AOR (95%CI) GA vs RA	p-value
Primigravida (Yes vs No)	0.43 (0.24–0.77)	0.004	Removed**	
ASA classification (2 vs ≥ 3)	0.11 (0.06–0.21)	< 0.001	0.14 (0.06–0.28)	< 0.001
Epidural in situ (Yes vs No)	0.28 (0.15–0.50)	< 0.001	Removed**	
Emergency code activation (Yes vs No)	13.55 (1.73–106.40)	0.013	Not included*	
Failure to progress (Yes vs No)	0.15 (0.06–0.36)	< 0.001	0.22 (0.08–0.60)	0.003
Labor in a patient scheduled for CD (Yes vs No)	0.16 (0.05–0.57)	0.005	0.07 (0.02–0.29)	< 0.001
Pregnancy-related illness (Yes vs No)	8.63 (1.06–70.38)	0.044	Not included*	
Cord/fetal prolapse (Yes vs No)	14.85 (1.90–115.94)	0.01	Not included*	
Gestational Age (weeks), per unit increase	0.86 (0.81–0.92)	< .001	0.92 (0.85–0.99)	0.03

Notes: *not included in the multivariate analysis since too few events (see Table 2)

AOR: adjusted odds ratio based on final multivariate logistic regression model derived by backward variable selection procedure. **Removed: the variable(s) were removed based on backward variable procedure. The covariates included in the full models were primigravida, ASA classification, epidural in situ, failure to progress, labor in a patient scheduled for CD, and gestational age

the odds of having GA for patients with ASA≤2 was 86% (AOR=0.14 (95CI 0.06-0.28)) lower compared to patients with ASA > 2, while emergency code activation, pregnancy-related illness and cord/fetal prolapse were positively associated with GA (OR > 1). For example, the odds of having GA for patients with an emergency code activation called was around 12 (=OR-1) times higher compared to patients without an emergency code activation.

Discussion

Our results demonstrate that the overall rate of GA for CD at our institution was 4.1%, with a 6.9% rate of GA for urgent/emergent CD. The most common obstetrical indication resulting in GA for urgent/emergent CD was an abnormal FHR (39%), while the most common anesthetic indication for GA was inadequate neuraxial anesthesia (17%). There was no morbidity related to airway management, and most patients had a Cormack–Lehane grade 1 airway (72%) and were intubated using direct laryngoscopy (89%).

In contrast to Palanisamy et al.'s retrospective review, we report a lower rate of cases undergoing GA due to limited or lack of time (39% vs. > 50%), but a much higher rate related to inadequate neuraxial anesthesia (17% vs. 0–4%) [13]. The SOAP Serious Complication Repository (SCORE) Project identified a 1.7% rate of failed neuraxial anesthesia requiring an alternate technique for CD amongst all CDs (elective or urgent/emergent), which is also considerably lower than our rate [15]. Opportunities to improve technical aspects (e.g., ultrasound guidance, techniques for confirmation of epidural catheter placement such as Tsui test or pressure waveform analysis) should be sought in patients who may be technically more challenging, such as those with obesity. Halpern et al. identified two or more clinician-initiated top-ups in labor as an independent risk factor for failure of conversion of labor epidural analgesia to epidural anesthesia for CD [19]. Thus, monitoring potentially problematic epidurals and having a low threshold to replace them is essential to decrease the risk of inadequate conversion to surgical anesthesia if an urgent/emergent CD is needed [20]. However, it is interesting to note that of the 14 cases of failed epidural top-ups

identified in our study, six of them were utilized in labor with no documentation of suboptimal function. Other factors that have previously been implicated in failed conversion include greater urgency for CD and care provided by a non-obstetric anesthesiologist [19–21]. Proposed reasons for this include greater confidence in a block if enough time is allowed and increased likelihood to convert to a spinal anesthetic instead of GA amongst obstetric anesthesiologists [20]. In our study, we did not compare the decision-making of formally trained obstetric anesthesiologists to non-obstetric anesthesiologists, as all of the anesthesiologists in our hospital work on our high-risk labor unit and thus have significant clinical experience in the high-risk obstetric setting.

Amongst patients with aFHR, a majority had fetal bradycardia. Of note, there were two cases of fetal bradycardia in which RA was still possible. In reviewing these specific scenarios, one had been experiencing recurrent fetal bradycardias (with recovery) that were progressively increasing in duration and frequency. These "warning signs" were communicated within the multidisciplinary team such that when the bradycardia episode leading to emergent CD occurred, the patient was already in the operating room with adequate surgical anesthesia established. In the second case, a prolonged second stage secondary to fetal malposition and forceps delivery was attempted; thus, the anesthesia team had already been involved prior to the development of persistent bradycardia and had administered an epidural top-up that was suitable for CD. These two patients illustrate that in certain clinical situations, timely multidisciplinary communication may result in the avoidance of GA. This is supported by Ikeda et al. who demonstrated a steady decline in the percentage of Cesarean deliveries performed under GA with the implementation of a specific obstetric anesthesia team to serve as a communication bridge between the department of anesthesiology and the department of obstetrics. [18]

Amongst the patients undergoing GA, a known contraindication to neuraxial anesthesia accounted for 25% of patients, of which 88% of the contraindications were attributable to a hematologic issue. Five patients in this group had received anticoagulant as in-patients leading up to their CD, emphasizing the importance of early identification and communication of patients who are at risk of urgent or emergent obstetric surgery. This also highlights the need for prompt consultation of hematology and anesthesiology to determine a suitable management plan, including optimization to facilitate regional anesthesia when appropriate.

Timing of CD under GA versus RA was examined in our study. Of all the CDs under GA that were reviewed, 73% occurred during evenings/nights (17:00–08:00) or weekends. This finding of greater GA administration during afterhours is consistent with Palanisamy et al.'s study. Underlying reasons for this should be further examined, but this preliminary observation is important to note given that most institutions have decreased staffing and resources available for assistance during these "afterhours" time periods.

There was no morbidity related to airway management. This is in keeping with recent data trends that suggest complications such as aspiration may not be as common as previously suspected in the obstetric population, largely due to vigilance when dealing with an obstetric airway and improved airway management techniques that have been developed in the past two decades. [2, 3, 15]

Finally, neonatal outcomes in the two groups were assessed. More "Infant Emergency" activations were initiated in CDs under GA compared to RA (six vs. two). Amongst the GA cases, there was a greater rate of neonatal resuscitation, NICU admission, and neonatal mortality. It is important to note that underlying fetal compromise resulting in the need for urgent/emergent CD may have contributed to this finding. [22]

Our data analysis suggests the following variables as potential predictors of GA for CD: ASA classification, emergency code activation, failure to progress, labor in a patient scheduled for CD, pregnancy related illness, cord/fetal prolapse, and gestational age. While there are few studies that have evaluated potential risk factors, one prospective observational study of preterm CD also noted an inverse relationship between gestational age and odds of receiving GA for CD [23]. While gestational age cannot be modified, the anesthesiologist's response in the setting of predictors such as aFHR and cord/fetal prolapse may be modifiable in certain clinical scenarios with early communication and planning. This may include proactively alerting all members of the labor and delivery team when such patients are admitted to the antenatal or labor unit, ensuring all members are aware of any early "warning signs" suggestive of fetal compromise, and, if appropriate, initiating early epidural placement for patients who are deemed at higher risk of requiring CD. To emphasize the importance of a well-functioning epidural, all members of the patient's care team should be educated regarding the risks of GA and strategies to avoid GA. All providers should also be knowledgeable about the expected clinical effect of an appropriate functioning epidural, and a culture should exist such that all care providers feel empowered to communicate any concerns regarding RA with the anesthesia team. Furthermore, patients deemed at higher risk of CD should receive antenatal education about the importance of a well-functioning epidural. At our high-risk obstetric anesthesia clinic, we routinely counsel patients about the possibility of an urgent or emergent CD and the potential benefits of early epidural placement in these scenarios. It is important to note that there were some predictors identified in the univariate

analysis but not included in the multivariate analysis, (i.e., emergency code activation, pregnancy-related illness, cord/fetal prolapse) as there were too few instances to be reliably included. Future, larger studies should be considered to better elicit potential predictors with low incidence.

Our study has several limitations. First, given the time-sensitive nature of these situations within the urgent and emergent groups, charting was mostly completed retrospectively by obstetricians and anesthesiologists, introducing the potential for retrospective charting bias. Second, charting was completed by various team members (residents, fellows, and staff) with variable clinical experience. Thus, the level of detail provided for each case and control was variable, and it was difficult to capture the multifactorial issues and true narrative that ultimately contributed to the decision to proceed with CD and the type of anesthesia utilized. Additionally, while the majority of our cases with aFHRs did not exhibit any warning signs of fetal compromise as per our electronic records, it is possible that there were subtle findings prior to the development of problematic FHRs that may not have been documented in the charts. Fourthly, due to the nature of our existing electronic medical record, it was not possible to separate the urgent and emergent CDs in our analysis, as these two clinically distinct scenarios are categorized together in our electronic medical records. Additionally, we were unable to collect information on our patient's social backgrounds, including patient race/ethnicity and socioeconomic status, which may be a source of bias. Lastly, we recognize that there are a wide range of practices among anesthesiologists and obstetricians, particularly in urgent scenarios, where utilization of a RA may be an option. The decision regarding anesthetic technique depends on both the individual obstetrician's perception of delivery urgency and the individual anesthesiologist's comfort with each anesthetic technique in the setting of expeditious delivery. Thus, it is possible that a regional technique may have been utilized if a different anesthesiologist–obstetrician team provided care for some of the cases, and vice versa for the controls.

In summary, our study revealed the most common obstetrical indication resulting in GA for urgent/emergent CD was an abnormal fetal heart rate, specifically bradycardia, with a perception of inadequate time to initiate adequate regional anesthesia. The largest modifiable anesthetic indication for GA was inadequate neuraxial anesthesia. Our study identified aFHR and cord/fetal prolapse as risk factors for GA that may be modifiable in certain situations.

Data availability The data supporting the findings of this study are available from the corresponding author (GR) on request.

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