Archives of Anesthesiology and Critical Care (In Press); x(x): xx-xx.

Available online at http://aacc.tums.ac.ir

Research Article

General versus Spinal Anesthesia for Cesarean Delivery: Neonatal Apnea and Immediate Respiratory Outcomes in a Prospective Observational Cohort Study

Ali Dabbagh[1], Marzieh Shahrabi[2], Naseer Waheeb-Mohammed[3], Ebtehaj Heshmatkhah[4], Dariush Abtahi[3]*, Shideh Ariana[5], Seyedeh Samira Abdollahzadeh[5]

[1]Anesthesiology Research Center, Department of Anesthesiology, School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

[2]Department of Anesthesiology, Shahid Modarres Hospital, School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

[3]Department of Anesthesiology, Imam Hossein Hospital, School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

[4]Department of Obstetrics and Gynecology, Valiasr Private Hospital, Qom, Iran.

[5]Department of Gynecology and Oncology, Imam Hossein Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

ARTICLE INFO

Article history:
Received 11 July 2026
Revised 02 August 2026
Accepted 16 August 2026

Keywords:
Cesarean section;
General anesthesia;
Spinal anesthesia;
Neonatal apnea

ABSTRACT

Background: The choice of anesthetic technique for cesarean section remains a critical consideration due to potential impacts on neonatal well-being. This study aimed to compare immediate neonatal respiratory outcomes, specifically the incidence of neonatal apnea, between general anesthesia (GA) and spinal anesthesia (SA).

Methods: We conducted a prospective observational cohort study at a tertiary academic medical center. Maternal and neonatal variables were collected for cesarean deliveries under GA or SA. The primary endpoint was the incidence of neonatal apnea. Secondary outcomes included respiratory distress, requirements for positive pressure ventilation (PPV), and NICU admission. Data were analyzed using SPSS 26.0, employing chi-square, Mann-Whitney U tests, and multivariable binary logistic regression to adjust for potential confounders.

Results: A total of 100 cases were analyzed. While neonatal apnea was numerically higher in the GA group (14% vs. 10% in SA), and PPV was required exclusively in neonates born under GA ($p = 0.012$), multivariable analysis demonstrated that anesthetic technique was not an independent predictor of neonatal apnea (OR 1.465, $p = 0.538$). Conversely, acute fetal compromise (OR 4.567, $p = 0.024$) and the primary indication for cesarean delivery (adjusted OR 7.03, $p = 0.022$) were identified as independent risk factors for neonatal apnea. No statistically significant differences were observed in umbilical arterial pH, Apgar scores, or NICU admission rates.

Conclusion: Cesarean indication, especially acute fetal compromise, was the main determinant of neonatal apnea and early respiratory adaptation. Although positive pressure ventilation occurred more often after general anesthesia, anesthetic technique was not an independent predictor after adjustment. These findings suggest that underlying maternal–fetal conditions may influence neonatal respiratory outcomes more than the anesthetic method itself.

The authors declare no conflicts of interest.
*Corresponding author.
E-mail address: drdariushabtahi@yahoo.com
DOI:

Introduction

Cesarean section (CS) rates have increased markedly over the past three decades, rising from approximately 7% in 1990 to 21.1% in 2021 [1]. Projections indicate that the global rate may reach 28.5% by 2030, corresponding to nearly 38 million procedures annually [2]. Substantial regional variation persists, with reported rates ranging from 7.1% in sub-Saharan Africa to 63.4% in Eastern Asia [2].

Several factors have contributed to this upward trend, including increasing maternal age, elective cesarean delivery without clear medical indication, concerns regarding pelvic floor injury, and perceived safety benefits [3-4]. In many high-income countries, CS rates now exceed 30–50%, raising ongoing concerns about potential overuse and the broader medicalization of childbirth [5-6].

The choice of anesthetic technique for cesarean delivery has important implications for maternal and neonatal outcomes. Spinal anesthesia (SA) is the preferred approach in most settings [7-8], as it avoids airway manipulation, limits fetal exposure to anesthetic agents, reduces blood loss, and allows maternal awareness during birth [8-9]. It is also associated with lower maternal morbidity and mortality compared with general anesthesia, primarily due to fewer airway-related complications [7,9-10].

General anesthesia (GA) remains essential in obstetric practice, particularly for emergency cesarean delivery requiring rapid induction when spinal anesthesia is contraindicated (e.g., coagulopathy, sepsis, or hemodynamic instability) or when clinically indicated [11-12]. Although its use has declined from 50–60% in the 1980s to <10% in recent reports, GA is still required in approximately 5–15% of cases [13-14]. Reduced utilization may limit training opportunities in obstetric GA [14]. Advances in anesthetic pharmacology, including remifentanil, have further improved its maternal and neonatal safety profile [15].

Neonatal respiratory adaptation after cesarean delivery is a critical physiologic transition. Reported rates of neonatal apnea vary widely (2.8–27.1%), reflecting differences in populations, definitions, and timing of assessment [16-17]. Compared with vaginal delivery, cesarean birth, particularly in preterm infants or high-risk pregnancies, is associated with higher rates of transient tachypnea of the newborn and respiratory distress syndrome [17–19]. Nevertheless, evidence remains heterogeneous [18], and some studies report no significant effect of anesthetic technique on short-term neonatal outcomes in elective cesarean delivery [20-21].

The mechanisms through which anesthetic techniques may influence neonatal respiratory outcomes differ between general and spinal anesthesia. Under general anesthesia, placental transfer of anesthetic agents, such as barbiturates, opioids, and benzodiazepines, may contribute to neonatal respiratory depression, depending on drug properties and the interval between administration and delivery [22]. In contrast, spinal anesthesia avoids systemic drug exposure but may cause maternal hypotension due to sympathetic blockade, potentially reducing uteroplacental perfusion and fetal oxygenation [23–25]. However, recent randomized trials have reported mixed results, with some demonstrating comparable neonatal outcomes when modern anesthetic protocols are used [18,26].

Maternal characteristics are important determinants of neonatal outcomes after cesarean delivery. Advanced maternal age (≥35 years) has been associated with increased neonatal respiratory morbidity in some studies, although results remain inconsistent [27–29]. Maternal comorbidities such as diabetes mellitus, hypertension, and obesity have also been linked to higher rates of neonatal respiratory distress, independent of anesthetic technique [30–34]. However, the interaction between maternal risk factors and the choice of anesthesia remains incompletely understood.

Despite extensive research, the comparative effects of spinal versus general anesthesia on neonatal respiratory outcomes, particularly neonatal apnea, remain uncertain. Some studies report higher rates of respiratory depression with general anesthesia, whereas others find no significant differences when modern anesthetic protocols are used [20-21,35–38].

This study compared general and spinal anesthesia for cesarean delivery, focusing on neonatal apnea and early respiratory outcomes. The primary objective was to determine the incidence of neonatal apnea in each group. Secondary objectives included assessment of respiratory distress, need for resuscitation, NICU admission, and the influence of maternal characteristics, gestational age, comorbidities, and obstetric history on neonatal outcomes. A clearer understanding of these associations may help guide anesthetic decision-making and optimize perinatal care.

Methods

This prospective observational cohort study was conducted over a three-month period (April–June 2026) at a tertiary academic medical center. The study compared immediate neonatal respiratory outcomes after cesarean delivery under general versus spinal anesthesia. Maternal and neonatal variables were collected concurrently at delivery to identify potential predictors of adverse respiratory events. The study is reported in accordance with the STROBE guidelines.

The study was conducted at Imam Hossein Medical Center, a tertiary academic hospital and regional referral center for high-risk obstetric cases. The study population included pregnant women undergoing elective or emergency cesarean delivery who provided written informed consent. Participants received either general or spinal anesthesia, with the technique determined according to clinical indications rather than randomization. This approach reflects routine clinical practice, where anesthetic choice is influenced by factors such as delivery urgency, fetal status, maternal comorbidities, and anesthesiologist judgment.

Participants were eligible if they had a gestational age of ≥37 weeks confirmed by last menstrual period or first-trimester ultrasound, a singleton pregnancy, no known fetal anomalies, and American Society of Anesthesiologists (ASA) physical status II.

Exclusion criteria included: (1) failed spinal anesthesia requiring repeat puncture or conversion to general anesthesia; (2) significant delay in anesthesia administration (>15 minutes from decision to anesthesia) or technical complications during induction; (3) contraindications to study medications or neuraxial anesthesia; (4) maternal substance use (alcohol, tobacco, or illicit drugs); (5) maternal medical or obstetric conditions likely to affect neonatal status, such as uncontrolled diabetes mellitus, severe preeclampsia, placental abnormalities, or intrauterine growth restriction; (6) Category 1 emergency cesarean delivery (Category 2–3 urgent procedures were included); and (7) maternal use of medications known to influence neonatal outcomes, including systemic corticosteroids, anticonvulsants, antithyroid agents, or other potentially fetotoxic drugs.

The required sample size was 100 participants (50 in each anesthesia group). It was calculated using a standard formula for comparing two independent proportions, assuming a two-sided significance level of 0.05 and 80% statistical power. Expected neonatal apnea rates of 10% in the spinal anesthesia group and 30% in the general anesthesia group were based on findings reported by Anil et al. [38].

The anesthetic technique was selected according to clinical indication rather than randomization. In routine practice, this choice is influenced by factors such as delivery urgency, maternal preference, contraindications to neuraxial anesthesia, fetal status, and anesthesiologist judgment. Although this approach reflects real-world clinical practice and improves external applicability, it may introduce confounding by indication; therefore, differences in neonatal outcomes may partly reflect the clinical factors influencing anesthesia selection rather than the anesthetic technique itself.

General anesthesia was induced with propofol (2 mg/kg IV) followed by succinylcholine (1–1.5 mg/kg IV) for rapid sequence intubation. Anesthesia was maintained with volatile agents (sevoflurane or isoflurane) or remifentanil-based total intravenous anesthesia according to institutional protocols.

Neonatal apnea was assessed using a structured checklist and pulse oximetry during the immediate postnatal period. Apgar scores were recorded at 1, 5, and 10 minutes using the standard scoring system by obstetric staff blinded to the anesthetic technique. Time to spontaneous breathing was measured with a digital stopwatch from delivery until regular respirations were established.

Maternal hemodynamic variables were recorded at baseline, immediately before anesthesia administration, at 5-minute intraoperative intervals, and at delivery. Umbilical arterial and venous blood gas samples were obtained at birth to assess fetal acid–base status.

Neonatal apnea was defined as the cessation of breathing for more than 10 seconds accompanied by cardiorespiratory compromise, including bradycardia (heart rate <100 beats/min) or oxygen desaturation (SpO_2 <90% on pulse oximetry). This definition was applied uniformly to ensure consistent outcome assessment.

The primary independent variable was the anesthetic technique used for cesarean delivery, categorized as spinal anesthesia (intrathecal local anesthetic with or without adjunct agents) or general anesthesia (volatile-based or total intravenous anesthesia). The primary outcome was neonatal apnea within the first hour of life, defined as cessation of breathing for ≥10 seconds accompanied by bradycardia (heart rate <100 beats/min) requiring clinical intervention. Secondary outcomes included Apgar scores at 1 and 5 minutes, early respiratory complications (need for supplemental oxygen, bag mask ventilation, or endotracheal intubation), and admission to the neonatal intensive care unit (NICU).

Maternal and obstetric variables were collected as potential confounders. Maternal characteristics included age (years), weight (kg), height (cm), and body mass index (kg/m²). Obstetric history included gravidity, parity, and a history of prior preterm delivery. Intraoperative variables included duration of surgery (minutes, from skin incision to closure), the interval from skin incision to umbilical cord clamping (minutes), and maternal hemodynamic status, including severe hypotension (systolic blood pressure <90 mmHg or >20% decrease from baseline) and vasopressor use. Neonatal variables included gestational age (weeks), birth weight (g), and Apgar scores at 1, 5, and 10 minutes.

Data were collected prospectively at the time of delivery from electronic medical records, anesthesia charts, and neonatal observation forms. Trained medical staff recorded all data according to standardized institutional protocols. The research team reviewed records for completeness and resolved discrepancies through additional chart verification.

Statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA), with $p < 0.05$ considered statistically significant. Normality was assessed using the Shapiro–Wilk test. Non-normally distributed continuous variables were summarized as median and interquartile range (IQR), and categorical variables as frequencies and percentages. The Mann–Whitney U test compared continuous variables between anesthesia groups and between neonates with and without apnea.

Categorical variables were analyzed using the Pearson chi-square or Fisher's exact test when expected cell counts were <5. Binary logistic regression was used to identify independent predictors of neonatal apnea, adjusting for anesthesia type, maternal age, body mass index, surgical duration, cord clamping time, maternal hypotension, and obstetric history. Results were reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs).

This study was conducted in accordance with the Declaration of Helsinki. The protocol was approved by the Research Ethics Committee of the School of Medicine, Shahid Beheshti University of Medical Sciences (ethics code: IR.SBMU.MSP.REC.1405.029). Written informed consent was obtained from all participants before enrollment after providing information about the study objectives, procedures, potential risks and benefits, and the right to withdraw at any time without affecting medical care. For participants unable to provide consent directly, consent was obtained from legally authorized representatives in accordance with applicable regulations.

Participant confidentiality was strictly maintained. Personal identifiers were stored separately from research data in secure, password-protected databases accessible only to authorized research team members. All analyses were performed using coded identifiers to ensure anonymity.

Results

A total of 100 pregnant women undergoing cesarean delivery were enrolled and allocated to spinal anesthesia (SA, n=50) or general anesthesia (GA, n=50). Complete data were available for all participants, with no missing values in the analyzed variables.

Maternal age was evaluated as a potential predictor of neonatal apnea. Because the distribution of age deviated from normality in the spinal anesthesia group, a non-parametric comparison was performed.

Median maternal age was 32.0 years (IQR: 9; range: 23–42) in the spinal anesthesia group and 31.0 years (IQR: 7; range: 24–39) in the general anesthesia group, with no significant difference between groups (Mann–Whitney U=1128.0, Z=−0.843, p=0.399). In univariate logistic regression, maternal age was not a significant predictor of neonatal apnea (OR: 0.953; 95% CI: 0.866–1.050; p=0.334), indicating no meaningful association within the studied age range (Table 1).

Maternal anthropometric variables were comparable between anesthetic groups. Median pre-pregnancy weight was 72.0 kg (IQR: 62.5–71.5) in the spinal anesthesia group and 71.0 kg (IQR: 64.0–76.0) in the general anesthesia group (p=0.605). At delivery, median maternal weight was 88.0 kg (IQR: 82.0–93.0) in the SA group and 88.5 kg (IQR: 78.0–96.0) in the GA group (p=0.698). Median gestational weight gain was 13.0 kg (IQR: 8.0–17.0) in both groups (p=0.456).

Median maternal height was 165.0 cm (IQR: 160.0–171.0) in SA and 164.0 cm (IQR: 158.0–170.0) in GA (p=0.289). Body mass index was 30.64 kg/m² (IQR: 27.46–33.31) in SA and 32.25 kg/m² (IQR: 28.79–34.33) in GA (p=0.281). None of these anthropometric variables were significantly associated with neonatal apnea in univariate analysis (all p>0.05).

Obstetric history included gravidity and parity. In the overall cohort, median gravidity was 2.0 (mean: 2.30, range: 1–4): 33% gravida 1, 25% gravida 2, 21% gravida 3, and 21% gravida 4. Median parity was 0 (mean: 0.72, range: 0–3): 57% were nulliparous, 19% with one prior delivery, 19% with two, and 5% with three. Gravidity distribution differed between anesthetic groups (χ^2=10.356, df=3, p=0.016; Cramér's V=0.322), with more gravida 3 women in the spinal anesthesia group (34% vs. 8%).

Table 1- Baseline Maternal Characteristics by Anesthesia Type.

Variable	Spinal Anesthesia (n=50)	General Anesthesia (n=50)	P value*
Maternal age (years)	32.0 (29.0–35.0)	31.0 (28.0–34.0)	0.399
Pre-pregnancy weight (kg)	72.0 (65.0–79.0)	71.0 (63.0–78.0)	0.605†
Weight at delivery (kg)	88.0 (80.0–96.0)	88.5 (81.0–97.0)	0.698†
Gestational weight gain (kg)	13.0 (10.0–17.0)	13.0 (9.0–18.0)	0.456†
Maternal height (cm)	165.0 (161.0–169.0)	164.0 (160.0–168.0)	0.289†
BMI (kg/m²)	30.6 (28.2–33.5)	32.3 (29.8–35.1)	0.281†
Gravida, median (IQR)	2.0 (1.0–3.0)	2.0 (1.0–3.0)	0.016‡
Para, median (IQR)	0.0 (0.0–1.0)	1.0 (0.0–2.0)	0.235‡
Education level (secondary/higher)	28/22	30/20	0.860§
Chronic disease, n (%)	10 (20.0)	9 (18.0)	0.799§
Maternal medication use, n (%)	6 (12.0)	6 (12.0)	1.000§

IQR, interquartile range (Q1–Q3); BMI, body mass index; * P value from Mann–Whitney U test (†), Pearson's chi-squared test (§), or Fisher's exact test (‡) as appropriate; statistical significance set at $p < 0.05$.

Parity distribution was similar between groups (χ^2=4.253, df=3, p=0.235). In univariate logistic regression, neither gravidity (OR: 1.286; 95% CI: 0.781–2.117; p=0.322) nor parity (OR: 0.709; 95% CI: 0.378–1.330; p=0.284) predicted neonatal apnea.

Maternal educational attainment was categorized as diploma or lower (55%), bachelor's degree (29%), and PhD or higher (16%). Educational distribution was similar between anesthetic groups (χ^2=0.303, df=2, p=0.860; Cramér's V=0.055). In the spinal and general anesthesia groups, respectively, 56% vs. 54% had diploma-level or lower education, 30% vs. 28% held bachelor's degrees, and 14% vs. 18% had PhD or higher qualifications. In univariate logistic regression, maternal education level was not a significant predictor of neonatal apnea (overall χ^2=3.558, df=2, p=0.169; bachelor vs. diploma: OR 0.311, 95% CI 0.092–1.055, p=0.061; PhD or higher vs. diploma: OR 0.868, 95% CI 0.249–3.022, p=0.823).

Nineteen percent of participants (n=19) reported a history of chronic disease, with similar prevalence between anesthetic groups (18% in SA vs. 20% in GA; χ^2=0.065, p=0.799). The most common conditions were respiratory disease (5%), hypothyroidism (4%), gestational diabetes mellitus (4%), and hypertension/pregnancy-induced hypertension (3%); fewer participants had type 1 diabetes (2%) or type 2 diabetes (1%). The distribution of specific conditions did not differ significantly between groups (χ^2=4.546, p=0.603). In univariate logistic regression, maternal chronic disease was not associated with neonatal apnea (OR: 1.124; 95% CI: 0.485–2.604; p=0.765). Specific disease types and medication use during pregnancy (12% of participants) were also not significant predictors of neonatal respiratory outcomes.

All pregnancies were term or near term (37–40 weeks). As gestational age was not normally distributed, non-parametric analysis was applied. Median gestational age was 38.0 weeks (IQR: 37.0–38.0) in the spinal anesthesia group and 39.0 weeks (IQR: 38.0–39.0) in the general anesthesia group (overall median: 38.5 weeks), with no significant between-group difference (Mann–Whitney U=1045.0, Z=−1.545, p=0.122). In univariate logistic regression, gestational age was not a significant predictor of neonatal apnea (OR: 1.060; 95% CI: 0.453–2.478; p=0.893).

Neonatal birth weight, length, and head circumference were measured immediately after delivery and compared between anesthetic groups. As all variables were non-normally distributed, non-parametric tests were used. Median birth weight was 2994.3 g (IQR: 430.4) in the spinal anesthesia group and 2887.7 g (IQR: 374.9) in the general anesthesia group (Mann–Whitney U=1173.0, Z=−0.531, p=0.596). Median neonatal length was 51.0 cm (IQR: 2.0) in both groups (Mann–Whitney U=1236.0, Z=−0.102, p=0.919), and median head circumference was 35.0 cm (IQR: 1.0 vs. 1.1) in the spinal and general anesthesia groups, respectively (Mann–Whitney U=1216.5, Z=−0.243, p=0.808). In univariate logistic regression, birth weight (OR: 1.000; 95% CI: 0.999–1.002; p=0.736), length (OR: 0.829; 95% CI: 0.563–1.221; p=0.343), and head circumference (OR: 1.111; 95% CI: 0.687–1.798; p=0.668) were not significant predictors of neonatal apnea.

Cesarean indications were classified as elective (77%), acute fetal compromise (11%), or maternal decompensation (12%). Their distribution was similar between anesthetic groups (χ^2=0.437, df=2, p=0.804; Cramér's V=0.066), with elective procedures accounting for 76% of cases in the spinal group and 78% in the general anesthesia group. In univariate logistic regression, cesarean delivery indication was a significant predictor of neonatal apnea (χ^2=6.476, df=2, p=0.039). Compared with elective cesarean delivery, acute fetal compromise was associated with a 4.6-fold increase in the odds of neonatal apnea (OR: 4.567; 95% CI: 1.217–17.145; p=0.024), whereas maternal decompensation showed a non-significant trend toward increased risk (OR: 2.971; 95% CI: 0.789–11.182; p=0.107).

The median time from skin incision to umbilical cord clamping was 3.86 minutes (IQR: 2.19–4.74) in the spinal anesthesia group and 4.20 minutes (IQR: 2.32–6.08) in the general anesthesia group, with no significant difference between groups (Mann–Whitney U=1162.0, Z=−0.607, p=0.544). In univariate logistic regression, this interval was not a significant predictor of neonatal apnea (OR: 1.031; 95% CI: 0.763–1.394; p=0.841).

Severe maternal hypotension requiring vasopressor administration occurred in 27% of cases (n=27), with similar prevalence in the spinal and general anesthesia groups (22% vs. 32%; χ^2=1.268, df=1, p=0.260; Cramér's V=0.113). In univariate logistic regression, severe hypotension was not associated with neonatal apnea (OR: 0.928; 95% CI: 0.340–2.528; p=0.883).

Neonatal apnea occurred in 12% of the cohort (n=12/100). Incidence was 10% in the spinal anesthesia group (n=5/50) and 14% in the general anesthesia group (n=7/50). This difference was not statistically significant (χ^2=0.379, df=1, p=0.538; Cramér's V=0.062; Fisher's exact test p=0.760).

The odds ratio was 1.465 (95% CI: 0.432–4.969), indicating no significant association between anesthetic modality and neonatal apnea (Table 2,3). Active neonatal resuscitation was required in 2 of 100 neonates (2.0%). The distribution was identical between groups, with one case in the spinal anesthesia group and one in the general anesthesia group (χ^2=0.000, p=1.000; Phi=0.000). The odds ratio was 1.000 (95% CI: 0.061–16.444), indicating no difference in resuscitation requirements between anesthetic techniques. Fisher's exact test likewise showed no association (p=1.000, two-tailed), consistent with the rarity of this outcome.

Table 2- Neonatal Baseline Characteristics and Intraoperative Parameters by Anesthesia Type.

Variable	Spinal Anesthesia (n=50)	General Anesthesia (n=50)	P value*
Neonatal baseline			
Gestational age at delivery (weeks)	38.0 (37.0–39.0)	39.0 (38.0–40.0)	0.122†
Birth weight (g), mean ± SD	2994.3 ± 487.2	2887.7 ± 521.8	0.596†
Neonatal length (cm)	51.0 (50.0–52.0)	51.0 (50.0–52.0)	0.919†
Head circumference (cm)	35.0 (34.0–36.0)	35.0 (34.0–36.0)	0.808†
Intraoperative parameters			
Skin-to-delivery time (min), median (IQR)	3.86 (3.2–4.5)	4.20 (3.5–4.9)	0.544†
Umbilical artery pH, mean ± SD	7.2725 ± 0.0451	7.2671 ± 0.0468	0.255†
Severe maternal hypotension, n (%)	11 (22.0)	16 (32.0)	0.260§
Cesarean indication, n (%)			0.804§
— Elective	39 (78.0)	38 (76.0)	
— Acute fetal compromise	6 (12.0)	5 (10.0)	
— Maternal decompensation	5 (10.0)	7 (14.0)	

SD, standard deviation; IQR, interquartile range (Q1–Q3); * P value from Mann–Whitney U test (†) or Pearson's chi-squared test (§); statistical significance set at $p < 0.05$.

Table 3- Neonatal Respiratory Outcomes and Secondary Measures by Anesthesia Type.

Outcome	Spinal Anesthesia (n=50)	General Anesthesia (n=50)	Total (N=100)	P value*
Primary outcome				
Neonatal apnea, n (%)	5 (10.0)	7 (14.0)	12 (12.0)	0.538§
Secondary outcomes				
Apgar score at 1 min, median (IQR)	8.0 (7.0–9.0)	8.0 (7.0–9.0)	—	>0.050†
Apgar score at 5 min, median (IQR)	9.0 (9.0–10.0)	9.0 (8.0–10.0)	—	>0.050†
Apgar score at 10 min, median (IQR)	10.0 (9.0–10.0)	10.0 (9.0–10.0)	—	>0.050†
Respiratory distress, n (%)	8 (16.0)	3 (6.0)	11 (11.0)	0.110§
Active neonatal resuscitation, n (%)	1 (2.0)	1 (2.0)	2 (2.0)	1.000‡
Positive pressure ventilation, n (%)	0 (0.0)	6 (12.0)	6 (6.0)	0.012*§
Immediate NICU admission, n (%)	4 (8.0)	3 (6.0)	7 (7.0)	0.695§

**NICU, neonatal intensive care unit; IQR, interquartile range (Q1–Q3); * P value from Mann–Whitney U test (†), Pearson's chi-squared test (§), or Fisher's exact test (‡); $p < 0.05$ (statistically significant); statistical significance set at $\alpha = 0.05$.

Immediate admission to the neonatal intensive care unit (NICU) occurred in 7 of 100 neonates (7.0%), including 4 cases in the spinal anesthesia group (8.0%) and 3 cases in the general anesthesia group (6.0%). This difference was not statistically significant (χ^2=0.154, p=0.695; Phi=0.039). The odds ratio was 0.734 (95% CI: 0.156–3.462), indicating no meaningful difference in NICU admission rates between anesthetic techniques. Fisher's exact test likewise confirmed the absence of a significant association (p=1.000, two-tailed).

Cyanosis or pallor during apneic episodes occurred in 12 of 100 neonates (12.0%), with a slightly higher prevalence in the general anesthesia group (7/50, 14.0%) compared to the spinal anesthesia group (5/50, 10.0%). This difference was not statistically significant (χ^2=0.379, p=0.538; Phi=0.062). The odds ratio was 1.465 (95% CI: 0.432–4.969), showing no significant association between anesthetic technique and skin color changes during apnea. Fisher's exact test confirmed this lack of statistical significance (p=0.760, two-tailed).

Physical stimulation was required in 13 of 100 neonates (13.0%), including 5 cases in the spinal anesthesia group (10.0%) and 8 cases in the general anesthesia group (16.0%). This difference was not statistically significant (χ^2=0.796, p=0.372; Phi=0.089). The odds ratio was 1.714 (95% CI: 0.520–5.657), indicating no meaningful difference between groups in the use of physical stimulation. Fisher's exact test likewise showed no significant association (p=0.554, two-tailed).

Supplemental oxygen was administered to 13 of 100 neonates (13.0%), including 5 cases in the spinal anesthesia group (10.0%) and 8 cases in the general anesthesia group (16.0%). This distribution mirrored that observed for physical stimulation and did not differ significantly between groups (χ^2=0.796, p=0.372; Phi=0.089). The odds ratio was 1.714 (95% CI: 0.520–

5.657), indicating no clinically meaningful difference between anesthetic techniques. Fisher's exact test similarly confirmed the absence of a significant association (p=0.554, two-tailed). Positive pressure ventilation (PPV) was administered to 6 of 100 neonates (6.0%). All cases occurred in the general anesthesia group, while no neonates in the spinal anesthesia group required PPV. This difference was statistically significant (χ^2=6.383, p=0.012; Phi=0.253; likelihood ratio=8.701, p=0.003). Fisher's exact test likewise confirmed a significant association between anesthetic technique and the need for PPV (p=0.027, two-tailed), making PPV the only intervention that differed significantly between groups. Several variables generated extremely large odds ratios during regression analysis due to sparse data and quasi-complete separation. To preserve model stability and avoid unreliable estimates, these variables were excluded from the final multivariable model. The wide confidence intervals observed for some predictors indicate limited precision of the effect estimates, which is likely attributable to the relatively small number of apnea events in the study population. Variables with $p < 0.20$ in univariate analysis, together with factors considered clinically relevant based on prior evidence, were entered into the multivariable logistic regression model using the enter method. In the adjusted analysis, cesarean delivery indication remained independently associated with neonatal apnea (adjusted OR = 7.03; 95% CI: 1.32–37.42; p = 0.022), confirming that obstetric factors contributed more strongly to apnea risk than anesthetic technique. In contrast, anesthesia type, maternal age, body mass index, gravidity, gestational age, amniotic fluid status, intraoperative hypotension, and the 1-minute Apgar score were not significant predictors in the multivariable model (Table 4).

Discussion

The primary objective of this study was to compare the effects of general anesthesia (GA) and spinal anesthesia (SA) on the incidence of neonatal apnea and early respiratory adaptation following term cesarean delivery. The main finding was that anesthetic technique was not significantly associated with neonatal apnea in logistic regression analysis (OR 1.465; p=0.538). In contrast, cesarean delivery indication, particularly acute fetal compromise, emerged as a major determinant of neonatal apnea. Neonates delivered because of acute fetal compromise had approximately 4.6-fold higher odds of apnea than those delivered electively (OR 4.567; 95% CI 1.217–17.145; p=0.024), and cesarean indication remained independently associated with apnea after multivariable adjustment. Although the incidence of apnea was numerically higher in the GA group (14%) than in the SA group (10%), and positive pressure ventilation (PPV) was required only among GA-exposed neonates (p=0.012), significant differences in Apgar scores, umbilical arterial pH, or NICU admission rates did not accompany these differences. Overall, these findings suggest that in a standardized term cesarean population, underlying maternal–fetal physiological conditions may have a greater influence on immediate neonatal respiratory adaptation than the choice of anesthetic technique. Our findings are consistent with those of the recent 2026 meta-analysis by Langer et al., which included 36 randomized controlled trials involving 3,456 neonates. The authors reported that although regional anesthesia was associated with slightly higher Apgar scores at one and five minutes, the absolute differences were small (+0.58 and +0.09 points) and did not translate into significant differences in NICU admission rates (RR 0.75; 95% CI 0.46–1.21) [18]. Similarly, our study showed a trend toward higher perfect Apgar scores in the spinal anesthesia group at five and ten minutes. Still, these differences were not statistically significant, suggesting limited clinical impact of anesthetic choice in elective settings. In addition, umbilical arterial pH did not differ significantly between groups in our cohort (mean difference 0.0054; p=0.255), consistent with meta-analytic evidence indicating comparable neonatal acid–base status between anesthetic techniques. Comparable findings were reported by Anıl İçel Saygı et al., whose randomized trial showed slightly better early Apgar scores with spinal anesthesia but overall similar neonatal well-being between techniques [38].

Table 4- Logistic Regression Analysis: Independent Predictors of Neonatal Apnea

Variable	Unadjusted OR (95% CI)	P value	Adjusted OR (95% CI)[a]	P value
Anesthesia type (General vs. Spinal)	1.465 (0.528–4.062)	0.538	—	—
Acute fetal compromise vs. elective	4.567 (1.217–17.145)	0.024*	7.03 (1.32–37.42)	0.022*
Maternal decompensation vs. elective	2.180 (0.612–7.765)	0.232	—	—
Maternal age (per year)	0.953 (0.866–1.050)	0.334	—	—
BMI (per unit)	1.087 (0.958–1.233)	0.201	—	—
Gestational age (per week)	0.891 (0.621–1.278)	0.528	—	—
Severe maternal hypotension	1.628 (0.571–4.639)	0.359	—	—

OR, odds ratio; CI, confidence interval; — indicates a variable not retained in the final adjusted model; [a] The adjusted model includes anesthesia type, maternal age, BMI, cesarean indication (acute fetal compromise), gestational age, and severe maternal hypotension; * $p < 0.05$ (statistically significant). Model fit statistics: Omnibus test χ^2 = 11.634, df = 10, p = 0.310; Hosmer-Lemeshow χ^2 = 6.375, df = 8, p = 0.605 (good model fit); Cox & Snell R^2 = 0.110; Nagelkerke R^2 = 0.211; Overall classification accuracy = 89.0%.

However, the Langer meta-analysis also identified a modest reduction in neonatal respiratory support with regional anesthesia, suggesting that subtle respiratory advantages of neuraxial techniques may emerge in larger pooled datasets, even if not detected in our cohort [18].

Discordant findings reported in larger observational studies require careful interpretation. For example, the seven-year retrospective analysis by Shi et al. reported substantially higher rates of 1-minute Apgar scores <7 (10.4% in GA vs. 0.7% in epidural) and NICU admission (23.1% vs. 2.9%) [19]. However, these differences likely reflect variations in study populations and clinical context. The Shi cohort included a high proportion of Category 1 emergency cesarean deliveries, in which GA is frequently selected because of its rapid induction in situations of acute maternal or fetal compromise. In such cases, neonatal outcomes may be strongly influenced by the underlying pathology, such as cord prolapse or placental abruption, and by prolonged decision-to-delivery intervals, both of which independently increase the risk of neonatal depression. Similarly, Kinsella et al. reported that in the United Kingdom, GA is commonly used for the most urgent cesarean deliveries, accounting for approximately 51% of Category 1 cases [11]. Although that study primarily described national anesthesia practice patterns rather than neonatal outcomes, it provides important context for understanding why GA is often used in the highest-risk clinical scenarios. By focusing on a more controlled population with short induction to delivery intervals (<5 minutes in GA cases), our study aimed to better isolate the effect of anesthetic technique, and no significant difference in neonatal apnea was observed between groups. The present analysis demonstrates that cesarean delivery indication, particularly acute fetal compromise, has a substantial and independent association with neonatal apnea. This finding highlights the dominant influence of fetal condition and the intrauterine environment over perioperative pharmacologic exposure. Neonates delivered for acute fetal compromise may already have experienced metabolic stress, placental insufficiency, or intrauterine hypoxemia before surgical delivery. In such circumstances, the rapid airway control and expedited delivery achievable with GA may be advantageous, provided that the interval from induction to delivery is minimized to limit fetal drug exposure. The mechanisms of GA-related neonatal respiratory depression are well recognized: agents such as propofol and volatile anesthetics readily cross the placenta and can transiently depress neonatal respiratory drive and muscle tone [16,35,38]. This likely explains why all neonates requiring positive pressure ventilation (PPV) in our cohort were in the GA group (p=0.012). These events likely reflected transient pharmacologic effects that were effectively managed with routine resuscitation and did not result in increased NICU admissions or evidence of sustained morbidity. The absence of labor-related physiological adaptations in elective cesarean delivery may contribute to neonatal respiratory morbidity regardless of anesthetic technique [16,39]. As described by Yeganegi et al., the lack of vaginal compression and labor-associated catecholamine surges results in delayed lung fluid clearance and surfactant release, predisposing neonates to transient tachypnea of the newborn (TTN) and respiratory distress syndrome (RDS) [16]. Maternal labor pain normally triggers increased catecholamine levels-particularly norepinephrine and epinephrine-which promote fetal lung fluid absorption through activation of epithelial sodium channels (ENaC). When delivery occurs without labor, this physiological mechanism is absent [16]. Gestational age also plays an important modifying role. Hansen et al. reported that neonates delivered by cesarean section at 37 weeks have nearly a fourfold higher risk of respiratory morbidity compared with those intended for vaginal delivery (OR 3.9), a risk that decreases as gestation approaches 39 weeks (OR 1.9) [39]. Although all deliveries in our study occurred at term (median 38.5 weeks), the overall apnea rate of 12% may reflect the elevated baseline risk associated with cesarean delivery without preceding labor. Maternal comorbidities, including gestational diabetes mellitus, may further increase the risk of neonatal respiratory complications [30]. These findings have important implications for anesthesiologists and perioperative physicians. Although spinal anesthesia remains the preferred first-line technique because of its favorable maternal profile, including faster postoperative recovery, earlier return of bowel function, and improved postoperative analgesia, general anesthesia should not be considered inherently harmful to the neonate in elective cesarean deliveries [38]. Our results suggest that GA represents a safe and reasonable alternative when neuraxial anesthesia is contraindicated, declined by the patient, or unsuccessful [38]. In addition, the absence of a significant association between maternal hypotension and neonatal apnea in the SA group (OR 0.928; p=0.883) likely reflects contemporary hemodynamic management strategies. Current obstetric anesthesia practice emphasizes proactive prevention and treatment of hypotension through vasopressor therapy (e.g., phenylephrine or ephedrine) and appropriate fluid administration to maintain uteroplacental perfusion [9,13]. These measures help mitigate the physiological consequences of sympathetic blockade.

Importantly, anesthetic technique was not independently associated with neonatal apnea after adjustment for confounders. In contrast, cesarean delivery indication remained independently associated with apnea, suggesting that the underlying maternal–fetal condition necessitating delivery may be a more important determinant of neonatal respiratory adaptation than the anesthetic technique itself. This study has several strengths. Its prospective design and the use of binary logistic regression allowed adjustment for clinical indications and helped reduce potential confounding. In addition, the relatively homogeneous cohort, consisting exclusively of term singleton pregnancies at a single academic center, reduced variability related to institutional practices and extreme prematurity.

Several limitations should be considered when interpreting these findings. First, the sample size of 100 deliveries (50 per group) may have limited the ability to detect small independent effects of anesthesia type on neonatal outcomes. Because only 12 apnea events occurred, the precision and stability of multivariable estimates were limited, as reflected by relatively wide confidence intervals for several predictors; therefore, the regression results should be interpreted cautiously.

Nevertheless, the significant association observed for fetal compromise suggests that the study retained sufficient power to detect clinically meaningful effects. Second, the prospective observational, single-center design may limit generalizability to institutions with different patient populations or neonatal resuscitation protocols. Third, although umbilical arterial pH was measured, detailed metabolic parameters such as base excess were not available, which could have provided additional insight into the severity of intrauterine acidosis. Finally, long-term neonatal neurodevelopmental outcomes and maternal satisfaction were not evaluated, preventing a more comprehensive assessment of the broader clinical implications of the anesthetic techniques.

Conclusion

In conclusion, anesthetic technique (general versus spinal) was not an independent determinant of immediate neonatal apnea in elective term cesarean delivery. Instead, acute fetal compromise emerged as the primary predictor of impaired early respiratory adaptation, underscoring the influence of underlying maternal–fetal conditions. While spinal anesthesia remains the preferred approach because of its established maternal benefits, general anesthesia remains an appropriate alternative when neuraxial techniques are contraindicated or not feasible. Future multicenter studies with larger cohorts and incorporation of fetal metabolic biomarkers may further clarify anesthetic decision-making in higher-risk obstetric populations.

Acknowledgment

The authors would like to express their sincere gratitude to all individuals who contributed to this study. We also acknowledge the cooperation of the clinical staff and participants whose contributions made this research possible. We especially thank Mrs. Hanieh Nateghi for her valuable support and assistance.

References

[1] Betran AP, Ye J, Moller AB, Souza JP, Zhang J. Trends and projections of caesarean section rates: global and regional estimates. BMJ Glob Health. 2021; 6(6):e005671.

[2] WHO Session. J Obstet Gynaecol Res. 2023; 49 Suppl 1:87-89.

[3] Keag OE, Norman JE, Stock SJ. Long-term risks and benefits associated with cesarean delivery for mother, baby, and subsequent pregnancies: systematic review and meta-analysis. PLoS Med. 2018; 15(1):e1002494.

[4] Sandall J, Tribe RM, Avery L, Mola G, Visser GH, Homer CS, et al. Short-term and long-term effects of caesarean section on the health of women and children. Lancet. 2018; 392(10155):1349-57.

[5] Boerma T, Ronsmans C, Melesse DY, Barros AJD, Barros FC, Juan L, et al. Global epidemiology of use of and disparities in caesarean sections. Lancet. 2018; 392(10155):1341-8.

[6] Betrán AP, Temmerman M, Kingdon C, Mohiddin A, Opiyo N, Torloni MR, et al. Interventions to reduce unnecessary caesarean sections in healthy women and babies. Lancet. 2018; 392(10155):1358-68.

[7] Rollins M, Lucero J. Overview of anesthetic considerations for Cesarean delivery. Br Med Bull. 2012; 101:105-25.

[8] Wadhwa G, Singh UK, Anand R, Swain BP, Nag DS, Sen B. Spinal anesthesia for cesarean delivery: does ropivacaine offer hemodynamic advantages over bupivacaine? Cureus. 2025; 17(5):e84809.

[9] Hawkins JL. Epidural analgesia for labor and delivery. N Engl J Med. 2010; 362(16):1503-10.

[10] Hawkins JL, Chang J, Palmer SK, Gibbs CP, Callaghan WM. Anesthesia-related maternal mortality in the United States: 1979-2002. Obstet Gynecol. 2011; 117(1):69-74.

[11] Kinsella SM, Walton B, Sashidharan R, Draycott T. Category-1 caesarean section: a survey of anaesthetic and peri-operative management in the UK. Anaesthesia. 2010; 65(4):362-8.

[12] Lucas DN, Yentis SM, Kinsella SM, Holdcroft A, May AE, Wee M, et al. Urgency of caesarean section: a new classification. J R Soc Med. 2000; 93(7):346-50.

[13] Bucklin BA, Hawkins JL, Anderson JR, Ullrich FA. Obstetric anesthesia workforce survey: twenty-year update. Anesthesiology. 2005; 103(3):645-53.

[14] Jenkins JG, Khan MM. Anaesthesia for Caesarean section: a survey in a UK region from 1992 to 2002. Anaesthesia. 2003; 58(11):1114-8.

[15] Kan RE, Hughes SC, Rosen MA, Kessin C, Preston PG, Lobo EP. Intravenous remifentanil: placental transfer, maternal and neonatal effects.

Anesthesiology. 1998; 88(6):1467-74.
[16] Yeganegi M, Bahrami R, Azizi S, Marzbanrad Z, Hajizadeh N, Mirjalili SR, et al. Caesarean section and respiratory system disorders in newborns. Eur J Obstet Gynecol Reprod Biol X. 2024; 23:100336.
[17] Hansen AK, Wisborg K, Uldbjerg N, Henriksen TB. Risk of respiratory morbidity in term infants delivered by elective caesarean section: cohort study. BMJ. 2008; 336(7635):85-7.
[18] Langer S, Lim G, Qiu Y, Biaesch J, Neuman MD. Neonatal outcomes with regional versus general anesthesia for cesarean delivery: a meta-analysis of randomized controlled trials. Anesthesiology. 2026; 144(2):325-36.
[19] Shi X, Xu C, Wen Y, Jiang M, Yu H, Wang X, et al. Perinatal outcome of emergency cesarean section under neuraxial anesthesia versus general anesthesia: a seven-year retrospective analysis. BMC Anesthesiol. 2024; 24(1):33.
[20] Kavak ZN, Başgül A, Ceyhan N. Short-term outcome of newborn infants: spinal versus general anesthesia for elective cesarean section. A prospective randomized study. Eur J Obstet Gynecol Reprod Biol. 2001; 100(1):50-4.
[21] Cojocaru L, Salvatori C, Sharon A, Seung H, Nyman K, Kodali BS, et al. General versus regional anesthesia and neonatal data: a propensity-score-matched study. Am J Perinatol. 2023; 40(3):227-34.
[22] Liu H, Miao JK, Cai M, Gan L, Zhao HQ, Lei XF, et al. Anesthetic drug concentrations and placental transfer rate in fetus between term and preterm infants, twins, and singletons. Front Pharmacol. 2023; 14:1213734.
[23] Veeser M, Hofmann T, Roth R, Klöhr S, Rossaint R, Heesen M. Vasopressors for the management of hypotension after spinal anesthesia for elective caesarean section. Systematic review and cumulative meta-analysis. Acta Anaesthesiol Scand. 2012; 56(9):1204.
[24] Ebrahim Elgzar WT, Ebrahim Said H, Ebrahim HA. Effect of lower leg compression during cesarean section on post-spinal hypotension and neonatal hemodynamic parameters: nonrandomized controlled clinical trial. Int J Nurs Sci. 2019; 6(4):478.
[25] Moisa RC, Negrut N, Macovei IC, Aur C, Botea MO, Maghiar PB, et al. The impact of maternal spinal anesthesia on newborn out-comes: a clinical perspective. Children (Basel). 2025; 12(4):450.
[26] Pečlin P, Pavlica M, Druškovič M, Kavšek G, Verdenik I, Pintarič TS. Effect of anesthetic modality on decision-to-delivery interval and maternal-neonatal outcomes in category 2 and 3 cesarean deliveries. J Clin Med. 2024; 13(24):7528.
[27] Nourkami-Tutdibi N, Tutdibi E, Faas T, Wagenpfeil G, Draper ES, Johnson S, et al. Neonatal morbidity and mortality in advanced aged mothers-maternal age is not an independent risk factor for infants born very preterm. Front Pediatr. 2021; 9:747203.
[28] Rodrigues I, Soares H, Rocha G, Azevedo I. Impact of advanced maternal age on neonatal morbidity: a systematic review. J Matern Fetal Neonatal Med. 2023; 36(2):2287981.
[29] Schwartz A, Many A, Shapira U, Rosenberg Friedman M, Yogev Y, Avnon T, et al. Perinatal outcomes of pregnancy in the fifth decade and beyond- a comparison of very advanced maternal age groups. Sci Rep. 2020; 10(1):1809.
[30] Yang F, Liu H, Ding C. Gestational diabetes mellitus and risk of neonatal respiratory distress syndrome: a systematic review and meta-analysis. Diabetol Metab Syndr. 2024; 16(1):294.
[31] Roguin N, Gutvirtz G, Wainstock T, Sheiner E. The impact of maternal chronic hypertension in pregnancy on offspring long-term respiratory morbidity. Pregnancy Hypertens. 2026; 43:101405.
[32] Brown HK, Fung K, Cohen E, Dennis CL, Grandi SM, Rosella LC, et al. Multiple maternal chronic conditions and risk of severe neonatal morbidity and mortality. JAMA Netw Open. 2026; 9(1):e2555558.
[33] Seo N, Lee YM, Kim YJ, Sung JH, Hur KY, Choi SJ, et al. Obesity is associated with higher risk of adverse maternal and neonatal outcomes than supervised gestational diabetes. J Korean Med Sci. 2023; 38(33):e268.
[34] Reed J, Case S, Rijhsinghani A. Maternal obesity: perinatal implications. SAGE Open Med. 2023; 11:20503121231176128.
[35] Langer S, Lim G, Qiu Y, Biaesch J, Neuman MD. Neonatal outcomes with regional versus general anesthesia for cesarean delivery: a meta-analysis of randomized controlled trials. Anesthesiology. 2026; 144(2):325-36.
[36] Cocchi E, Pini R, Gallipoli A, Stella M, Antonazzo P, Marchetti F, et al. Impact of general vs. neuraxial anesthesia on neonatal outcomes in non-elective cesarean sections. Front Pediatr. 2025; 13:1518456.
[37] Watson SE, Richardson AL, Lucas DN. Neuraxial and general anaesthesia for caesarean section. Best Pract Res Clin Anaesthesiol. 2022; 36(1):53-68.
[38] Saygı Aİ, Özdamar Ö, Gün İ, Emirkadı H, Müngen E, Akpak YK. Comparison of maternal and fetal outcomes among patients undergoing cesarean section under general and spinal anesthesia: a randomized clinical trial. Sao Paulo Med J. 2015; 133(3):227-34.
[39] Hansen AK, Wisborg K, Uldbjerg N, Henriksen TB. Risk of respiratory morbidity in term infants delivered by elective caesarean section: cohort study. BMJ. 2008; 336(7635):85-7.