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Original Research

The Influence of Interpregnancy Interval on Maternal Complications and Pregnancy Outcomes After Prior Cesarean: A Retrospective Cohort Study

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Abstract

Background: The interpregnancy interval (IPI) is a significant factor influencing pregnancy outcomes, particularly in women with a prior cesarean section. Understanding how IPI influences maternal complications and pregnancy outcomes is crucial for guiding post-cesarean pregnancy management. **Methods**: A retrospective cohort study was conducted on 1803 women who underwent cesarean delivery at Guangzhou Women and Children's Medical Center between January 1, 2011, and June 30, 2022. Those with a first cesarean delivery followed by one or more subsequent births were included. Participants were assigned into four IPI-based groups for comparison. Data of clinical characteristics (including age, marital status, mode of delivery, newborn weight, and medical history), maternal complications [including gestational diabetes mellitus (GDM), gestational hypertension, preeclampsia, polyhydramnios, oligohydramnios, placenta accreta, and placenta previa], and pregnancy outcomes [including fetal distress, macrosomia, postpartum hemorrhage, premature rupture of membranes (PROM), and preterm birth] were collected and analyzed using univariate and multivariate logistic regression. **Results**: Significant differences in clinical characteristics and maternal complications were observed across the IPI groups after cesarean section. Women with IPIs of $\geq$60 months had the highest mean age (34.09 $\pm$ 2.92, $p < 0.001$) and increased risks of GDM (26.04%, $p = 0.021$) and placenta accreta (7.29%, $p = 0.010$). The IPI group of $<$18 months exhibited the highest rates of gestational hypertension (15.15%) and oligohydramnios (4.55%). Significant associations between IPI and adverse pregnancy outcomes, such as fetal distress and PROM, were observed, particularly at the extremes of IPI ($<$18 months and $\geq$60 months). After adjusting for potential confounding factors, including age and history of gestational hypertension, preeclampsia, postpartum hemorrhage, macrosomia, placenta previa, and fetal distress, multivariate logistic regression analysis revealed that the risk of GDM was significantly reduced in the 18–23 months IPI group compared to the 24–59 month group [adjusted odds ratio (OR) = 0.630; 95% confidence interval (CI): 0.431–0.920; $p < 0.017$]. Gestational hypertension was strongly associated with shorter IPIs, whereas preeclampsia and placenta accreta were more common with longer IPIs. The risk of PROM increased with both very short and very long IPIs. Postpartum hemorrhage was more frequent in the 18–23 months group, and preterm birth risk increased significantly with IPIs of $\geq$60 months. **Conclusion**: Both short and long IPIs following a cesarean section are associated with specific adverse maternal complications and pregnancy outcomes. Individualized counseling and planning for subsequent pregnancies may benefit women with a history of cesarean delivery to minimize these risks.

Keywords: interpregnancy interval; cesarean section; pregnancy outcomes; maternal complications

1. Introduction

As global cesarean section rates continue to rise, understanding their implications for subsequent pregnancies has become a paramount concern in obstetric care [1]. In China, the rate of cesarean sections is relatively high, and with the comprehensive relaxation of China's fertility policy, an increasing number of pregnant women are opting for pregnancy after prior cesarean (PAPC). The interpregnancy interval (IPI), defined as the time between a live birth and the conception of the next pregnancy, is a crucial aspect that influences maternal and neonatal outcomes [2,3]. A growing body of evidence suggests that both short and long IPIs may be associated with increased risks of adverse pregnancy outcomes [4,5]. When the IPI is too short, the mother may not fully recover from the physical demands of pregnancy and breastfeeding, potentially leading to adverse pregnancy outcomes, such as preterm birth. Conversely, an excessively long IPI may increase the risk of developing pregnancy complications or comorbid conditions [6,7]. However, the specific implications of IPI following a pre-

vious cesarean delivery remain poorly understood. This issue is particularly relevant given the unique physiological and surgical considerations that follow a cesarean section, including concerns of uterine scar healing and the potential for complications such as uterine rupture in subsequent pregnancies.

The World Health Organization (WHO) and the American College of Obstetricians and Gynecologists (ACOG) have provided guidelines recommending optimal IPIs to reduce the risk of adverse perinatal outcomes. Practice Guidelines from ACOG advise an IPI of at least 18 months to reduce the risk of preterm birth, highlighting the importance of this modifiable factor [8]. In addition, guidelines on optimal IPIs recommend waiting at least 24 months before becoming pregnant again to reduce the risk of adverse maternal and child health outcomes [9]. However, these recommendations are primarily based on outcomes following vaginal deliveries. Research on IPI after cesarean sections, especially regarding maternal complications, remains limited and inconclusive. This knowledge gap hinders the development of clear clinical guidance for women and healthcare providers when planning the timing of subsequent pregnancies after a cesarean.

A recent study has begun to explore the relationship between IPI and pregnancy outcomes after a prior cesarean, suggesting potential risks associated with both short and extended IPIs. A quantile regression analysis reported that IPIs $<$12 and $>$36 months were associated with adverse perinatal outcomes, such as low birth weight, preterm delivery, and small-for-gestational age infants. Conversely, a long IPI may be associated with an increased risk of gestational diabetes mellitus (GDM), and obesity, impacting birth weight [10]. Nevertheless, these studies often lack the methodological rigor required for translation into clinical practice, with many failing to adequately control for confounding variables that can influence both the decision to conceive and the pregnancy outcomes.

This study aims to provide a comprehensive evaluation of the impact of IPI on maternal complications and pregnancy outcomes among women with a history of cesarean delivery, a high-risk cohort that has been relatively underrepresented in previous research. By categorizing participants into four IPI-based groups and employing robust statistical analyses, we aim to clarify how varying IPIs influence maternal and neonatal risks, thereby offering clinically relevant evidence to guide counseling and pregnancy planning after cesarean delivery.

2. Methods

2.1 Study Cohort and Design

This study retrospectively included women who delivered by cesarean section at Guangzhou Women and Children's Medical Center from January 1, 2011, to June 30, 2022. Inclusion criteria were women whose first delivery was by cesarean section and who subsequently had one or more deliveries at Guangzhou Women and Children's Medical Center, with had complete clinical information available. All participants underwent repeat cesarean delivery, and trial of labor after cesarean (TOLAC) was not performed. Exclusion criteria were: (1) twin or multiple pregnancies; (2) miscarriage before 28 weeks of gestation; and (3) missing data on IPI or outcomes. A total of 1803 women were ultimately enrolled into the study cohort.

The IPI was defined as the time from the delivery of the first child by cesarean cessation to the estimated date of the last menstrual cycle preceding the subsequent conception, measured in complete months. In accordance with the IPI thresholds recommended by the WHO and the ACOG at 18, 24, and 60 months, participants were categorized into four IPI-based groups: $<$18 months (n = 66), 18–23 months (n = 250), 24–59 months (n = 1391), and $\geq$60 months (n = 96). Clinical characteristics, maternal complications and pregnancy outcomes were compared across the groups. Following WHO guidelines, the 24–59 months group served as the reference to assess the influence of IPI on maternal complications and pregnancy outcomes in PAPC.

2.2 Data Collection

Data were collected from medical records, including age, marital status, IPI, mode of delivery, history of GDM, gestational hypertension, preeclampsia, postpartum hemorrhage, preterm birth, macrosomia, polyhydramnios, oligohydramnios, premature rupture of membranes (PROM), placenta previa, fetal distress, nosocomial infection, and placenta accreta. Maternal complications analyzed included GDM, gestational hypertension, preeclampsia, polyhydramnios, oligohydramnios, placenta accreta, and placenta previa, while pregnancy outcomes included fetal distress, macrosomia, postpartum hemorrhage, PROM, and preterm birth in PAPC.

2.3 Statistical Analyses

Statistical analyses were conducted using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables with a normal distribution, measurements were expressed as mean $\pm$ standard deviation, and comparisons among multiple groups were performed using one-way analysis of variance (ANOVA). Categorical variables were presented as case numbers and percentages. The Chi-square (χ^2) test was used for comparisons when all expected frequencies were $\geq$5, whereas Fisher's exact test was applied when the expected frequency in any cell was $<$5. The influence of the IPI on pregnancy outcomes in multiparous women was analyzed using univariate analysis and multivariate logistic regression models. The multivariate logistic regression model was adjusted for confounding factors, including age, history of gestational hypertension, preeclampsia, postpartum hemorrhage, macrosomia, placenta previa and fetal distress. Odds ratios (OR) and 95%

Table 1. Demographic characteristics and maternal medical history in previous pregnancies at second pregnancy in relation to IPI in women with pregnancy after prior cesarean (PAPC).

Variables	<18 months (n = 66)	18–23 months (n = 250)	24–59 months (n = 1391)	≥60 months (n = 96)	F/χ^2	*p*-value
Age (years)	30.89 ± 4.48	30.39 ± 4.19	32.19 ± 3.57	34.09 ± 2.92	29.717	<0.001
Marital status [n (%)]						0.294
Married	65 (98.48)	243 (97.20)	1369 (98.42)	93 (96.87)		
Other	1 (1.52)	7 (2.80)	22 (1.58)	3 (3.13)		
Modes of delivery [n (%)]						0.171
Cesarean section	66 (100.00)	235 (94.00)	1315 (93.54)	90 (93.75)		
Natural childbirth	0 (0.00)	15 (6.00)	76 (5.46)	6 (6.25)		
Newborn weight (g)	3137.29 ± 648.23	3200.72 ± 429.86	3193.27 ± 475.40	3202.40 ± 353.90	0.343	0.795
Maternal medical history in previous pregnancies [n (%)]						
GDM	11 (16.67)	53 (21.20)	248 (17.83)	12 (12.50)	3.813	0.282
Gestational hypertension	8 (12.12)	7 (2.80)	63 (4.53)	6 (6.25)	10.819	0.013
Preeclampsia	1 (1.52)	8 (3.20)	25 (1.80)	6 (6.25)		0.031
Postpartum hemorrhage	4 (6.06)	17 (6.80)	39 (2.80)	1 (1.04)		0.005
Preterm birth	0 (0.00)	4 (1.60)	27 (1.94)	0 (0.00)		0.567
Macrosomia	1 (1.52)	11 (4.40)	113 (8.12)	5 (5.21)		0.036
Polyhydramnios	0 (0.00)	7 (2.80)	24 (1.73)	4 (4.17)		0.159
Oligohydramnios	8 (12.12)	24 (9.60)	105 (7.55)	7 (7.29)	2.847	0.416
PROM	17 (25.76)	50 (20.00)	317 (22.79)	17 (17.71)	2.580	0.461
Placenta previa	0 (0.00)	16 (6.40)	48 (3.45)	1 (1.04)		0.024
Fetal distress	6 (9.09)	20 (8.00)	62 (4.46)	3 (3.13)		0.037
Nosocomial infection	1 (1.52)	1 (0.40)	6 (0.43)	1 (1.04)		0.247
Placenta accreta	0 (0.00)	1 (0.40)	10 (0.72)	1 (1.04)		0.810

IPI, interpregnancy interval; GDM, Gestational diabetes mellitus; PROM, premature rupture of membranes.

confidence intervals (CI) were calculated. Sensitivity analyses were performed by excluding the extreme IPI groups (<18 months and ≥60 months) in separate models, using 24–59 months as the reference. The results are shown in the supplementary materials (**Supplementary Tables 1,2,3,4**). *p*-value < 0.05 was considered statistically significant.

3. Results

3.1 Comparison of Clinical Characteristics in PAPC Across Different IPIs

The mean age differed significantly across the groups ($p < 0.001$), with the highest average age observed in the ≥60 months group (34.09 ± 2.92 years) and the lowest in the <18 months group (30.89 ± 4.48 years). Marital status did not show significant differences between groups ($p = 0.294$), with the majority of women in all groups being married. Regarding modes of delivery, there were no significant differences among the groups ($p = 0.171$). Cesarean section was the predominant mode of delivery, with the highest rate observed in the <18 months group (100.00%). Newborn weight did not differ significantly across the groups ($p = 0.795$), with mean weights being similar across all groups. In terms of medical history, significant differences were found in gestational hypertension ($p = 0.013$), preeclampsia ($p = 0.031$), postpartum hemorrhage ($p = 0.005$), macrosomia ($p = 0.036$), placenta previa ($p = 0.024$), and fetal distress ($p = 0.037$). Gestational hypertension was most frequent in the <18 months group (12.12%), preeclampsia in the ≥60 months group (6.25%), and postpartum hemorrhage in the 18–23 months (6.80%) and <18 months (6.06%) groups. The 24–59 months group showed the highest rate of macrosomia (8.12%), while placenta previa (6.40%) and fetal distress (9.09%) were more common in the 18–23 months and <18 months groups, respectively. No significant differences were found in GDM, preterm birth, polyhydramnios, oligohydramnios, PROM, nosocomial infection, or placenta accreta (Table 1).

3.2 Comparison of Maternal Complications of PAPC With Varying IPIs

To determine the impact of IPI on various maternal complications in PAPC, the occurrence of complications from the four different IPI groups was recorded. GDM showed a statistically significant association with IPI ($p = 0.021$), with incidence increasing at longer intervals, peaking in the ≥60 months group (26.04%) and being the lowest in the <18 month group (15.15%). Gestational hypertension was significantly affected by the IPI ($p = 0.001$), with the highest prevalence found in the <18 month group (15.15%). The occurrence was notably less frequent in the other groups, with 3.20% for 18–23 months, 5.10% for 24–59 months, and 7.29% for ≥60 months. Preeclampsia did

Table 2. Maternal complications during the index pregnancy in PAPC across different IPIs.

Complications	<18 months (n = 66)	18–23 months (n = 250)	24–59 months (n = 1391)	≥60 months (n = 96)	F/χ^2	*p*-value
GDM	10 (15.15)	41 (16.40)	334 (24.01)	25 (26.04)	9.759	0.021
Gestational hypertension	10 (15.15)	8 (3.20)	71 (5.10)	7 (7.29)	15.753	0.001
Preeclampsia	1 (1.52)	5 (2.00)	25 (1.80)	5 (5.21)		0.161
Polyhydramnios	0 (0.00)	5 (2.00)	37 (2.66)	1 (1.04)		0.601
Oligohydramnios	3 (4.55)	7 (2.80)	17 (1.22)	1 (1.04)		0.049
Placenta accreta	3 (4.55)	4 (1.60)	28 (2.01)	7 (7.29)		0.010
Placenta previa	0 (0.00)	4 (1.60)	20 (1.46)	3 (3.13)		0.443

Table 3. Pregnancy outcomes during the index pregnancy of PAPC with varying IPIs.

Outcomes	<18 months (n = 66)	18–23 months (n = 250)	24–59 months (n = 1391)	≥60 months (n = 96)	F/χ^2	*p*-value
Fetal distress	8 (12.12)	25 (10.00)	87 (6.25)	14 (14.58)	14.446	0.002
Macrosomia	3 (4.55)	5 (2.00)	35 (2.52)	1 (1.04)		0.527
Postpartum hemorrhage	2 (3.03)	15 (6.00)	35 (2.52)	1 (1.04)		0.025
PROM	8 (12.12)	11 (4.40)	81 (5.82)	12 (12.50)	11.096	0.010
Preterm birth	5 (7.58)	10 (4.00)	67 (4.82)	11 (11.46)		0.022

not differ significantly across the IPI groups (p = 0.161). Similarly, the incidence of polyhydramnios and placenta previa did not differ significantly across IPI groups (p = 0.601 and p = 0.443, respectively). Oligohydramnios was significantly associated with IPI (p = 0.049), with the highest rate in the <18 month group (4.55%). Placenta accreta incidence significantly varied across the groups (p = 0.010), with the highest frequency observed in the ≥60 month group (7.29%). These results indicate that both short and long IPIs may be associated with specific adverse maternal outcomes. Short intervals (<18 months) were significantly associated with gestational hypertension and oligohydramnios, while long intervals (≥60 months) were associated with an increased risk of GDM and placenta accreta (Table 2).

3.3 Comparison of Outcome of PAPC With Varying IPIs

Furthermore, we assessed the influence of different IPIs on pregnancy outcomes in PAPC, including fetal distress, macrosomia, postpartum hemorrhage, PROM, and preterm birth. Fetal distress was significantly associated with IPI (p = 0.002), with the highest incidence reported in the ≥60 month group (14.58%) and the lowest in the 24–59 month group (6.25%). Macrosomia did not show a significant association with IPI (p = 0.527), indicating that the interval between pregnancies does not significantly affect the risk of this condition. Postpartum hemorrhage showed a significant association with IPI (p = 0.025), with a higher incidence in the 18–23 month group (6.00%) compared to the 24–59 month group (2.52%). PROM was significantly associated with IPI (p = 0.010), with similarly high rates in the <18 month group (12.12%) and the ≥60 month group (12.50%), suggesting that both very short and very long intervals may increase the risk of PROM. Preterm birth was also significantly associated with IPI (p = 0.022), with the highest incidence found in the ≥60 month group (11.46%) and the lowest in the 18–23 month group (4.00%) (Table 3). The data indicate that both very short and very long IPIs are associated with an increased risk of certain adverse pregnancy outcomes.

3.4 Multivariate Logistic Analysis of the Influence of IPI on the Maternal Complications in PAPC

Multivariate logistic analysis was further performed to evaluate the influence of IPI on specific maternal complications. For GDM, the crude ORs indicated no significant association for intervals of <18 months (OR = 0.565; 95% CI: 0.285–1.120; p = 0.102) and ≥60 months (OR = 1.114; 95% CI: 0.695–1.787; p = 0.653) when compared to the 24–59 month reference group. However, the 18–23 months group showed a statistically significant association(OR = 0.621; 95% CI: 0.435–0.887; p = 0.009), indicating that the risk of GDM in PAPC with an IPI of 18–23 months was significantly decreased when compared with 24–59 month group. The adjusted ORs, which adjusted the potential confounders including age, history of gestational hypertension, preeclampsia, postpartum hemorrhage, macrosomia, placenta previa, and fetal distress, followed the similar pattern. Regarding gestational hypertension, the crude OR for the <18 month group was statistically significantly higher (OR = 3.320; 95% CI: 1.626–6.780; p = 0.001), suggesting a strong association between shorter IPIs and an increased risk of gestational hypertension. The adjusted OR further supported this with even higher significance (OR = 4.317; 95% CI: 2.033–9.167; $p < 0.001$). The other IPI groups did not show significant differences. For preeclampsia, no significant associations were observed in the crude ORs for IPI groups <18 months and 18–23 months. However, a significant association was found for the ≥60 months group (OR = 3.002; 95% CI: 1.123–8.026; p = 0.028), which did not remain significant after adjustment (OR = 2.245; 95% CI: 0.783–6.434; p = 0.132). Oligohydramnios showed a sig-

Table 4. The influence of IPI on the maternal complications of PAPC revealed by multivariate logistic analysis.

Complications of second pregnancy	<18 months (n = 66)		18–23 months (n = 250)		24–59 months (n = 1391)	≥60 months (n = 96)	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value	OR	OR (95% CI)	*p*-value
GDM							
Crude	0.565 (0.285–1.120)	0.102	0.621 (0.435–0.887)	0.009	1.000	1.114 (0.695–1.787)	0.653
Adjusted	0.572 (0.281–1.163)	0.123	0.630 (0.431–0.920)	0.017	1.000	0.885 (0.536–1.461)	0.634
Gestational hypertension							
Crude	3.320 (1.626–6.780)	0.001	0.615 (0.292–1.293)	0.200	1.000	1.462 (0.653–3.273)	0.355
Adjusted	4.317 (2.033–9.167)	<0.001	0.689 (0.315–1.508)	0.351	1.000	1.104 (0.460–2.650)	0.825
Preeclampsia							
Crude	0.841 (0.112–6.300)	0.866	1.115 (0.423–2.941)	0.826	1.000	3.002 (1.123–8.026)	0.028
Adjusted	0.617 (0.068–5.593)	0.668	0.901 (0.279–2.904)	0.861	1.000	2.245 (0.783–6.434)	0.132
Oligohydramnios							
Crude	3.849 (1.099–13.475)	0.035	2.328 (0.955–5.674)	0.063	1.000	0.851 (0.112–6.462)	0.876
Adjusted	3.849 (1.070–13.848)	0.039	2.496 (0.996–6.253)	0.051	1.000	0.894 (0.116–6.892)	0.914
Placenta accreta							
Crude	2.318 (0.686–7.829)	0.176	0.792 (0.275–2.276)	0.664	1.000	3.829 (1.627–9.007)	0.002
Adjusted	2.178 (0.604–7.854)	0.234	0.835 (0.277–2.514)	0.748	1.000	3.118 (1.255–7.745)	0.014

OR, odds ratio; CI, confidence interval.

nificant crude OR in the <18 month group (OR = 3.849; 95% CI: 1.099–13.475; $p = 0.035$), suggesting an increased risk with shorter IPIs, which remained significant after adjustment (OR = 3.849; 95% CI: 1.070–13.848; $p = 0.039$). The 18–23 month group approached significance but did not reach it (crude OR = 2.328, 95% CI: 0.955–5.674, $p = 0.063$; adjusted OR = 2.496, 95% CI: 0.996–6.253, $p = 0.051$). Placenta accreta exhibited no significant association in the <18 month group (crude OR = 2.318; 95% CI: 0.686–7.829; $p = 0.176$) but did show a significant association in the ≥60 months group (crude OR = 3.829; 95% CI: 1.627–9.007; $p = 0.002$). This association remained significant after adjustment (adjusted OR = 3.118; 95% CI: 1.255–7.745; $p = 0.014$) (Table 4). Sensitivity analyses excluding the extreme IPI groups confirmed the consistency of the main findings. The associations between short IPI and gestational hypertension and oligohydramnios, and of long IPI with GDM, placenta accreta, preterm birth, and fetal distress, remained directionally consistent, although some lost significance due to smaller sample sizes (**Supplementary Tables 1,2,3,4**).

3.5 Multivariate Logistic Analysis of the Influence of IPI on the Outcomes in PAPC

Next, we applied multivariate logistic analysis to investigate the impact of IPI on the outcomes of PAPC. For PROM, the <18 months group showed a significant increase in risk (crude OR = 2.231, 95% CI: 1.030–4.830, $p = 0.042$). The adjusted OR was even higher at 2.414 (95% CI: 1.092–5.337, $p = 0.029$). A similar significant increase in risk was observed for intervals of ≥60 months, with a crude OR of 2.310 (95% CI: 1.212–4.404, $p = 0.011$) and an adjusted OR of 1.977 (95% CI: 1.006–3.884, $p = 0.048$). Postpartum hemorrhage did not show a significant association with an IPI of less than 18 months (crude OR = 1.211, 95% CI: 0.285–5.145, $p = 0.796$; adjusted OR = 1.060, 95% CI: 0.238–4.717, $p = 0.939$). However, there was a significant association for the 18–23 months interval, with a crude OR of 2.473 (95% CI: 1.330–4.599, $p = 0.004$) and an adjusted OR of 2.237 (95% CI: 1.135–4.412, $p = 0.02$). The risk of preterm birth was not significantly increased for intervals of <18 months (crude OR = 1.620, 95% CI: 0.630–4.164, $p = 0.317$; adjusted OR = 1.586, 95% CI: 0.588–4.275, $p = 0.362$) or 18–23 months (crude OR = 0.823, 95% CI: 0.418–1.623, $p = 0.575$; adjusted OR = 0.920, 95% CI: 0.451–1.876, $p = 0.819$). However, a significant increase in risk was noted for ≥60 months, with a crude OR of 2.557 (95% CI: 1.303–5.019, $p = 0.006$), although this was not significant in the adjusted model (OR = 1.830, 95% CI: 0.891–3.757, $p = 0.100$). Macrosomia showed no significant association with IPI in any interval category, with both crude and adjusted ORs remaining nonsignificant across all groups. Fetal distress was significantly associated with an IPI of less than 18 months in the adjusted model (OR = 2.319, 95% CI: 1.048–5.130, $p = 0.038$) and with an IPI of ≥60 months in both the crude (OR = 2.559, 95% CI: 1.395–4.695, $p = 0.002$) and adjusted (OR = 2.057, 95% CI: 1.070–3.957, $p = 0.031$) models. The 18–23 months interval also showed a significant association (crude OR = 1.665, 95% CI: 1.044–2.656, $p = 0.032$; adjusted OR = 1.916, 95% CI: 1.174–3.127, $p = 0.009$) (Table 5).

4. Discussion

This retrospective cohort study provides valuable evidence into the influence of IPI on maternal complications and pregnancy outcomes in women with a prior cesarean

Table 5. The influence of IPI on the outcomes of PAPC revealed by multivariate logistic analysis.

Outcomes of second pregnancy	<18 months (n = 66)		18–23 months (n = 250)		24–59 months (n = 1391)	≥60 months (n = 96)	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value	OR	OR (95% CI)	*p*-value
PROM							
Crude	2.231 (1.030–4.830)	0.042	0.744 (0.391–1.418)	0.744	1.000	2.310 (1.212–4.404)	0.011
Adjusted	2.414 (1.092–5.337)	0.029	0.863 (0.446–1.668)	0.660	1.000	1.977 (1.006–3.884)	0.048
Postpartum hemorrhage							
Crude	1.211 (0.285–5.145)	0.796	2.473 (1.330–4.599)	0.004	1.000	0.408 (0.055–3.009)	0.379
Adjusted	1.060 (0.238–4.717)	0.939	2.237 (1.135–4.412)	0.020	1.000	0.342 (0.046–2.551)	0.295
Preterm birth							
Crude	1.620 (0.630–4.164)	0.317	0.823 (0.418–1.623)	0.575	1.000	2.557 (1.303–5.019)	0.006
Adjusted	1.586 (0.588–4.275)	0.362	0.920 (0.451–1.876)	0.819	1.000	1.830 (0.891–3.757)	0.100
Macrosomia							
Crude	1.845 (0.552–6.161)	0.320	0.791 (0.307–2.038)	0.627	1.000	0.408 (0.055–3.009)	0.379
Adjusted	1.815 (0.535–6.165)	0.339	0.782 (0.299–2.048)	0.617	1.000	0.443 (0.059–3.296)	0.426
Fetal distress							
Crude	2.067 (0.957–4.467)	0.065	1.665 (1.044–2.656)	0.032	1.000	2.559 (1.395–4.695)	0.002
Adjusted	2.319 (1.048–5.130)	0.038	1.916 (1.174–3.127)	0.009	1.000	2.057 (1.070–3.957)	0.031

section. Our findings suggest that both short (<18 months) and long (≥60 months) IPIs are associated with specific adverse maternal and pregnancy outcomes, which is consistent with earlier research. According to a meta-analysis, IPIs shorter than 18 months and longer than 59 months significantly increase the risk of adverse perinatal outcomes, such as preterm birth, small-for-gestational-age infants, and low birth weight [11]. This suggests that an appropriate IPI may help prevent such outcomes. Based on a retrospective cohort study of 227,352 cases in South China from 2000 to 2015, IPIs shorter than 18 months were associated with increased risks of preterm birth and small-for-gestational-age infants, while IPIs longer than 60 months increased the risks of preterm birth and large-for-gestational-age infants [12]. In addition, previous studies have confirmed that both very short and very long IPIs can adversely affect perinatal outcomes [13,14].

According to the results of our study, short IPIs were significantly associated with increased risks of gestational hypertension and oligohydramnios. This aligns with previous research indicating that insufficient recovery time between pregnancies can adversely affect maternal health, potentially due to inadequate time for the restoration of nutritional reserves and physiological recovery after childbirth, thereby increasing vulnerability to these complications [5,15,16]. The increased risk of gestational hypertension with short IPIs could potentially reflect insufficient time for the cardiovascular system to return to its pre-pregnancy physiological baseline. Pregnancy induces significant cardiovascular adaptations, including increased blood volume and cardiac output [17,18]. A short interval between pregnancies may not allow these changes to fully revert, which could predispose women to hypertension in a subsequent pregnancy. In addition, oligohydramnios, a condition characterized by reduced amniotic fluid, could be related to cumulative stress on the kidneys and the uterine environment [19]. The kidneys play a crucial role in maintaining amniotic fluid volume by regulating the balance of fluids and electrolytes. Closely spaced pregnancies may not provide adequate recovery time for the kidneys, compromising their ability to maintain appropriate amniotic fluid levels. Similarly, inadequate recovery time may adversely affect the uterine environment, contributing to the development of oligohydramnios.

Conversely, long IPIs (≥60 months) were associated with an elevated risk of GDM and placenta accreta. Age is a well-established risk factor for GDM, and women with longer IPIs are typically older, which can increase the likelihood of developing GDM during pregnancy [20,21]. Furthermore, the increased risk of placenta accreta in cases with longer IPIs may be associated with alterations in the uterine scar tissue over time [22]. This scar tissue, often a result of previous cesarean deliveries or other uterine surgeries, can undergo changes that affect its structure and integrity [22]. These alterations may lead to abnormal placental attachment and increase the risk of placenta accreta, a condition in which the placenta invades the uterine wall, making it difficult to detach after childbirth [23]. This can lead to significant maternal complications, such as hemorrhage and the need for surgical intervention. Interestingly, our multivariate analysis revealed that the risk of GDM was significantly reduced in women with an IPI of 18–23 months compared with those with intervals of 24–59 months. One possible explanation for this finding may be the residual metabolic adaptations from the previous pregnancy. Pregnancy induces profound physiological and metabolic changes, including improved insulin sensitivity during the early postpartum period and adapta-

tions in glucose and lipid metabolism. It is plausible that within 18–23 months after a prior cesarean delivery, these favorable metabolic adaptations may persist to some extent, thereby exerting a protective effect against the development of GDM in the subsequent pregnancy. In contrast, with longer IPIs, such protective adaptations may gradually diminish, leading to a higher baseline risk of GDM. These findings highlight a potentially important biological mechanism linking pregnancy spacing and maternal metabolic health, which warrants further investigation in prospective studies.

In addition, our analysis showed that the crude OR for preterm birth in women with an IPI of $\geq$60 months was statistically significant; however, this association lost significance after adjusting for confounders. A similar trend was observed for preeclampsia. These findings suggest that maternal age, a key confounder in our models, likely accounts for a substantial portion of the observed risks associated with long IPIs. Advanced maternal age is a well-recognized independent risk factor for adverse pregnancy outcomes, and its role may attenuate the independent effects of prolonged IPI. This underscores the importance of interpreting long IPI-related risks in the context of maternal age and highlights the complex interplay between pregnancy spacing and biological aging. Interestingly, the study found that the risk of certain complications, such as GDM, was significantly reduced in the 18–23 months IPI group compared with the 24–59 month group. This suggests the existence of an optimal IPI range that may minimize specific risks associated with cesarean sections. However, it is important to note that this observation needs further investigation in future studies to provide conclusive evidence.

The study's findings on the influence of IPI on pregnancy outcomes are particularly noteworthy. Both very short and very long IPIs were associated with increased risks of PROM, postpartum hemorrhage, and preterm birth. Consistent with previous research, an IPI shorter than 6 months has been associated with a significantly increased risk of preterm birth, low birth weight infants, and neonatal mortality [24,25]. Additionally, a recent meta-analysis encompassing 26 studies has demonstrated a substantial increase in perinatal mortality risk with an IPI shorter than 6 months [26]. As for the women with long IPI, it has been reported that an IPI longer than 59 months has been associated with a 12% to 45% higher risk of preterm birth [27]. Moreover, both very short and very long IPIs were also associated with an increased risk of fetal distress in this study. Similarly, in the case of very short IPIs, the insufficient recovery time may lead to various physiological challenges, such as nutritional depletion and an inadequate replenishment of essential nutrients required for a healthy pregnancy, which can consequently contribute to an increased risk of fetal distress during the subsequent pregnancy. In contrast, very long IPIs may result in changes in the maternal body that reduce its adaptability to the demands of pregnancy, potentially increasing the risk of fetal distress. These associations highlight the complex interplay between maternal recovery, age, and the physiological challenges of pregnancy following a cesarean section.

Our findings indicate that IPIs of 18–23 months and 24–59 months are associated with relatively favorable maternal and pregnancy outcomes compared with very short ($<$18 months) or very long ($\geq$60 months) intervals. Short IPIs were strongly associated with increased risks of gestational hypertension and oligohydramnios, whereas long IPIs were linked to higher incidences of GDM, placenta accreta, preterm birth, and fetal distress. These results suggest that both extremes of IPI carry increased risks, and that an intermediate IPI ranging from 18 to 59 months may be more favorable. From a clinical perspective, these findings underscore the importance of integrating individualized risk assessment into counseling for women with a history of cesarean delivery. In particular, when advising women on pregnancy spacing, clinicians should consider not only the IPI but also maternal age, underlying comorbidities, and reproductive intentions to optimize outcomes. No cases of uterine rupture or uterine dehiscence were observed in this cohort.

This study has several strengths. Firstly, it addresses a crucial gap in the literature by specifically focusing on the influence of IPI on maternal complications and pregnancy outcomes following a cesarean section. Secondly, it employs a retrospective cohort design with a substantial sample size, enhancing the statistical power of the findings. Thirdly, the study categorizes participants into four IPI-based groups, enabling a more detailed and nuanced analysis of the impact of varying IPIs. Finally, the study employs robust statistical analyses, including univariate and multivariate logistic regression, to control for potential confounding factors.

Limitations

This study has several limitations. First, it was conducted at a single tertiary hospital, which may limit the generalizability of the findings to broader populations or different healthcare settings. Second, although multiple confounding factors were adjusted for, residual confounding from unmeasured variables, such as socioeconomic status, lifestyle behaviors, or detailed comorbidities cannot be completely excluded. Third, the sample sizes in the very short or very long IPIs were relatively small, which may have reduced the statistical power to detect certain associations.

5. Conclusion

In conclusion, this retrospective cohort study confirmed that both short and long IPIs are associated with adverse maternal complications and pregnancy outcomes. Short IPIs increase the risk of gestational hypertension and oligohydramnios, whereas long IPIs are linked to higher

risks of GDM and placenta accreta. Very short and very long IPIs also elevate the risks of PROM, postpartum hemorrhage, and preterm birth. Notably, IPIs of 18–23 months and 24–59 months were associated with more favorable outcomes, suggesting that these intervals may be safer. These findings highlight the importance of tailored counseling that considers IPI alongside maternal age, comorbidities, and reproductive intentions to optimize outcomes for women with prior cesarean delivery.

Availability of Data and Materials

The data that support the findings of this study are available from Guangzhou Women and Children's Medical Center but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of Guangzhou Women and Children's Medical Center.

Author Contributions

YZ: conceptualization, methodology, writing-original draft, writing-review & editing, funding acquisition, project administration. YH: methodology, formal analysis, writing-original draft, writing-review & editing, visualization, data curation. HT: methodology, formal analysis, data curation. YW: conception and design, acquisition of data, writing-review & editing. QC: analysis and interpretation of data, writing-original draft, writing - review & editing. XD: analysis and interpretation of data, writing-review & editing. WW: analysis and interpretation of data, writing-review & editing. MC: data curation, writing-review & editing, formal analysis. All authors contributed to critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The design of this study was carried out in accordance with the guidelines of the Declaration of Helsinki and was approved by the Ethics Committee of Guangzhou Women and Children's Medical Center, Guangzhou Medical University (NO. 2024.020B00). For the retrospective study, we can not provide informed consent for all patients (whose data was used for the study), and have provided a statement on the waiver of consent from the Ethics committee (the Ethics Committee of Guangzhou Women and Children's Medical Center).

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/CEOG45612.

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