# Risk Factors and Pregnancy Outcome in Women With a History of Cesarean Section Complicated by Placenta Accreta

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# Abstract

**Objective:** To explore the risk factors and pregnancy outcomes in women with a history of cesarean section complicated by placenta accreta.

**Methods:** This retrospective study included clinical data from singleton mothers with a history of cesarean section in 11 public tertiary hospitals in 7 provinces of China between January 2017 and December 2017. According to the intraoperative findings or the pathologic diagnosis after delivery, the study population was divided into placenta accreta (PA) and non-PA groups. We compared the pregnancy outcomes between the 2 groups, used multivariate logistic regression to analyze the risk factors for placental accreta, and used receiver operating characteristic curves to evaluate the value of the risk factors.

**Results:** For this study we included 11,074 pregnant women with a history of cesarean section; and of these, 869 cases were in the PA group and 10,205 cases were in the non-PA group. Compared with the non-PA group, the probability of postpartum hemorrhage, severe postpartum hemorrhage, diffuse intravascular coagulation, puerperal infection, intraoperative bladder injury, hysterectomy, and blood transfusion was significantly increased in the placenta accreta group ($P<0.05$)). At the same time, the rate of neonatal low-birth weight, the probability of neonatal comorbidities, and the rate of neonatal intensive care unit admission also increased significantly ($P<0.05$). Weight, parity, number of miscarriages, number of previous cesarean sections, history of premature rupture of membrane, previous cesarean-section transverse incisions, history of placenta previa, and the combination of prenatal hemorrhage and placenta previa were all independent risk factors for placenta accreta; while non-Han ethnicity was an independent protective factor for placenta accreta ($P<0.05$). The area under the ROC curve (AUC) was 0.93 (95% CI=0.92-0.94); and the specificity, sensitivity, and accuracy rate were 0.87, 0.93, and 0.93, respectively.

**Conclusions:** There was an increased risk of adverse outcomes in pregnancies complicated by placenta accreta in women with a history of cesarean section, and this required close clinical attention. Weight before pregnancy, parity, number of miscarriages, number of previous cesarean sections, Han ethnicity, history of premature rupture of membranes, past transverse incisions in cesarean sections, a history of placenta previa, prenatal hemorrhage, and placenta previa were independent risk factors for pregnancies complicated with placenta accreta in women with a history of cesarean section. These independent risk factors showed a high value in predicting the risk for placental accreta in pregnancies of women with a history of cesarean section.


# Background

Placenta accreta (PA) has developed into a serious obstetric complication that threatens the lives of mothers and children; and in the past 30 years its incidence has increased from 0.12–0.31%, with a mortality rate of approximately 7.0%[1]. In addition, it can lead to severe postpartum hemorrhage,

massive blood transfusion, intraoperative bladder injury, hysterectomy, and even deaths of mothers and children [2]. PA refers to the abnormal invasion by placental villi into the uterus, which can cause placental separation disorder at delivery—and this can then result in severe postpartum hemorrhage, which threatens the lives of mother and child [3]. Many investigators have attempted to discern the risk factors for PA; and it has been reported that maternal age (≥ 35 years)—combined with placenta previa—is significantly related to the development of PA [4]. Similarly, advanced maternal age and previous cesarean sections (CS) are also independent risk factors for PA [5].

Since the Chinese government has tried to encourage women to give birth in health facilities, the proportion of births in such facilities has risen sharply, paralleling the increase in cesarean sections. In 2008, 29% of births in China were performed by cesarean section [6], and the rate of CS then increased to 45.3% in 2012, and dropped to 41.1% in 2016. After adjusting for relevant social factors, the CS rate dropped by 18% from 2012 to 2016. Even at the lower rate, the CS rate in China remains high [7]. Since China implemented the two-child policy in 2013, the proportion of women with a scarred uterus has almost doubled, increasing from 9.8% in 2012 to 17.7% in 2016. At the same time, the proportion of women delivering at an advanced maternal age and complicated with PA has also increased [8–11].

In summary, it is particularly important to identity the predictive risk factors for placenta accreta in women with a scarred uterus in early pregnancy. In this retrospective study, we thus analyzed the clinical data from 11,074 women with a history of cesarean section who underwent singleton pregnancies at 11 public tertiary hospitals in 7 provinces of China from January 2017 to December 2017; and we identified the risk factors for PA.

# Methods

### 1.1 Study participants

In this study, we selected as research subjects 11,074 women who had a history of cesarean section and who underwent singleton pregnancies at 11 public tertiary hospitals in 7 provinces of China between January 2017 and December 2017. According to the guidelines of FIGO for the diagnosis and treatment of placenta accreta [12], all cases were divided into a non-placenta accreta group (non-PA, 10,205 cases) and a placenta accreta group (PA, 869 cases).

### 1.2 Observation index

Clinical data included general patient data (age, height, weight before pregnancy, body mass index before pregnancy [BMI], ethnicity, use of assisted reproductive technology [ART], gravida, parity, gestational weight gain [GWG], and whether they presented in outpatient clinic or were referred), previous medical history (history of miscarriage, number of CS, previous CS, history of preterm delivery, history of postpartum hemorrhage [PPH], history of premature rupture of membranes [HPROM], history of hysteroscopic surgery [HHS], history of uterine fibroid removal, history of endometrial injury, history of PA, history of PP, history of preeclampsia [PE]), and pregnancy outcomes (prenatal hemorrhage, PP, PPH,

severe postpartum hemorrhage [SPPH], uterine rupture, diffuse intravascular coagulation barriers, puerperal infection, hysterectomy, blood transfusion, low birth weight, neonatal comorbidities, and time to neonatal intensive care unit admission [NICU]). SPPH refers to the amount of bleeding ≥1500 ml within 24 hours of cesarean section.

### 1.3 Statistical analysis

We performed all of the analyses using Empower (R) (www. empowerstats. com, X& Y solutions, inc. Boston MA) and R (http:// www. R-project.org). Means±1 standard deviation (SD) were calculated for numerical and normally distributed data, while numbers and percentages were calculated for categorical data; and non-normally distributed numerical data were represented by medians (with 25% quantile and 75% quantile). For comparisons of quantitative data, we used an independent-sample *t* test or the non-parametric Kruskal-Wallis rank-sum test. For comparisons of qualitative data, Chi-squared test or Fisher exact method was used; with the latter used when the theoretical frequency was <10. For the analysis of risk factors, we used univariate and multivariate logistic regression analyses; and used receiver operating characteristic (ROC) curves to identity the value of these risk factors in predicting the development of PA in women with a scarred uterus. Differences with P-values of < 0.05 were considered to be statistically significant.

## Results

Table 1 depicts the general characteristics of all of our studied cases. We observed significant differences in ethnicity, age, weight before pregnancy, BMI before pregnancy, GWG, gravida, parity, number of miscarriages, number of CS, and patient referral status (P<0.05). The principal source of patients with PA was referral, while the primary source of patients in the non-PA group was the outpatient service. Compared with the non-PA group, more women in the PA group had experienced miscarriage, premature rupture of membranes, transverse incision in a previous cesarean section, PP, PA, endometrial injury, uterine fibroid removal, and/or hysteroscopic surgery. Additionally, there were also more women with prenatal hemorrhage and PP in the latter group, and the interval between the previous and current cesarean sections was shorter (P<0.05).

Table 1 The general characteristics in Non-PA group and PA group

| Variable | Non-PA（n=10205） | PA（n=869） | *P* |
|---|---|---|---|
| Source | | | <0.001 |
| Hospital | 8522 (83.51%) | 422 (48.56%) | |
| Referral | 1683 (16.49%) | 447 (51.44%) | |
| Nationality | | | <0.001 |
| Han Population | 9971 (97.71%) | 864 (99.42%) | |
| Others | 234 (2.29%) | 5 (0.58%) | |
| Age(years) | 33.00 (30.00-36.00) | 33.00 (29.00-36.00) | 0.049 |
| Weight before pregnancy(kg) | 59.00 (52.00-65.00) | 60.00 (54.00-67.00) | <0.001 |
| Height | 160.00 (157.00-164.00) | 160.00 (157.00-164.00) | 0.079 |
| BMI before pregnancy (kg/cm2) | 22.83 (20.62-24.97) | 23.44 (20.96-25.34) | <0.001 |
| GWG(kg) | 13.00 (11.00-15.00) | 12.00 (11.00-14.00) | <0.001 |
| Gravida | 3.00 (2.00-3.00) | 3.00 (2.00-4.00) | <0.001 |
| Parity | 1.00 (1.00-1.00) | 1.00 (1.00-2.00) | <0.001 |
| ART | | | 0.325 |
| 0 | 9955 (97.55%) | 843 (97.01%) | |
| 1 | 250 (2.45%) | 26 (2.99%) | |
| History of Miscarriage | | | <0.001 |
| 0 | 4229 (41.44%) | 251 (28.88%) | |
| 1 | 5976 (58.56%) | 618 (71.12%) | |
| Number of Miscarriage | 1.00 (0.00-1.00) | 1.00 (0.00-2.00) | <0.001 |
| Missed abortion | | | 0.015 |
| 0 | 9147 (89.63%) | 756 (87.00%) | |
| 1 | 1058 (10.37%) | 113 (13.00%) | |
| Drug abortion | | | <0.001 |
| 0 | 9532 (93.41%) | 785 (90.33%) | |
| 1 | 673 (6.59%) | 84 (9.67%) | |
| Induced abortion | | | <0.001 |
| 0 | 4926 (48.27%) | 324 (37.28%) | |

| | | | |
|---|---|---|---|
| 1 | 5279 (51.73%) | 545 (62.72%) | |
| Numbers of previous CS | 1.00 (1.00-1.00) | 1.00 (1.00-1.00) | <0.001 |
| Interval-CS(year) | 6.00 (4.00-9.00) | 5.00 (3.00-9.00) | 0.008 |
| Interval-CS(month) | 72.00 (48.00-108.00) | 60.00 (36.00-108.00) | <0.001 |
| History of preterm childbirth | | | 0.478 |
| 0 | 8285 (81.19%) | 714 (82.16%) | |
| 1 | 1920 (18.81%) | 155 (17.84%) | |
| History of PROM | | | <0.001 |
| 0 | 8725 (85.50%) | 679 (78.14%) | |
| 1 | 1480 (14.50%) | 190 (21.86%) | |
| Previous CS transverse incision | | | 0.047 |
| 0 | 2220 (21.75%) | 164 (18.87%) | |
| 1 | 7985 (78.25%) | 705 (81.13%) | |
| History of wound tear | | | 0.212 |
| 0 | 10128 (99.25%) | 866 (99.65%) | |
| 1 | 77 (0.75%) | 3 (0.35%) | |
| History of wound infection | | | 1 |
| 0 | 10196 (99.91%) | 869 (100.00%) | |
| 1 | 9 (0.09%) | 0 (0.00%) | |
| history of PPH | | | 0.798 |
| 0 | 10154 (99.50%) | 866 (99.65%) | |
| 1 | 51 (0.50%) | 3 (0.35%) | |
| Previous history of PP | | | <0.001 |
| 0 | 10088 (98.85%) | 836 (96.20%) | |
| 1 | 117 (1.15%) | 33 (3.80%) | |
| Previous history of PA | | | <0.001 |
| 0 | 10191 (99.86%) | 861 (99.08%) | |
| 1 | 14 (0.14%) | 8 (0.92%) | |
| Previous history of endometrial injury | | | <0.001 |

| | | | |
|---|---|---|---|
| 0 | 9978 (97.78%) | 827 (95.17%) | |
| 1 | 227 (2.22%) | 42 (4.83%) | |
| History of uterine fibroids removal | | | 0.005 |
| 0 | 10068 (98.66%) | 847 (97.47%) | |
| 1 | 137 (1.34%) | 22 (2.53%) | |
| History of PE | | | 1 |
| 0 | 10187 (99.82%) | 868 (99.88%) | |
| 1 | 18 (0.18%) | 1 (0.12%) | |
| History of hysteroscopic surgery | | | <0.001 |
| 0 | 10099 (98.96%) | 846 (97.35%) | |
| 1 | 106 (1.04%) | 23 (2.65%) | |
| Combined with prenatal hemorrhage | | | <0.001 |
| 0 | 9576 (93.84%) | 525 (60.41%) | |
| 1 | 629 (6.16%) | 344 (39.59%) | |
| Complicated with PP | | | <0.001 |
| 0 | 9498 (93.07%) | 111 (12.77%) | |
| 1 | 707 (6.93%) | 758 (87.23%) | |

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The pregnancy outcomes of the two groups are shown in Table 2. Compared with the non-PA group, women with PA had an increased probability of PPH, SPPH, DIC, puerperal infection, intraoperative bladder injury, hysterectomy, and blood transfusion ($P<0.05$). In addition, the birth weight was lower and the probability of neonatal complications and the time to NICU admission were also increased significantly with PA ($P<0.05$).

Table 2 The pregnant outcomes in Non-PA group and PA group

| Variables | Non-PA（n=10205） | PA（n=869） | *P* |
|---|---|---|---|
| PPH | | | <0.001 |
| 0 | 9969 (97.69%) | 586 (67.43%) | |
| 1 | 236 (2.31%) | 283 (32.57%) | |
| SPPH | | | <0.001 |
| 0 | 10116 (99.13%) | 680 (78.25%) | |
| 1 | 89 (0.87%) | 189 (21.75%) | |
| Uterine rupture | | | 1 |
| 0 | 10173 (99.69%) | 867 (99.77%) | |
| 1 | 32 (0.31%) | 2 (0.23%) | |
| DIC | | | <0.001 |
| 0 | 10202 (99.97%) | 865 (99.54%) | |
| 1 | 3 (0.03%) | 4 (0.46%) | |
| Puerperal infection | | | <0.001 |
| 0 | 10172 (99.68%) | 857 (98.62%) | |
| 1 | 33 (0.32%) | 12 (1.38%) | |
| Intraoperative bladder injury | | | <0.001 |
| 0 | 10204 (99.99%) | 853 (98.16%) | |
| 1 | 1 (0.01%) | 16 (1.84%) | |
| Hysterectomy | | | <0.001 |
| 0 | 10075 (98.73%) | 810 (93.21%) | |
| 1 | 130 (1.27%) | 59 (6.79%) | |
| Transfusion | | | <0.001 |
| 0 | 9877 (96.79%) | 638 (73.42%) | |
| 1 | 328 (3.21%) | 231 (26.58%) | |
| Birth weight(g) | 3250.00 (2950.00-3520.00) | 2920.00 (2530.00-3250.00) | <0.001 |
| Neonatal comorbidities | | | <0.001 |
| 0 | 9960 (97.60%) | 808 (92.98%) | |
| 1 | 245 (2.40%) | 61 (7.02%) | |

| | | | |
|---|---|---|---|
| Rate to NICU admission | | | <0.001 |
| 0 | 9388 (91.99%) | 659 (75.83%) | |
| 1 | 817 (8.01%) | 210 (24.17%) | |

Using univariate analysis we found that Han ethnicity, weight before pregnancy, GWG, BMI before pregnancy, gravida, parity, history of miscarriage, number of miscarriages, history of missed abortion, history of drug-induced abortion, history of induced abortions, number of CS, interval-CS, previous CS with transverse incision, history of PROM, history of PP, history of PA, history of endometrial injury, history of uterine fibroids, history of hysteroscopy, and complications with PP or prenatal hemorrhage were all risk factors related to PA in a subsequent pregnancy with a scarred uterus (P<0.05, Table 3).

Table 3 Univariate analysis of placenta accreta in women

with scarred uterus during the second pregnancy

| Variables | OR(95%CI) | *P* |
|---|---|---|
| Non- Han Population | 0.25 (0.10, 0.60) | <0.001 |
| Height(m) | 1.01 (1.00, 1.03) | 0.100 |
| Age(years) | 0.98 (0.97, 1.00) | 0.061 |
| Weight before pregnancy | 1.01 (1.01, 1.02) | <0.001 |
| Pregnant gian weight | 0.96 (0.94, 0.98) | <0.001 |
| BMI before pregnancy | 1.04 (1.02, 1.06) | <0.001 |
| Gravida | 1.28 (1.22, 1.34) | <0.001 |
| Parity | 1.60 (1.42, 1.79) | <0.001 |
| With History of Miscarriage | 1.74 (1.50, 2.03) | <0.001 |
| Number of Miscarriage | 1.28 (1.21, 1.35) | <0.001 |
| With history of missed abortion | 1.29 (1.05, 1.59) | 0.016 |
| With history of drug abortion | 1.52 (1.19, 1.92) | <0.001 |
| With history of induced abortion | 1.57 (1.36, 1.81) | <0.001 |
| Numbers of previous CS | 2.89 (2.47, 3.39) | <0.001 |
| Interval-CS (year) | 0.98 (0.96, 1.00) | 0.085 |
| Interval-CS (month) | 1.00 (1.00, 1.00) | 0.011 |
| Previous CS transverse incision | 1.20 (1.00, 1.43) | 0.048 |
| With history of PROM | 1.65 (1.39, 1.96) | <0.001 |
| With history of PP | 3.40 (2.30, 5.04) | <0.001 |
| With history of PA | 6.76 (2.83, 16.17) | <0.001 |
| With previous history of endometrial injury | 2.23 (1.59, 3.13) | <0.001 |
| With history of uterine fibroids removal | 1.91 (1.21, 3.01) | 0.005 |
| With history of hysteroscopic surgery | 2.59 (1.64, 4.09) | <0.001 |
| Complicated with prenatal hemorrhage | 9.98 (8.52, 11.68) | <0.001 |
| Complicated with PP | 91.74 (74.11, 113.56) | <0.001 |

OR: odds ratio CI: confidence interval.

Our multivariate logistic regression model showed that weight before pregnancy (OR=1.03, 95% CI=1.01-1.05), parity (OR=1.18, 95% CI=1.03-1.34), number of miscarriages (OR=1.31, 95% CI=1.17-1.47), number

of CS (OR=2.57, 95% CI=2.02- 3.26)), history of PROM (OR=1.61, 95% CI=1.32-1.96), previous CS by transverse incision (OR=1.38, 95% CI=1.12-1.69), history of PP (OR=2.44, 95% CI=1.50-3.96), history of prenatal hemorrhage (OR=9.95, 95% CI=8.42-11.75), and complications with PP (OR=91.74, 95% CI=74.11-113.56) were independent risk factors for PA. However, non-Han ethnicity (OR=0.19, 95% CI=0.07-0.49) was a protective factor (P<0.05, Table 4).

Table 4 Multivariate analysis of placental accreta in women

with history of cesarean section during the second pregnancy

| Variables | OR(95%CI) | *P* |
|---|---|---|
| Non- Han Population | 0.19 (0.07, 0.49) | <0.001 |
| Height(m) | 1.03 (1.01, 1.05) | 0.013 |
| Parity | 1.18 (1.03, 1.34) | 0.014 |
| Number of Miscarriage | 1.31 (1.17, 1.47) | <0.001 |
| Number of previous CS | 2.57 (2.02, 3.26) | <0.001 |
| Previous CS transverse incision | 1.38 (1.12, 1.69) | 0.002 |
| With history of PROM | 1.61 (1.32, 1.96) | <0.001 |
| With history of PP | 2.44 (1.50, 3.96) | <0.001 |
| Complicated with prenatal hemorrhage | 9.95 (8.42, 11.75) | <0.001 |
| Complicated with PP | 91.74 (74.11, 113.56) | <0.001 |

OR: odds ratio CI: confidence interval.

To investigate the predictive value of selected risk factors for PA, we calculated the AUC, which was 0.93 (95% CI=0.92-0.94, P < 0.001). The sensitivity, specificity, and accuracy were 87.00%, 93%, and 93%, respectively (Table 5, Fig. 1).

Table 5 Receiver operating characteristic curve of risk factors for placenta accreta

| Model | AUC | 95%CI | Sensitivity (%) | Specificity (%) | accuracy (%) |
|---|---|---|---|---|---|
| All risk factors | 0.93 | 0.92, 0.94 | 0.87 | 0.93 | 0.93 |

AUC: area under the receiver operating characteristic curve OR: odds ratio CI: confidence interval

# Discussion

There are differences in the rates of cesarean section among countries worldwide. In China, the cesarean section rate has risen sharply in the past 30 years [13–16]. According to the 4 National Health Service Surveys conducted in 1993, 1998, 2003, and 2008, the national cesarean section rate rose from 14.9 to 64.1% in urban areas and from 1.5 to 23.6% in rural areas between 1993 and 2008 [17]. In addition, according to the World Health Organization global survey report conducted in 2007–2008, the cesarean section rate in China was 46.2%, the highest in the world at the time [15]. Compared with vaginal delivery, cesarean section exerts a negative long-term impact on future pregnancies; which increased risk for uterine rupture, PA, stillbirth, and premature delivery [18].

Placenta accreta is one of the most common complications in obstetrics, and it was reported that [11] its incidence had increased annually from 1.593% in 2011 to 6.176% in 2015. In addition, a previous study showed that the prevalence of PA between 1982 and 2018 ranged from 0.01 to 1.1% [19]. The principal pathologic manifestation of PA is penetration of the decidua basalis by placental villous tissue and invasion into uterine muscle. During delivery it is easy to cause incomplete placental dissection and postpartum hemorrhage. Additionally, the deep blood vessels of the uterus are destroyed after manual removal of the placenta; which can then cause massive bleeding, hemorrhagic shock, fetal distress, and even hypoxic death. In order to save the lives of women or fetuses, pregnancy is then terminated early or hysterectomy is performed; which results in an increased rate of premature birth, hysterectomy, and neonatal mortality [19–21].

### 3.1 Risk factors for placenta accreta

The present results revealed that risk factors for PA were pre-pregnancy weight, gravida, number of miscarriages, number of CS, history of PROM, previous transverse incisions with cesarean section, a history of PP, and with prenatal hemorrhage or placenta previa. These results are consistent with previous studies [7–14].

We herein reported that the independent risk factors for placenta accreta(OR=91.74, 95% CI=74.11-113.56), and this has also been reported in other studies[22,23]. However, the underlying mechanism(s) of action remains unclear. The muscle layer and decidua basalis of the lower part of the uterus are too weak in the third trimester to supply sufficient nutrients, and this may lead to PA. Thus, the placental villi may penetrate the decidua basalis in order to obtain sufficient nutrients, and this would augment the risk for PA [24]. The novelty of our study was the finding that women with a history of cesarean section and whose pregnancy was by prenatal hemorrhage had an approximately 10-fold increased risk for PA during a second pregnancy (OR=9.95, 95% CI =8.42-11.75). It has been reported that most prenatal hemorrhage is related to abnormal embryonic implantation, and the increase in the amount of bleeding may produce inflammation and pathologic damage to the endometrium and decidua—leading to PP [25]. Additionally, we found that PP was an independent risk factor for PA, and this might explain why prenatal hemorrhage increased PA incidence. However, the specific underlying mechanism(s) requires further clarification.

Our research also suggested that the number of CS (OR=2.57, 95% CI=2.02-3.26) was a risk factor for PA, which is consistent with other results [23,26]. A number of studies [12–13] have shown that as cesarean-section number increases, so does the probability of PA in a second pregnancy. This may be due to dysplasia of the decidua at the uterine scar after cesarean section, which leads to excessive infiltration of trophoblast cells into the myometrium during the second pregnancy [29]. We also found that a history of PP (OR=2.44, 95% CI=1.50-3.96) was an independent risk factor for PA, consistent with the studies by Gelany [28] and Zhang [1]. This correlation may be due to pathologic damage to the endometrium during previous placenta previa, resulting in insufficient vascular remodeling during the second pregnancy in women with a history of cesarean section. In order to absorb additional nutrients the placenta extends downward, increasing the risk of placenta previa, which is the most significant independent risk factor for PA.

The present results showed that weight before pregnancy (OR=1.03, 95% CI=1.01-1.05), parity (OR=1.18, 95% CI= 1.03-1.34), and number of miscarriages (OR=1.31, 95% CI=1.17-1.47) were risk factors for PA, consistent with previous work [23,28]. Repeated abortions and deliveries might damage the endometrium and myometrium; and during the subsequent pregnancy, defects in decidual development, abnormal vascular remodeling, and reduced blood supply might lead to excessive infiltration of trophoblast cells through the endometrium, and increase the probability of PA [21]. Our results also suggested that a history of PROM (OR=1.61, 95% CI=1.61 1.32-1.96) and previous cesarean section with transverse incisions (OR=1.38, 95% CI=1.12-1.69) were independent risks for PA. However, the mechanism(s) underlying these phenomena remains unclear and requires further exploration. We hypothesize that a history of PROM is likely to cause ascending pathogen infection and endometritis, which would in turn induce endometrial damage. Moreover, decidual defects occur readily, which may lead to PA during a second pregnancy,

### 3.2 Pregnancy Outcomes with PA

Placenta accreta seriously threatens the lives of mothers and children. In this study we found that the probability of PPH, SPPH, and blood transfusion in the PA group was much higher than that in the non-PA group, which is consistent with previous studies [23,30]. Research by Nyfløt [31] suggested that the uterine tissue at the implantation site was too weak to maintain uterine contractions, and that residual placental tissue and blood sinusoids that could not be completely closed off would lead to uncontrollable PPH. This study also showed that the incidence of DIC in the PA group was higher, which may be related to the incidence of PPH and an insufficient endogenous supply of coagulation factors. In the present study, the incidence of puerperal infection and intraoperative bladder injury in the PA group was significantly increased ($P<0.05$), which is consistent with a previous report [32]. In addition, we found that the rate of hysterectomy, low birth weight, neonatal comorbidities, and time to NICU admission in the PA group were also significantly increased ($P<0.05$), which was consistent with the results of several previous investigations [23,33,34].

# Conclusions

We observed an increased risk for adverse outcomes in pregnancies complicated by placenta accreta in women with a history of cesarean section—especially PPH, which threatens the health of mothers and children, and requires close clinical attention. Weight before pregnancy, parity, number of miscarriages, number of cesarean sections, Han ethnicity, a history of PROM, past transverse incisions in cesarean sections, a history of placenta previa, and complications of? prenatal hemorrhage or placenta previa were all independent risk factors for PA in pregnant women with a history of cesarean section. These factors were of high value in predicting the risk of PA.

The innovation of this article lies in our inclusion of variables that have not been studied previously—such as ethnicity, history of PROM, GWG, or hysteroscopic surgery. This study was a multi-center study, which effectively avoided selection and regional biases inherent in a single-center study. However, there were also several limitations—e.g., this was a retrospective analysis, and lacked information on maternal living habits and imaging data during pregnancy—and therefore this work requires additional investigation.

# Declarations

1. Ethics approval and consent to participate

All methods were carried out in accordance with relevant guidelines and regulations. This study was approved by the Research Ethics Board of The Third Affiliated Hospital of Guangzhou Medical University. All patients had signed a written informed consent after they have been made aware of the purpose of the study.

2. Consent for publication

Not applicable.

3. Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

4. Competing interests

There are no competing financial or non-financial interests regarding this work.

5. Funding

This study was supported by grants from the National Key R&D Program of China (No.2016YFC1000405, 2017YFC1001402, and 2018YFC10029002) and the National Natural Science Foundation (No. 81830045, 81671533 and 82071652).

6. Authors' contributions

YL and LZ: propose ideas, data analysis, writing, review and editing. SB: data analysis, review and editing. JC: propose original questions, review and editing. SZ, LH, YL, MH and HT: investigation, data collection, and visualization. JJ, SW, ZW, YC, SW, XX, LF, XZ, YZ, QZ, HQ, LZ and HL: investigation, and resources. LD, and DC: supervision, project administration, and funding acquisition.

7. Acknowledgements

This study was supported by grants from the National Key R&D Program of China (No.2016YFC1000405, 2017YFC1001402, and 2018YFC10029002) and the National Natural Science Foundation (No. 81830045, 81671533 and 82071652).

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# Figures

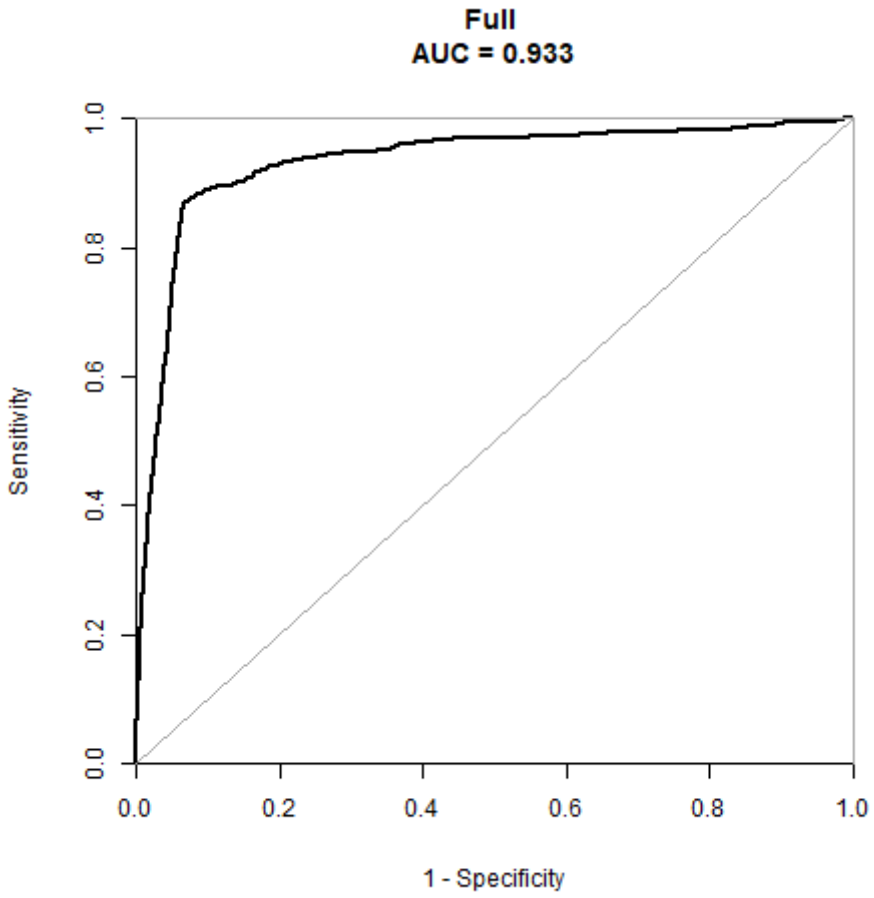
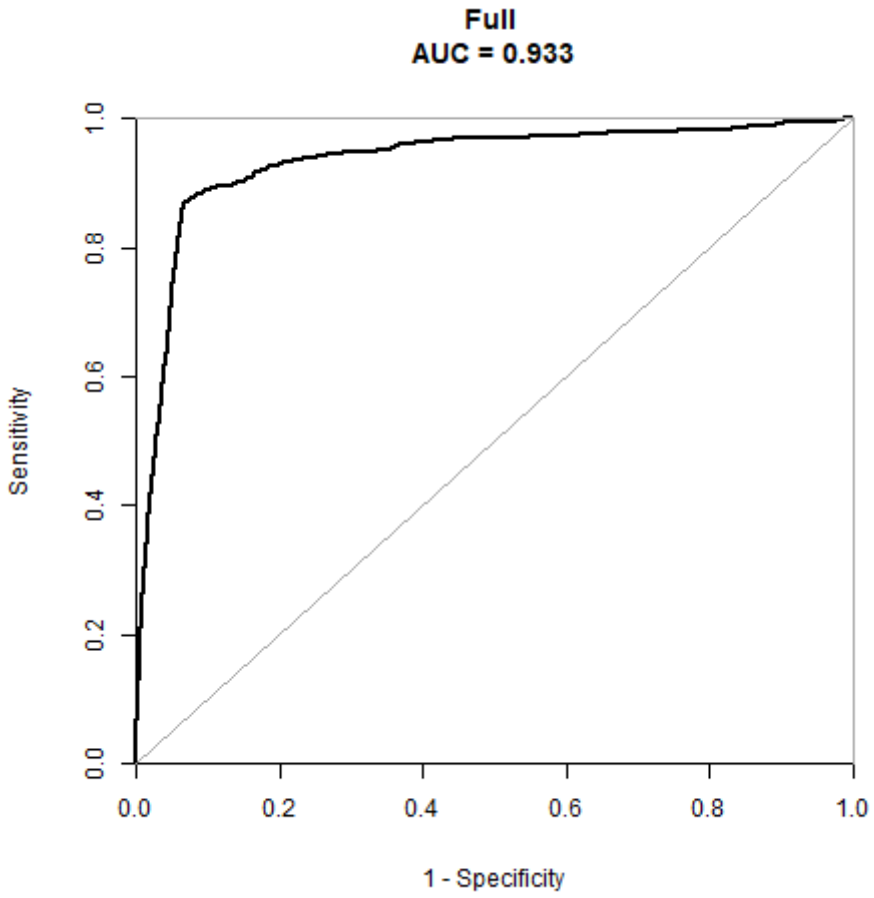



**Figure 1**

Receiver operating characteristic curve of risk factors for placenta accreta

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