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ORIGINAL ARTICLE

Perinatal outcomes comparison between neuraxial and general anesthesia in pregnant women with placenta accreta spectrum: a multicenter retrospective study

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Abstract

Purpose We investigated the impact of anesthesia mode on perinatal outcomes in patients with placenta accreta spectrum (PAS) undergoing cesarean delivery and identified factors associated with adverse perinatal events.

Methods The multicenter retrospective analysis was conducted in patients with PAS who delivered at three medical centers. Patients were classified according to whether they received general anesthesia (GA) or neuraxial anesthesia (NA). We compared the basic clinical characteristics of patients in the pre-propensity score matching (PSM) and post-PSM cohorts and identified factors associated with a high risk of adverse maternal outcomes.

Results This study included a total of 425 patients, with 307 (72.2%) in the GA group and 118 (27.8%) in the NA group. After PSM, 162 patients were identified for analysis. In the post-matched cohort, the NA group exhibited shorter total operation time ($P = 0.030$) and postoperative length of hospital stay ($P = 0.037$). Additionally, the NA group experienced lower intraoperative blood loss ($P < 0.001$) and received fewer units of transfused packed red blood cells (PRBC) ($P < 0.001$). Multivariate logistic regression analysis indicated that GA ($P < 0.001$), emergency cesarean delivery ($P = 0.010$), vascular lacunae within the placenta ($P < 0.001$), hypervascularity of uterine-placental margin ($P = 0.002$), hypervascularity of the cervix ($P = 0.014$), and balloon placement in the abdominal aorta ($P < 0.001$) were associated with a high risk of adverse maternal events.

Conclusion In comparison to GA, cesarean delivery with NA in PAS patients appears to be associated with reduced intraoperative blood loss, PRBC transfusion, operating duration, and postoperative hospital stay.

Keywords Placenta accreta spectrum · Propensity score matching · General anesthesia · Neuraxial anesthesia

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Introduction

Placenta accreta spectrum (PAS) is a broad term used to describe the abnormal attachment of the placenta to the myometrium, the muscular layer of the uterus. It is further classified into three subtypes based on the depth of placental villi invasion into the myometrium: placenta adherenta, placenta increta, and placenta percreta [1, 2]. With the increasing rates of cesarean deliveries and other intrauterine procedures, the prevalence of PAS has seen a significant fivefold increase from 1980 to 2019, reaching 0.17% in 2019 [3, 4]. PAS is a severe pregnancy complication and one of the primary causes of perinatal hemorrhage, hysterectomy, and even maternal mortality [3].

Cesarean section is typically the preferred method for terminating pregnancy in patients with PAS [1]. Neuraxial anesthesia (NA) is the preferred choice for cesarean section procedures, allowing the mother to remain awake and actively participate in the labor process, promoting immediate mother-infant contact following birth [5]. By opting for NA, the need for tracheal intubation is avoided, minimizing airway manipulation and the risk of aspiration [6]. Furthermore, NA poses minimal risk to the fetus in terms of exposure to anesthetics and has been associated with favorable neonatal outcomes, including higher Apgar scores [7]. NA also has minimal impact on uterine tone, and some studies have demonstrated improved hemodynamic stability and reduced blood transfusion requirements in the NA group [8, 9].

General anesthesia (GA) is most commonly used in emergency caesarean section [10]. During cesarean section termination of pregnancy in patients with PAS, there is a notable risk of excessive bleeding and the potential need for hysterectomy [1]. In these cases, GA may be considered a preferable option at the beginning of the cesarean section [11–14]. However, the impact of NA and GA on patient and fetal outcomes during cesarean section in PAS patients remains a subject of ongoing debate and uncertainty.

Therefore, we conducted a multicenter retrospective clinical study to examine the impact of NA and GA on maternal and fetal perinatal adverse events in PAS patients. Propensity score matching (PSM) was used to compare clinical outcomes between the two anesthesia modes. We also analyzed the risk factors associated with adverse perinatal outcomes. The study findings are expected to provide valuable insights for perioperative anesthesia selection in PAS patients.

Methods

General information

The multicenter retrospective study was conducted at three medical centers: Qilu Hospital of Shandong University, Jinan Maternity and Child Care Hospital, and Qilu Hospital of Shandong University Dezhou Hospital. Data were collected from a total of 425 patients with PAS across all perinatal periods, spanning from January 2016 to January 2022. This retrospective study (protocol number KYLL-202209-028) received approval from the Ethical Committee of Qilu Hospital, Shandong University. Written informed consent was waived, and patient data were anonymized to ensure privacy protection before analysis.

Due to the low frequency of hysterectomy among most patients and the challenges associated with pathologic examination in the absence of hysterectomy, the diagnosis of PAS in our study mostly relied on a combination of clinical and histologic criteria. The diagnosis of PAS was established if at least one of the following criteria was met: (1) prenatal diagnosis of PAS confirmed at delivery, (2) inability or incompleteness of manual placenta delivery with a lack of separation plane between the placenta and the myometrium, (3) significant bleeding at the site of placental insertion following difficult manual placenta delivery, and (4) histologic confirmation of the abnormal placentation from either the hysterectomy (uterine) or placental specimens [15].

The study included patients who met the following inclusion criteria: (1) diagnosed with PAS, (2) absence of preexisting coagulopathy, and (3) availability of complete clinical data. The choice of anesthesia method for cesarean delivery was determined based on the patient's wishes and condition, the preference of the anesthesiologist, and the surgical technique of the obstetrician. Patients were categorized into either the NA group or the GA group, depending on the actual mode of anesthesia received. In the NA group, patients received spinal, epidural, or combined spinal-epidural anesthesia as the sole method, or their anesthesia was converted from regional to general anesthesia mainly due to intraoperative hemodynamic instability. Patients who did not meet these criteria were assigned to the GA group. The specific anesthetic drugs and techniques were determined by the anesthesiologist, while the surgeries were performed by experienced chief obstetricians.

Patient variables

Detailed demographic, obstetric, surgical, and anesthetic data were obtained from the electronic medical records. The collected variables encompassed various aspects, including age at delivery, gestational week, pregnancy history, laboratory examinations, antenatal ultrasound findings, intraoperative surgical techniques, intraoperative blood loss, transfusion of packed red blood cells (PRBC), surgical duration, length of hospital stay, early and late complications, neonatal Apgar scores, neonatal weight, and neonatal intensive care unit (NICU) treatment. Regarding the ultrasound signs of PAS, the inclusion criteria in this study were in accordance with guidelines recommended by The International Federation of Gynecology and Obstetrics (FIGO) and the Chinese Medical Association. The ultrasound signs considered for PAS diagnosis were retroplacental myometrial thickness < 1 mm, presence of vascular lacunae within the placenta, hypervascularity of the uterine-placental margin, irregularity of the uterine-bladder interface, hypervascularity of the uterine serosa-bladder wall interface, and hypervascularity of the cervix [16, 17].

Endpoints

The primary outcome measure in this study was adverse maternal events. However, there is currently no standardized definition for adverse events in patients with PAS. In our study, adverse maternal events were defined if at least one of the following criteria was met: estimated intraoperative blood loss of ≥ 2000 mL, transfusion of ≥ 10 units of PRBC, hysterectomy, disseminated intravascular coagulation (DIC), or reoperation [18]. The secondary outcomes assessed in the study included intraoperative blood loss, units of transfused PRBC, duration of surgery, length of hospital stay, early and late complications, neonatal Apgar scores, neonatal weight, and treatment in the NICU.

Statistical analysis

Patients were initially divided into two groups: GA group and NA group. We adopted median values as cutoff points for classifying the continuous variables. The Mann–Whitney *U* test and the Chi-square test were employed for comparing continuous and categorical data, respectively. However, due to significant differences in characteristics observed between the two groups, PSM was applied to minimize the influence of potential confounders and selection bias on maternal and neonatal outcomes. Bivariate logistic regression analysis was used to calculate the propensity scores for each patient, taking into account variables such as age, gestational age, gravidity, parity, history of vaginal bleeding, history of uterine curettage and previous cesarean delivery, preoperative hemoglobin and platelet levels, pregnancy-induced hypertension, gestational diabetes mellitus, classification of placenta previa and placenta accreta, prenatal ultrasound results, emergency cesarean delivery, dexamethasone administration to promote fetal lung development, and balloon placement in the abdominal aorta (BPAA). The GA group patients were matched with the NA group patients at a fixed ratio of 1:1 using the propensity scores. Matching was performed using the nearest available Mahalanobis metric within calipers, with a caliper value of 0.2 defined by the propensity score, and standardized mean difference (SMD) < 0.2 is considered to have little difference between the two groups. All reported P values are two-sided, and statistical significance was defined as $P < 0.05$.

To identify the clinical characteristics associated with adverse maternal outcomes, univariable logistic regression analysis was performed. Variables with a significance level of $P < 0.10$ in the univariable analysis were then included in the multivariate logistic regression analysis to determine independent high-risk factors. The results are presented as odds ratios (OR) with 95% confidence intervals (CI), corresponding P values, and the respective outcomes. The discrimination ability of the independent high-risk factors was assessed using receiver operating characteristic (ROC) curves and calculating the area under the curve (AUC).

Statistical analyses were performed using IBM SPSS Statistics (version 26.0) and the R software (version 4.1.2). IBM SPSS Statistics (version 26.0) was used for conducting the Mann–Whitney *U* test and the Chi-square test. The R software (version 4.1.2) was utilized for performing additional calculations such as PSM, ROC analysis, and calculation of the AUC.

Results

General characteristics of patients

A total of 425 patients diagnosed with PAS underwent cesarean delivery and were included in the study. Among them, 307 patients (72.2%) received general anesthesia (GA) only, while 118 patients (27.8%) were administered neuraxial anesthesia (NA). Out of the NA group, 9 patients (2.1%) were switched to GA due to hemodynamic instability, and 3 cases required GA due to the performance of a hysterectomy. Adverse maternal events were observed in 144 patients (33.8%), with 127 occurring in the GA group and 17 in the NA group. There were 405 live births (95.2%), including 266 (61.5%) at term. PSM analysis selected a total of 162 patients, with 81 patients in each group. The entire study process is illustrated in Fig. 1.

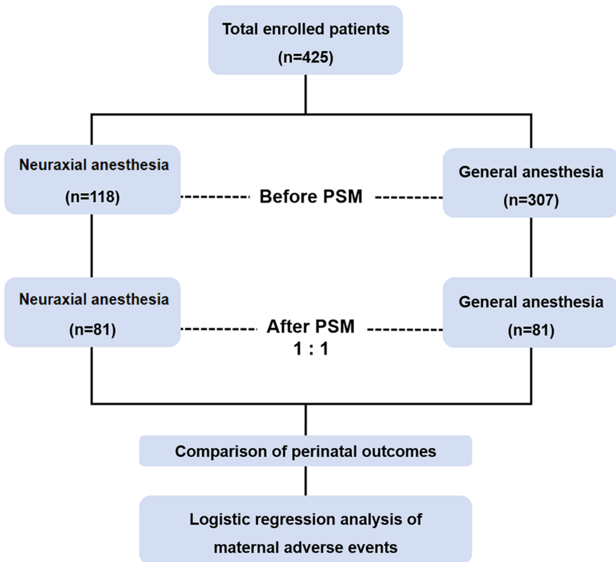

Fig. 1 Flowchart of the study. *PSM* propensity score matching

Intergroup comparison before and after PSM

Table 1 presents the demographic and clinical characteristics of patients who received GA or NA. Prior to PSM, several significant differences were observed between the two groups. These included gravidity ($P = 0.047$), PAS classification ($P = 0.005$), history of cesarean delivery ($P = 0.003$), preoperative HGB level ($P = 0.001$), pregnancy-induced hypertension ($P = 0.003$), placenta previa classification ($P < 0.001$), BPAA ($P < 0.001$), and prenatal ultrasound results ($P < 0.001$). The prenatal ultrasound results encompassed retroplacental myometrial thickness < 1 mm, vascular lacunae within the placenta, hypervascularity of uterine-placental margin, irregularity of uterine-bladder interface, hypervascularity of the uterine serosa-bladder wall interface, and hypervascularity of the cervix. Additionally, the NA group exhibited a lower number of patients with characteristics such as gravidity > 4, placenta increta, history of cesarean delivery > 1, complete placenta previa, and abnormal prenatal ultrasound results compared to the GA group. No significant differences were observed in other preoperative characteristics between the two groups ($P > 0.05$).

Using the information collected prior to surgery, we estimated the propensity scores to account for the bias in features between NA and GA. We selected 81 patients for each group using PSM, and after matching, there were no noticeable differences in the characteristics of the patients between the two groups. Figure 2 illustrates the distribution of propensity scores before and after the cohort underwent propensity matching. The PSM procedure resulted in an equal distribution of propensity scores in the cohort.

Intergroup comparison of perinatal outcomes before and after PSM

The perinatal outcomes are presented in Tables 2 and 3. In the pre-matched cohort, the NA group exhibited shorter total operation times (median 75 vs. 95 min, $P < 0.001$), hospital stays (median 8 vs. 12 days, $P < 0.001$), and postoperative hospital stays (median 4 vs. 5 days, $P < 0.001$). Patients receiving NA had lower intraoperative blood loss (median 700 vs. 1500 mL, $P < 0.001$) and required fewer units of PRBC transfusion (median 2 vs. 6, $P < 0.001$). The NA group had 4 patients who required bladder repair, compared to 27 patients in the GA group (3.4 vs. 8.8%, $P = 0.055$). However, they had a higher likelihood of ICU admission (7.6 vs. 1.3%, $P = 0.002$) and systemic infections (8.5 vs. 3.3%, $P = 0.023$), and a higher likelihood of ligation of the ascending branch of the uterine artery (38.1 vs. 17.9%, $P < 0.001$). Neonates with gestational age less than 28 weeks were excluded from the analysis. There were no noticeable differences in neonatal outcomes between the two groups.

In the post-matched cohort, the results were consistent with those in the pre-matched group. The NA group had a shorter total operation time (median 78 vs. 87 min, $P = 0.030$), a shorter postoperative length of hospital stay (median 4 vs. 5 days, $P = 0.037$), and lower intraoperative blood loss (median 800 vs. 1500 mL, $P < 0.001$) and units of PRBC transfused (median 2 vs. 4, $P < 0.001$). The ascending branch of the uterine artery was more frequently ligated in the NA group (39.5 vs. 13.6%, $P < 0.001$), and the lower uterine segment was more frequently tourniquet-bound (37.0 vs. 18.5%, $P = 0.009$).

High-risk factors associated with adverse maternal events

In the before-matched cohort, we conducted univariate and multivariate logistic regression analyses to assess the clinical characteristics associated with adverse maternal events (Table 4). Multivariate logistic regression analysis was performed after conducting univariable logistic regression analysis on the following variables: GA [odds ratio (OR) 4.19, 95% confidence interval (CI) 2.39–7.35, $P < 0.001$], gravidity > 4 (OR 1.77, 95% CI 1.12–2.80, $P = 0.015$), history of cesarean delivery > 1 (OR 1.73, 95% CI 1.12–2.69, $P = 0.014$), preoperative HGB level ≤ 100 g/L (OR 1.48, 95% CI 0.96–2.28, $P = 0.075$), emergency cesarean delivery (OR 1.78, 95% CI 1.01–3.13, $P = 0.046$), retroplacental myometrial thickness < 1 mm (OR 1.93, 95% CI 1.23–3.02, $P = 0.004$), vascular lacunae within the placenta (OR 3.33, 95% CI 2.15–5.17, $P < 0.001$), hypervascularity of uterine-placental margin (OR 2.30, 95% CI 1.48–3.57, $P < 0.001$), irregularity of uterine-bladder interface (OR 1.68, 95% CI 1.07–2.62, $P = 0.023$), hypervascularity of the uterine

Table 1 Preoperative characteristics of patients before and after PSM

Characteristics	Before matching					After matching				
	Total (n = 425)	NA (n = 118)	GA (n = 307)	P-value	SMD	Total (n = 162)	NA (n = 81)	GA (n = 81)	P-value	SMD
Age at delivery (years)										
≤ 33	229 (53.9)	60 (50.8)	169 (55.0)	0.436	0.085	88 (54.3)	43 (53.1)	45 (55.6)	0.752	0.050
> 33	196 (46.1)	58 (49.2)	138 (45.0)		− 0.085	74 (45.7)	38 (46.9)	36 (44.4)		− 0.050
Gravidity										
≤ 4	325 (76.5)	98 (83.1)	227 (73.9)	0.047	− 0.208	118 (72.8)	61 (75.3)	57 (70.4)	0.480	− 0.113
> 4	100 (23.5)	20 (16.9)	80 (26.1)		0.208	44 (27.2)	20 (24.7)	24 (29.6)		0.113
Parity										
≤ 1	284 (66.8)	86 (72.9)	198 (64.5)	0.100	− 0.175	110 (67.9)	58 (71.6)	52 (64.2)	0.313	− 0.155
> 1	141 (33.2)	32 (27.1)	109 (35.5)		0.175	52 (32.1)	23 (28.4)	29 (35.8)		0.155
PAS classification										
Adherenta	7 (1.6)	6 (5.1)	1 (0.3)	0.005	− 0.835	2 (1.2)	1 (1.2)	1 (1.2)	0.764	< 0.001
Increta	370 (87.1)	98 (83.1)	272 (88.6)		0.175	141 (87.0)	69 (85.2)	72 (88.9)		0.117
Percreta	48 (11.3)	14 (11.9)	34 (11.1)		− 0.025	19 (11.7)	11 (13.6)	8 (9.9)		− 0.118
History of curettage of uterine										
≤ 1	327 (76.9)	90 (76.3)	237 (77.2)	0.839	0.022	124 (76.5)	61 (75.3)	63 (77.8)	0.711	0.059
> 1	98 (23.1)	28 (23.7)	70 (22.8)		− 0.022	38 (23.5)	20 (24.7)	18 (22.2)		− 0.059
History of cesarean delivery										
≤ 1	309 (72.7)	98 (83.1)	211 (68.7)	0.003	− 0.309	127 (78.4)	66 (81.5)	61 (75.3)	0.340	− 0.133
> 1	116 (27.3)	20 (16.9)	96 (31.3)		0.309	35 (21.6)	15 (18.5)	20 (24.7)		0.133
Preoperative HGB level (g/L)										
≤ 100	298 (70.1)	97 (82.2)	201 (65.5)	0.001	− 0.352	48 (29.6)	19 (23.5)	29 (35.8)	0.085	− 0.260
> 100	127 (29.9)	21 (17.8)	106 (34.5)		0.352	114 (70.4)	62 (76.5)	52 (64.2)		0.260
Preoperative platelets level (10^9/L)										
≤ 100	9 (2.1)	3 (2.5)	6 (2.0)	0.713	− 0.043	3 (1.9)	2 (2.5)	1 (1.2)	1.000	− 0.089
> 100	416 (97.9)	115 (97.5)	301 (98.0)		0.043	159 (98.1)	79 (97.5)	80 (98.8)		0.089
Obstetric complications										
Pregnancy-induced hypertension	19 (4.5)	11 (9.3)	8 (2.6)	0.003	− 0.422	8 (4.9)	4 (4.9)	4 (4.9)	1.000	< 0.001
Gestational diabetes mellitus	67 (15.8)	24 (20.3)	43 (14.0)	0.109	− 0.183	29 (17.9)	18 (22.2)	11 (13.6)	0.151	− 0.249
Placenta previa classification										
Marginal	58 (13.6)	19 (16.1)	39 (12.7)	< 0.001	− 0.102	25 (15.4)	11 (13.6)	14 (17.3)	0.726	0.111
Partial	12 (2.8)	5 (4.2)	7 (2.3)		− 0.131	6 (3.7)	2 (2.5)	4 (4.9)		0.165
Complete	334 (78.6)	76 (64.4)	258 (84.0)		0.536	124 (76.5)	64 (79.0)	60 (74.1)		− 0.135
None	21 (4.9)	18 (15.3)	3 (1.0)		− 1.451	7 (4.3)	4 (4.9)	3 (3.7)		− 0.126
Prenatal ultrasound results										
Retroplacental myometrial thickness < 1 mm	279 (65.6)	49 (41.5)	230 (74.9)	< 0.001	0.770	90 (55.6)	46 (56.8)	44 (54.3)	0.752	− 0.057

Table 1 (continued)

Characteristics	Before matching					After matching				
	Total ($n=425$)	NA ($n=118$)	GA ($n=307$)	*P*-value	SMD	Total ($n=162$)	NA ($n=81$)	GA ($n=81$)	*P*-value	SMD
Vascular lacunae within the placenta	234 (55.1)	34 (28.8)	200 (65.1)	< 0.001	0.763	58 (35.8)	30 (37.0)	28 (34.6)	0.743	− 0.052
Hypervascularity of uterine-placental margin	260 (61.2)	40 (33.9)	220 (71.7)	< 0.001	0.838	69 (42.6)	37 (45.7)	32 (39.5)	0.427	− 0.137
Irregularity of uterine-bladder interface	110 (25.9)	17 (14.4)	93 (30.3)	0.001	0.346	27 (16.7)	14 (17.3)	13 (16.0)	0.833	− 0.027
Hypervascularity of the uterine serosa-bladder wall interface	125 (29.4)	16 (13.6)	109 (35.5)	< 0.001	0.459	31 (19.1)	14 (17.3)	17 (21.0)	0.549	0.077
Hypervascularity of the cervix	60 (14.1)	5 (4.2)	55 (17.9)	< 0.001	0.357	13 (8.0)	5 (6.2)	8 (9.9)	0.386	0.097
Dexamethasone practice to promote fetal lung	225 (52.9)	63 (53.4)	162 (52.8)	0.909	− 0.012	92 (56.8)	48 (59.3)	44 (54.3)	0.526	− 0.099
BPAA	89 (20.9)	0 (0.0)	89 (29.0)	< 0.001	0.639	0 (0.0)	0 (0.0)	0 (0.0)	–	< 0.001
Emergency cesarean delivery	57 (13.4)	19 (16.1)	38 (12.4)	0.313	0.106	30 (18.5)	15 (18.5)	15 (18.5)	1.000	< 0.001
Gestational age (weeks)										
$14 \leq GW < 34$	69 (16.2)	15 (12.7)	54 (17.6)	0.124	0.128	24 (14.8)	10 (12.3)	14 (17.3)	0.609	0.130
$34 \leq GW < 37$	200 (47.1)	51 (43.2)	149 (48.5)		0.106	81 (50.0)	43 (53.1)	38 (46.9)		− 0.124
$37 \leq GW$	156 (36.7)	52 (44.1)	104 (33.9)		− 0.215	57 (35.2)	28 (34.6)	29 (35.8)		0.026

Values are *n* (%)

PSM propensity score matching, *PAS* placenta accreta spectrum, *NA* neuraxial anesthesia, *GA* general anesthesia, *SMD* standardized mean difference, *HGB* hemoglobin, *HGB* hemoglobin, *BPAA* balloon placement in the abdominal aorta, *GW* gestational weeks

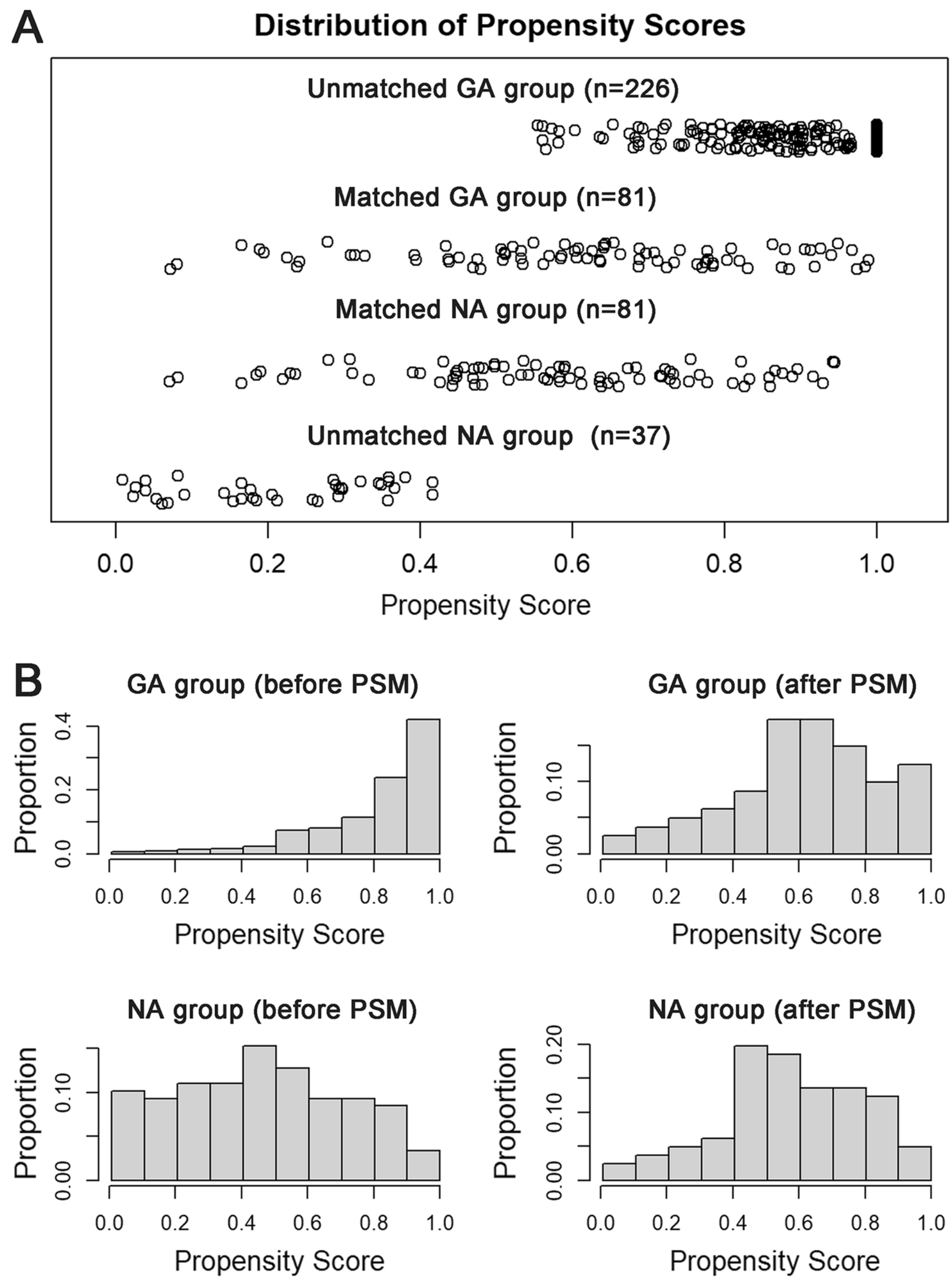

Fig. 2 The distribution of propensity score before and after PSM analysis. **A** 81 patients in the NA group and 81 patients in the GA group were successfully matched. **B** Histograms show the propensity scores of the two groups are evenly more uniformly distributed after matching. *PSM* propensity score matching, *NA* neuraxial anesthesia, *GA* general anesthesia

serosa-bladder wall interface (OR 2.62, 95% CI 1.70–4.03, $P<0.001$), hypervascularity of the cervix (OR 3.29, 95% CI 1.88–5.76, $P<0.001$), BPAA (OR 0.54, 95% CI 0.31–0.92, $P=0.022$), and gestational age ($P=0.013$). After considering potential confounding variables, GA (OR 4.23, 95% CI 2.27–7.87, $P<0.001$), emergency cesarean delivery (OR 2.40, 95% CI 1.23–4.69, $P=0.010$), vascular lacunae within the placenta (OR 3.30, 95% CI 1.95–5.59, $P<0.001$), hypervascularity of uterine-placental margin (OR 2.40, 95% CI 1.37–4.19, $P=0.002$), hypervascularity of the cervix (OR 2.29, 95% CI 1.18–4.46, $P=0.014$), and balloon placement in the abdominal aorta (OR 0.14, 95% CI 0.07–0.27, $P<0.001$) were significantly associated with a higher likelihood of adverse maternal events. The AUC for these high-risk factors in the post-matched cohort was 0.78 (95% CI 0.74–0.83) (Fig. 3).

Discussion

In this study, we observed significant differences in certain characteristics between the GA and NA groups, such as gravidity > 4, placenta increta, history of cesarean delivery > 1, complete placenta previa, and prenatal ultrasound results. To

Table 2 Comparisons of surgical outcomes before and after PSM

Surgical outcomes	Before matching				After matching			
	Total (n = 425)	NA (n = 118)	GA (n = 307)	P-value	Total (n = 162)	NA (n = 81)	GA (n = 81)	P-value
Total operation time (mins)	90 (70–120)	75 (60–101)	95 (75–127)	< 0.001	81 (70–109)	78 (63–107)	87 (75–110)	0.030
Length of hospital stay (days)	10 (7–17)	8 (6–12)	12 (8–19)	< 0.001	10 (7–14)	9 (7–12)	10 (8–15)	0.142
Postoperative Length of hospital stay (days)	5 (4–7)	4 (4–6)	5 (4–7)	< 0.001	5 (4–6)	4 (4–6)	5 (4–6)	0.037
Intraoperative blood loss (mL)	1100 (600–2000)	700 (400–1100)	1500 (800–2500)	< 0.001	1000 (600–2000)	800 (500–1200)	1500 (800–2050)	< 0.001
Units of PRBC transfused	4 (2–8)	2 (0–4)	6 (4–8)	< 0.001	4 (1–6)	2 (0–4)	4 (2–7)	< 0.001
B-Lynch suture	109 (25.6)	36 (30.5)	73 (23.8)	0.155	50 (30.9)	27 (33.3)	23 (28.4)	0.496
Ligation of the ascending branch of the uterine artery	100 (23.5)	45 (38.1)	55 (17.9)	< 0.001	43 (26.5)	32 (39.5)	11 (13.6)	< 0.001
Tourniquet binding the lower uterine segment	102 (24.0)	36 (30.5)	66 (21.5)	0.051	45 (27.8)	30 (37.0)	15 (18.5)	0.009
Hysterectomy	18 (4.2)	7 (5.9)	11 (3.6)	0.289	8 (4.9)	3 (3.7)	5 (6.2)	0.720
Bladder repair	31 (7.3)	4 (3.4)	27 (8.8)	0.055	8 (4.9)	2 (2.5)	6 (7.4)	0.277
Reoperation for bleeding	2 (0.5)	0 (0.0)	2 (0.7)	1.000	1 (0.6)	0 (0.0)	1 (1.2)	1.000
Systemic infections	20 (4.7)	10 (8.5)	10 (3.3)	0.023	10 (6.2)	7 (8.6)	3 (3.7)	0.192
Pulmonary embolism	1 (0.2)	0 (0.0)	1 (0.3)	1.000	0 (0.0)	0 (0.0)	0 (0.0)	–
DVT or thrombotic requiring therapy	2 (0.5)	1 (0.8)	1 (0.3)	0.479	1 (0.6)	1 (1.2)	0 (0.0)	1.000
DIC	3 (0.7)	0 (0.0)	3 (1.0)	0.564	1 (0.6)	0 (0.0)	1 (1.2)	1.000
ICU	13 (3.1)	9 (7.6)	4 (1.3)	0.002	10 (6.2)	8 (9.9)	2 (2.5)	0.050

Values are median (interquartile range) or n (%)

PSM propensity score matching, *NA* neuraxial anesthesia, *GA* general anesthesia, *PRBC* packed red blood cells, *DVT* deep vein thrombosis, *DIC* disseminated intravascular coagulation, *ICU* intensive care unit

account for these differences, we conducted a rigorous 1:1 propensity score matching of the preoperative characteristics of the two groups using a PSM algorithm. Both in the pre-matched and post-matched cohorts, the NA group exhibited lower intraoperative blood loss, fewer units of PRBC transfusion, shorter operating duration, and shorter postoperative length of hospital stay compared to the GA group. The NA group also had higher rates of tourniquet binding the lower uterine segment and ligation of the ascending branch of the uterine artery. There were no differences in neonatal outcomes between the two groups. Notably, the incidence of adverse events was lower in the NA group in our study.

It is well recognized that GA can have adverse effects on both the mother and the newborn, including complications such as failed intubations, neonatal respiratory depression, and lower Apgar scores [19]. The rates of these complications are significantly higher in interventions involving GA compared to interventions involving NA alone. For instance, the complication rates are two-fold higher per 100,000 interventions with GA, and seven-fold higher with GA plus NA, compared to NA alone [20]. However, in the case of PAS, which is considered one of the most critical obstetric emergencies, there is a strong association with adverse maternal outcomes, primarily due to massive blood loss, which can

Table 3 Comparisons of neonatal outcomes before and after PSM

Neonatal outcomes	Before matching				After matching			
	Total (*n* = 405)	NA (*n* = 117)	GA (*n* = 288)	*P*-value	Total (*n* = 157)	NA (*n* = 80)	GA (*n* = 77)	*P*-value
Apgar score (points)								
1 min								
0–7	46 (11.4)	10 (8.5)	36 (12.5)	0.256	14 (8.9)	8 (10.0)	6 (7.8)	0.627
8–10	359 (88.6)	107 (91.5)	252 (87.5)		143 (91.1)	72 (90.0)	71 (92.2)	
5 min								
0–7	18 (4.4)	5 (4.3)	13 (4.5)	0.915	9 (5.7)	5 (6.3)	4 (5.2)	1.000
8–10	387 (95.6)	112 (95.7)	275 (95.5)		148 (94.3)	75 (93.8)	73 (94.8)	
Weight (g)	2900 (2500–3200)	2850 (2510–3300)	2900 (2500–3200)	0.854	2800 (2475–3250)	2800 (2463–3250)	2850 (2475–3275)	0.943
NICU	187 (46.2)	57 (48.7)	130 (45.1)	0.513	82 (52.2)	46 (57.5)	36 (46.8)	0.178
Death	3 (0.7)	0 (0.0)	3 (1.0)	0.560	2 (1.3)	0 (0.0)	2 (2.6)	0.239

Values are median (interquartile range) or *n* (%)

PSM propensity score matching, *NA* neuraxial anesthesia, *GA* general anesthesia, *NICU* neonatal intensive care unit

be life-threatening [1]. Anesthesiologists may lean towards using GA in PAS cases due to concerns about significant bleeding, potential hemodynamic instability, and the risk of intraoperative hypotension associated with sympathetic blockade caused by neuraxial anesthesia [7].

Recent investigations comparing the two anesthesia modalities, GA and NA, for patients with PAS have reported favorable outcomes with the use of NA. These studies have shown that NA is a viable and effective option for managing PAS, with positive results [21, 22]. However, it is worth noting that these studies have been relatively small in scale. The current study is the largest multicenter study to date comparing the application of GA and NA in PAS cases. In this study, 27.8% of cesarean deliveries were performed under NA, and the frequency of adverse maternal outcomes in the NA group was significantly lower than that in the GA group. Additionally, only a small proportion of patients (10%) required conversion from NA to GA during surgery, indicating that NA is a feasible and acceptable anesthesia method for managing PAS cases. These findings suggest that NA can be a suitable alternative to GA in the management of PAS, providing positive outcomes and potentially minimizing the risks associated with GA-related complications.

The data, both before and after matching, indicated that the NA group had lower intraoperative blood loss and units of PRBC transfused compared to the GA group. Similar findings have been reported in previous studies [23, 24]. A prospective randomized study comparing GA with epidural anesthesia for cesarean delivery with grade 4 placenta previa also found that epidural anesthesia was superior to GA in terms of maternal hemodynamics and blood loss [23, 25]. In our study, the rates of tourniquet binding of the low uterine segment and ligation of the ascending branch of the uterine artery were higher in the NA group. Because in NA-managed cesarean sections, doctors may perform preventative binding of the low uterine segment and ligation of the uterine artery out of concern for massive intraoperative hemorrhage. We also found that ICU admission substantially higher in the NA group before and after matching. That is because the criteria for ICU admission are different slightly in three hospitals. One of our medical centers, which has a high rate of NA, has established MICU specifically for perinatal women with urgent circumstances, such as massive bleeding and severe infections. Therefore, they prefer to transfer PAS patients with intraoperative hemorrhage to the MICU to monitor vital signs.

Opioids and GA induction agents have the potential to affect neonatal Apgar scores due to their rapid transfer across the placenta to the fetus [26]. However, our study, in line with a review, found no significant impact of anesthesia modality on neonatal scores, birth weight, ICU transfer rate, or mortality [24]. This lack of effect could be attributed to the short duration of GA exposure from the incision to the delivery of the baby.

Ultrasonography is commonly used as an auxiliary examination for the prenatal diagnosis of PAS, and it has shown high sensitivity. Intraplacental lacunae, which are vascular lakes within the placental parenchyma, can be observed during ultrasonography. Finberg and Williams classified these lacunae into four grades based on their number, size, and shape. They reported that higher-grade lacunae were associated with a higher frequency of adherent placenta [27]. Intraplacental vascular lacunae can also serve as predictors of obstetric complications. A study involving fifty-one patients with placenta previa diagnosed by transvaginal sonography found that cases with intraplacental lacunae had a significantly higher incidence of clinical complications, particularly related to the need for massive transfusion, admission

Table 4 Univariable and multivariate logistic regression analysis for the maternal adverse event in the before PSM cohort

Characteristics	Univariable		Multivariate	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
GA (vs. NA)	4.19 (2.39–7.35)	< 0.001	4.23 (2.27–7.87)	< 0.001
Age at delivery > 33 years (vs. ≤ 33)	1.27 (0.85–1.89)	0.251		
Gravidity > 4 (vs. ≤ 4)	1.77 (1.12–2.80)	0.015		
Parity > 1 (vs. ≤ 1)	1.34 (0.88–2.04)	0.176		
History of curettage of uterine > 1 (vs. ≤ 1)	1.40 (0.88–2.29)	0.159		
History of cesarean delivery > 1 (vs. ≤ 1)	1.73 (1.12–2.69)	0.014		
Preoperative HGB level ≤ 100 g/L (vs. > 100)	1.48 (0.96–2.28)	0.075		
Preoperative platelets level ≤ $100*10^9$ (vs. > 100)	2.49 (0.66–9.42)	0.179		
Pregnancy-induced hypertension (vs. no)	0.35 (0.10–1.23)	0.102		
Gestational diabetes mellitus (vs. no)	1.50 (0.88–2.55)	0.138		
Placenta previa classification		0.290		
Marginal	2.24 (0.66–7.55)	0.195		
Partial	0.85 (0.13–5.51)	0.865		
Complete	2.32 (0.76–7.06)	0.138		
None	Reference			
Emergency cesarean delivery (vs. no)	1.78 (1.01–3.13)	0.046	2.40 (1.23–4.69)	0.010
Retroplacental myometrial thickness < 1 mm (vs. no)	1.93 (1.23–3.02)	0.004		
Vascular lacunae within the placenta (vs. no)	3.33 (2.15–5.17)	< 0.001	3.30 (1.95–5.59)	< 0.001
Hypervascularity of uterine-placental margin (vs. no)	2.30 (1.48–3.57)	< 0.001	2.40 (1.37–4.19)	0.002
Irregularity of uterine-bladder interface (vs. no)	1.68 (1.07–2.62)	0.023		
Hypervascularity of the uterine serosa-bladder wall interface (vs. no)	2.62 (1.70–4.03)	< 0.001		
Hypervascularity of the cervix (vs. no)	3.29 (1.88–5.76)	< 0.001	2.29 (1.18–4.46)	0.014
BPAA	0.54 (0.31–0.92)	0.022	0.14 (0.07–0.27)	< 0.001
Preoperative vaginal bleeding	1.12 (0.94–1.34)	0.215		
Dexamethasone practice to promote fetal lung	1.33 (0.89–2.00)	0.165		
Gestational age (weeks)		0.013		
14 ≤ GW < 34	2.05 (1.12–3.74)	0.020		
34 ≤ GW < 37	1.88 (1.18–2.98)	0.007		
37 ≤ GW	Reference			

PSM propensity score matching, *OR* odds ratio, *CI* confidence interval, *NA* neuraxial anesthesia, *GA* general anesthesia, *HGB* hemoglobin, *BPAA* balloon placement in the abdominal aorta, *GW* gestational weeks

to the intensive care unit, and cesarean hysterectomy [28]. These findings are consistent with our own research and our previous investigation on PAS [29].

Our study is the largest multicenter study to date comparing the application of two anesthesia methods in PAS. We utilized the PSM algorithm to enhance the accuracy and reliability of our findings by comparing perinatal outcomes before and after matching the patient cohort. However, since our study is retrospective in nature, we had to rely solely on recorded data, which is a limitation. To validate our results, more prospective randomized-controlled trials should be conducted. Additionally, most PAS diagnoses are made during cesarean delivery based on the expertise of the obstetrician, and some patients lack pathological evidence of the uterus due to conservative therapy constraints. Nevertheless, the use of PSM helped exclude patients with high propensity scores in the GA group and those with low propensity scores in the NA group. The matched GA group had a lower percentage of placental percreta diagnoses, which limits the generalizability of our findings to high-risk PAS patients. The data of the time from induction of anesthesia to delivery of the baby and the time from the skin incision to delivery of the baby were not included in the study.

In our study, the NA group had higher rates of tourniquet binding the lower uterine segment and ligation of the ascending branch of the uterine artery. The decision of ligation of uterine artery or tourniquet binding of the lower uterine segment depends on the condition during the surgery as well as the choice and preference of the obstetrician and this is one of our limitations. Furthermore, it is

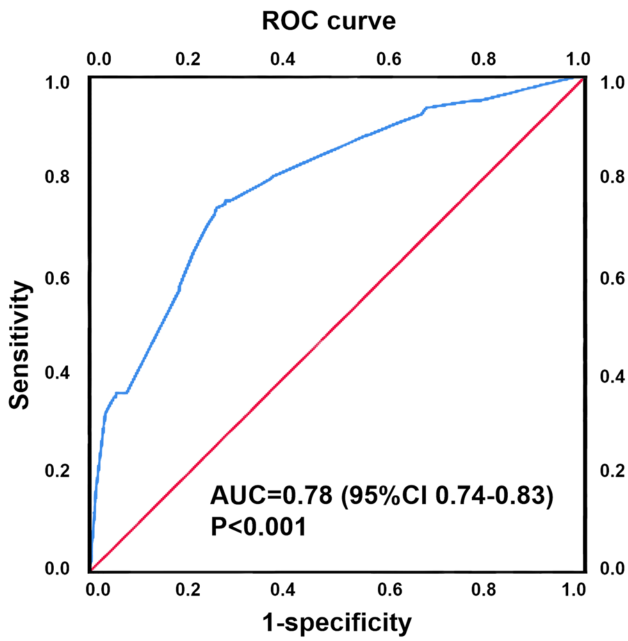

Fig. 3 ROC curves. *PSM* propensity score matching, *ROC* receiver operating characteristic, *AUC* area under the receiver operating characteristic curve, *CI* confidence interval

important to note that PSM cannot account for unmeasured characteristics, which introduces the potential risk of bias.

Conclusion

Our findings indicate that PAS patients who underwent cesarean section with NA experienced lower levels of intraoperative blood loss, PRBC transfusion, operating duration, and postoperative hospital stay compared to those who received GA. These results suggest that NA can be considered as a primary anesthesia mode for such cases. However, the indications of patients who can accept NA need to be further explored.

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Declarations

Conflict of interest The authors have no potential conflicts to disclose.

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