Clinical and Experimental Obstetrics & Gynecology

Systematic Review

Clinical efficacy of aortic balloon occlusion during caesarean section in patients with placenta accreta spectrum disorders: a systematic review and meta-analysis

Yu Huang[1], Fang-Yuan Luo[1,*]

[1] *Department of Obstetrics and Gynecology, Sichuan Academy of Medical Sciences & Sichuan Provincial People's Hospital, No.32 West Second Section First Ring Road, 610041 Chengdu, Sichuan, China*

*Correspondence: 20180299120030@stu.swmu.edu.cn (Fang-Yuan Luo)

DOI:10.31083/j.ceog.2021.02.2293

Submitted: 13 September 2020 Revised: 07 November 2020 Accepted: 13 November 2020 Published: 15 April 2021

Object: This systematic review and meta-analysis aim to examine evidence on the effectiveness and safety of aortic balloon occlusion (ABO) during caesarean deliveries in placenta accreta spectrum (PAS) disorders. *Methods*: MEDLINE, Science Citation Index, Elsevier, clinicaltrials.gov, and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched for articles dated from database inception to February 2020. The primary outcomes were intraoperative blood loss volume (BLV) and hysterectomy rate. *Results*: Of the 793 articles, 11 were included in this study, with a total of 915 patients. Of the 535 patients who underwent ABO, 48 (9%) had placenta creta; 309 (57%), placenta increta; and 124 (23%), placenta percreta. Meta-analysis showed that ABO significantly reduced BLV and blood transfused volume ($P < 0.001$), and reduced the rate of hysterectomy ($P < 0.001$). The overall catheter-related complication rate was 3.36%. The primary outcomes were available for 60 patients with placenta percreta. Meta-analysis of these patients showed ABO was associated with a decrease in BLV ($P < 0.001$), but not a statistically significant reduction in hysterectomy ($P = 0.48$). *Conclusions*: ABO is effective at controlling haemorrhage and reducing the need for hysterectomy in PAS disorders, but it did not appear to be effective for uterine preservation in patients with placenta percreta.

Keywords

Aorta; Balloon occlusion; Placenta accreta; Placenta percreta; Caesarean section

1. Introduction

The placenta accreta spectrum (PAS) disorders were first defined by Luke *et al.* as "morbidly adherent placenta", but in 2018 the International Federation of Gynecology and Obstetrics (FIGO) replaced the former name with placenta accreta spectrum to emphasise the histopathology of these disorders [1]. Based on the depth of villi invasion into the myometrium, the PAS disorder is classified into three subtypes: (1) adherent placenta accreta, also described by pathologists as "placenta creta, vera, or adherenta", when the villi has simply adhered to the myometrium; (2) placenta increta, when the villi has invaded the myometrium; (3) placenta percreta, when the villi has invaded the full thickness of the myometrium including the uterine serosa, and in some cases the adjacent pelvic organs [2].

PAS disorders can cause maternal morbidity and mortality from massive obstetric haemorrhaging, disseminated intravascular coagulation (DIC), and caesarean hysterectomy. The worldwide prevalence rate for PAS disorders was reported to be between 0.01% and 0.19% in 2018 [3–5]. With the new second-child policy in China being passed in 2015, the reported PAS disorders prevalence rate was as high as 1.47% in a Southwest Chinese critical maternal treatment centre [6].

Most experts still recommend a planned caesarean hysterectomy for the management of PAS disorders, especially in more invasive subtypes [2]. However, this approach results in the permanent loss of fertility. Leaving the placenta *in situ* is an option for women who wish to preserve their fertility, but continuous long-term follow-up with adequate expertise would be required, as late postpartum haemorrhage, infection, and delayed hysterectomy could still occur [2]. Alternatively, some experts try to solve the problem at the time of caesarean section surgery. A one-step conservative and stepwise surgical approach was described by Palacios-Jaraquemada *et al.* and Shabana *et al.*, respectively [7, 8]. The key aspects of these procedures were surgical uterine devascularization followed by placental extraction. The reported uterine preservation rate ranged from 27.3% to 95.7% [9].

Another strategy for uterine or pelvic devascularization is prophylactic endovascular balloon occlusion. The most common vascular occlusion was the internal iliac arteries followed by the infernal abdominal aorta. In recent years, aortic balloon occlusion (ABO) has been widely used in Chinese obstetrics to simultaneously block the collateral circulation during the caesarean section or caesarean hysterectomy of patients with complicated PAS disorders, for uterus preservation and blood saving. Usually, a 5–10 F balloon catheters are inserted into infrarenal abdominal aorta by an interventional radiologist before surgery. During the surgery, as obstetrist requested, the balloon is inflated immediately after delivery and umbilical cord clamping to block the uterine blood supply

temporarily to minimize haemorrhage. Typically, a continuous aortic occlusion should not be more than 40 min and the balloon were routinely deflated before closing the peritoneal cavity to confirm hemostasis.

The objective of this study was to examine the available evidence to determine the effectiveness and safety of ABO for haemorrhage control and uterine preservation in caesarean deliveries complicated by a PAS disorder, particularly those with the more invasive subtype placenta percreta. The effectiveness of ABO for blood saving during planed caesarean section was not evaluated in this study.

2. Materials and methods

2.1 Search strategy

A systematic search of the medical databases MEDLINE, Science Citation Index, Elsevier, clinicaltrials.gov, and CENTRAL was performed. The following MeSH terms and free keywords were used: "placenta accreta", "placenta increta", "placenta percreta", "aorta", "balloon occlusion", and "balloon". The search was limited to studies involving humans. In addition, the reference lists of relevant articles were searched to identify articles missed by the electronic searches. This study was reported in line with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR (Assessing the methodological quality of systematic reviews) Guidelines. The PROSPERO registration number was CRD42020175898.

2.2 Inclusion and exclusion criteria

The inclusion criteria for studies to be included in this systematic review were as follows: (1) the population investigated included patients with PAS disorders (adherent accreta, increta, and percreta) who delivered by caesarean section; (2) the intervention was prophylactic ABO during surgery for haemorrhage control and uterine preservation, while the patients in the control group underwent a direct caesarean section without any endovascular intervention modalities; (3) the primary outcomes were intraoperative blood loss volume (BLV) and hysterectomy rate; secondary outcomes were volume of packed red blood cells (PRBC) transfused, operation duration, the rate of intensive care unit (ICU) admissions, mean occlusion time, surgery and catheter-related complications; (4) studies published in English or Chinese from database inception until Feb 2020.

Two authors performed screening the articles and meta-analysis. Studies were excluded if date could not be extracted from the published report or if ABO was performed during planned caesarean hysterectomy. Patients with contraindications to ABO or underwent other interventional methods were excluded from each article. Studies from the same institution were identified and assessed carefully to avoid analysing the same eligible patients twice. The studies that closely matched our inclusion criteria and reported on the greatest number of patients with PAS disorders were finally included in our study.

2.3 Data extraction

The following data was recorded for each study: first author, year of publication, country of publication, institution of first author, and patient characteristics. If the target information (the rate of caesarean hysterectomy and BLV in patients with placenta percreta) could not be extracted from the published report, the authors of the included studies were contacted. Two independent researchers reviewed the titles and abstracts, and selected potentially relevant articles, and then obtained the full text. The full text was reviewed separately, and two researchers selected articles for inclusion or exclusion. The selectivity bias was mitigated by discussing about the review process and search findings regularly and resorting to professional third-party adjudication when conflicts existed between researchers. The quality assessment was completed by two researchers using the Newcastle-Ottawa Quality Assessment Scale.

2.4 Statistical analysis

The weighted mean difference (WMD) and 95% confidence interval (CI) was calculated for the continuous outcomes, while the odds ratio (OR) and 95% CI was calculated for the dichotomous outcomes. In studies reporting the medians and interquartile ranges, the medians were taken to be representative of the means, and the interquartile ranges were converted into standard deviations by dividing by 1.35 [10]. In studies reporting the PRBCs transfused in units, 1 unit was converted into 200 mL. The treatment effect was considered significant if the P value was < 0.050. Heterogeneity between studies was tested using both the chi-squared test (significant if the P value was < 0.100) and the I^2 test (with substantial heterogeneity defined as $> 50\%$). When studies showed significant heterogeneity, a random effects model was used to calculate the pooled effect size. A fixed-effects model was used when heterogeneity was insignificant. Review Manager version 5.0 (The Cochrane Collaboration 2008) was used for data analysis.

3. Results

3.1 Literature search

A total of 793 articles were identified in the electronic databases, of which 759 were excluded based on the article title and abstract. The full articles of the remaining 34 studies were collected and evaluated. Of these studies, 13 met the inclusion criteria for this systematic review [11–20] (Table 1). As Duan *et al.* and Wu *et al.* were from the same research institution, and Xie *et al.* and Zheng *et al.* were from the same department of the same hospital, the articles by Duan *et al.* and Xie *et al.* were excluded [20, 21]. The reasons for exclusion are summarised in the PRISMA flow diagram presented in Fig. 1. Finally, a total of 11 articles were included in this systemic review.

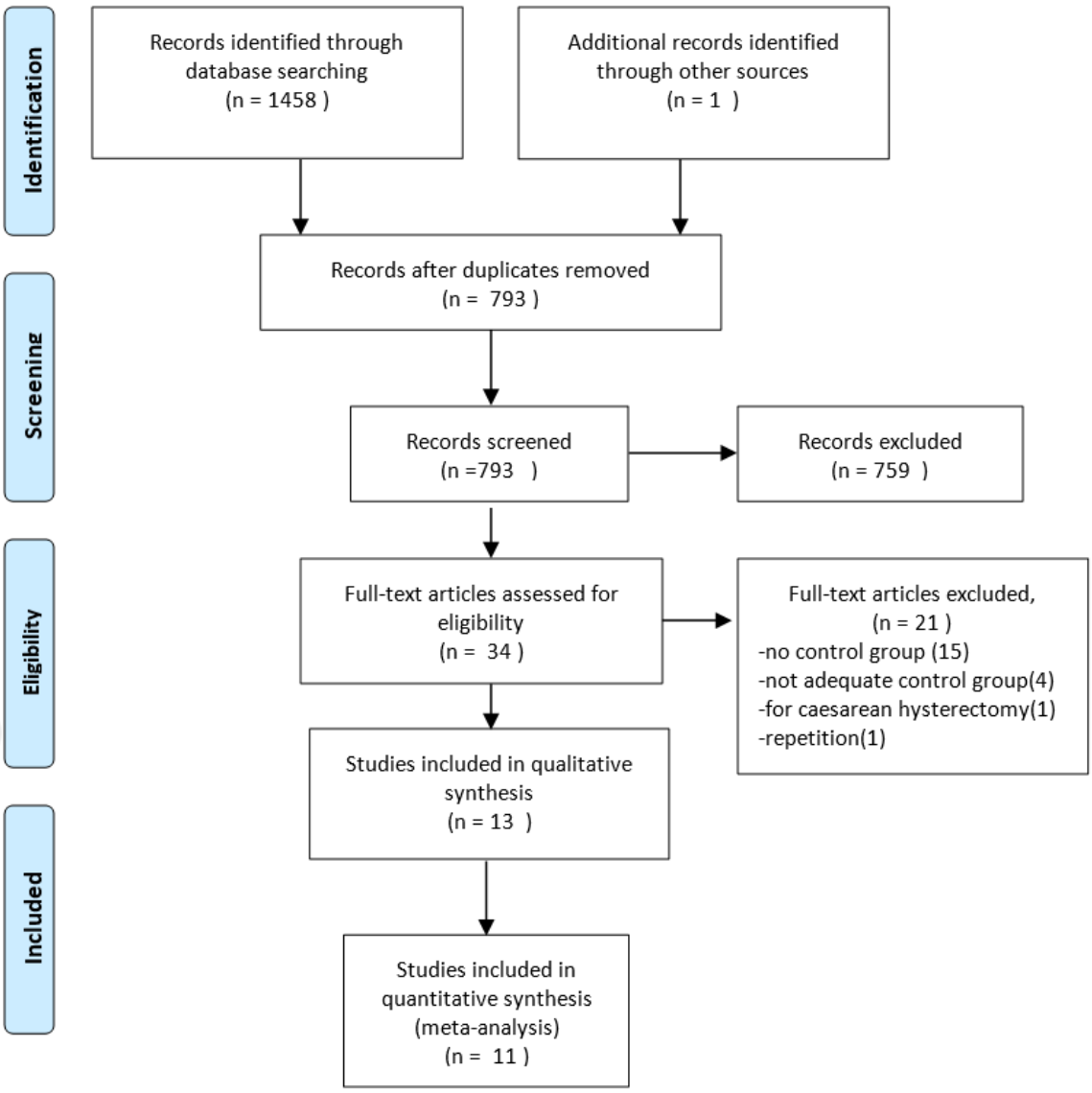

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) study flow diagram summarising the literature search, inclusion, and exclusion criteria for this study.

3.2 Study quality and characteristics

All 11 of the included studies were single-centre, retrospective cohort, or case-controlled studies published between 2012 and 2018. The retrospective aspect of these studies might have resulted in selection and information bias. Not all of the PAS disorder diagnoses in these studies were based on a pathological examination, potentially resulting in bias. Overall, the methodological quality of the included studies in this meta-analysis was moderate. The corresponding Newcastle-Ottawa Quality Assessment results are presented in Table 2.

The 11 included articles contained a total of 915 patients. Among these patients, 535 (58%) underwent prophylactic ABO during a caesarean section, while the remaining 380 (42%) patients had a direct caesarean section without any endovascular intervention modalities. The mean age of the patients was 30.8 years (27.5 years [14] to 35 years [15]). The mean gestational age at delivery was 35.8 weeks (35.1 weeks [20] to 38.2 weeks [21]).

Of the 535 patients who underwent ABO, 48 (9%) had placenta creta, 309 (57%) placenta increta, and 124 (23%) placenta percreta. Of these patients, 181 (34%) had undergone a previous caesarean section, and 425 (79%) were complicated with placenta previa. Balloon inflation time ranged from 5 min [19] to 80 min [15]. The maternal radiation exposure dose ranged from 3.2 milligray (mGy) [18] to 7.6 mGy [12]. Three patients developed a hematoma at the ABO puncture sites and 15 patients developed thrombosis. The total catheter-related complication rate was 3.36% (n = 15/535). Other characteristics of the patients and studies are summarised in Table 1.

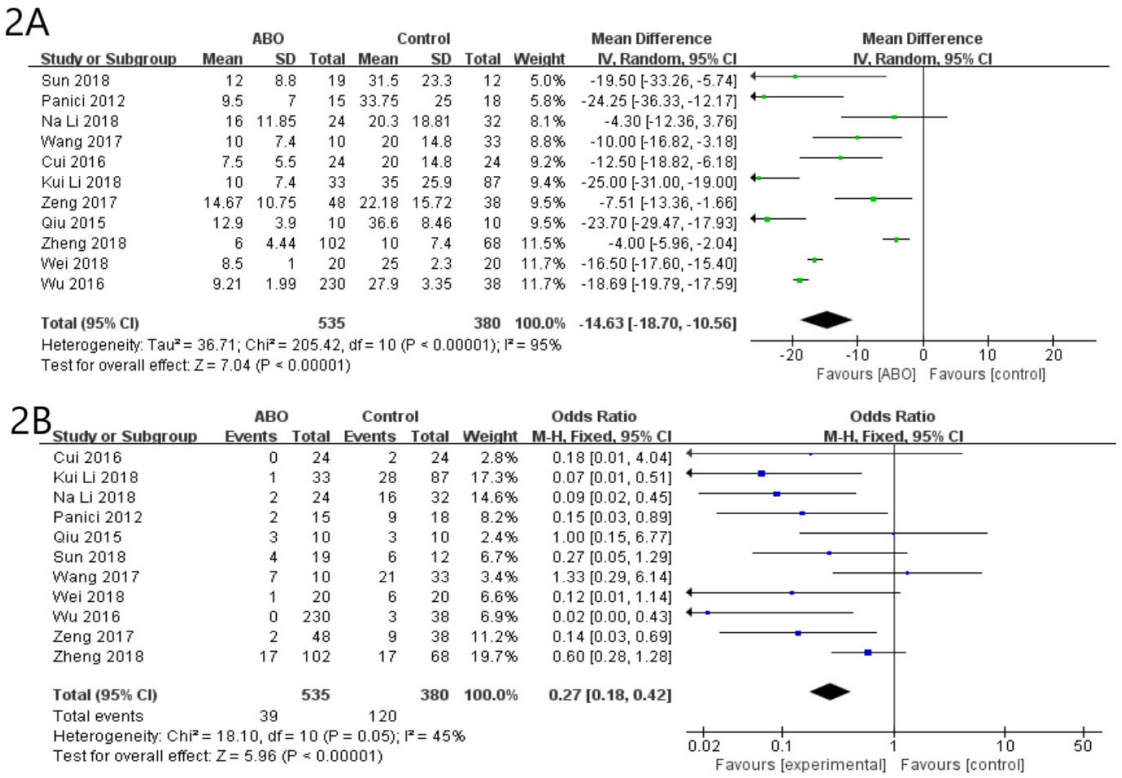

Fig. 2. Forest plot comparing the blood loss volume (BLV) in milliliters (2A) and hysterectomy rates (2B) between the aortic balloon occlusion (ABO) group and the control group.

3.3 Quantitative synthesis (meta-analysis)

3.3.1 Primary outcomes

Overall, 11 articles compared the intraoperative BLV between the ABO groups and the control groups [11–21]. The prophylactic use of ABO before surgery significantly reduced BLV compared with a direct caesarean section (WMD, -1463 mL; 95% CI, -1870 to -1056 mL; $P < 0.001$) (Fig. 2A). The unplanned caesarean hysterectomy rates in patients who underwent ABO and in those who did not were compared for all 11 included articles. Overall, the hysterectomy rates were significantly different between the ABO and control group (OR, 0.27; 95% CI, 0.18 to 0.42; $P < 0.001$) (Fig. 2B).

3.3.2 Secondary outcomes

The amount of PRBCs transfused was compared in 10 studies [11, 13, 15–21]. Overall, the patients who underwent ABO for haemorrhage control had less PRBCs transfused than those who did not (WMD, -940 mL; 95% CI, -1172 to -707 mL; $P < 0.001$) (Fig. 3A). The operative duration was reported in 9 studies [11–13, 15, 17–21]. The operation duration was significantly shorter in the ABO group than in the control group (WMD, -28.2 min; 95% CI, -43.48 to -12.93 min; $P < 0.001$) (Fig. 3B). The rate of ICU admission was compared in 8 articles [12–14, 17–21] and it was significantly lower in the ABO group (OR, 0.32; 95% CI, 0.14 to 0.74; $P = 0.007$) (Fig. 3C).

3.3.3 Hysterectomy rate and BLV of patients with placenta percreta

Two articles compared the rate of caesarean hysterectomy and BLV in patients with placenta percreta between the two groups [18, 19]. The required data was obtained by contacting the author of reference 15, while the data from other articles could not be acquired [15, 17, 20]. The three articles [16, 18, 19] contained a total of 60 patients with placenta percreta (the villi has invaded the external myometrium or the bladder), 30 of which underwent ABO during surgery. Prophylactic ABO prior to a caesarean section significantly reduced BLV compared with a direct caesarean section (WMD, -1285 mL; 95% CI, -2019 to -551 mL; $P < 0.001$) (Fig. 4A). While the hysterectomy rate was not significantly different between the two groups (OR, 0.49; 95% CI, 0.07 to 0.42; $P = 0.48$) (Fig. 4B). The total caesarean hysterectomy rate for patients with placenta percreta was high at 91% (n = 55/60).

Table 1. The characteristics of the included studies.

Reference	Country	Research institute	Years of study	No. of patients	Subtypes of PAS disorders (n)	Placenta previa (n)	Prior caesarean section (n)	Diameter of balloon catheter	Balloon occlusion time (min)	Mean maternal radiation exposure dose (mGy)	Intraoperative blood loss volume (mL)	Hysterectomy (n)	Volume of packed red blood cells transfused (units)	Catheter-related complications
Cui, 2016 [11]	China	Department of Obstetrics, the Third Affiliated Hospital of Zhengzhou University	January 2015 to February 2016	24	Increta (19) Percreta (5)	24	24	5-F	NR	3.4	750	0	1	One thrombosis
Kui Li, 2018 [12]	China	Department of Radiology, Women's Hospital, School of Medicine Zhejiang University	August 2015 to	33	NR	33	NR	10-F	NR	7.6	1000	1	1	One thrombosis of internal iliac artery
Na Li, 2018 [13]	China	Department of Obstetrics and Gynecology, Shengjing Hospital of China Medical University	January 2014 and December 2016	24	Accreta (6) Increta (17)	24	24	5-F	23	NR	1600	2	5.83	One thrombosis of the right external iliac artery
Panici, 2012 [14]	Italy	Department of Gynecology, Università Sapienza	March 2005 and January 2011	15	Accreta (13) Increta (2)	15	15	8-F	32	NR	950	2	0	no
SUN, 2018 [15]	China	Department of Obstetrics, The Second Hospital of Shandong University	January 1, 2014 and December 30, 2016	19	increta (19)	19	19	NR	18	4.2	1200	4	4	One thrombosis in right internal iliac artery
Wang, 2017 [16]	China	Department of Obstetrics and Gynecology, People's Hospital of Shenzhen	January 2009 to January 2014	10	Increta (5) Percreta (5)	10	10	5-F	NR	NR	1000	7	5.5	no
Wu, 2016 [17]	China	Departments of Prenatal Diagnosis, and Obstetrics, Obstetric Critical Treatment Center of Henan Province, The First Affiliated Hospital of Zhengzhou Universit	January 2012 to June 2015	230	Increta (142) Percreta (88)	230	NR	8-F	23	5.1	921	0	2.1	Two thrombosis

Table 1. Continued.

Reference	Country	Research institute	Years of study	No. of patients	Subtypes of PAS disorders (n)	Placenta previa (n)	Prior caesarean section (n)	Diameter of balloon catheter	Balloon occlusion time (min)	Mean maternal radiation exposure dose (mGy)	Intraoperative blood loss volume (mL)	Hysterectomy (n)	Volume of packed red blood cells transfused (units)	Catheter-related complications
Zheng, 2018 [18]	China	Department of Obstetrics and Gynecology, Sichuan Academy of Medical Sciences & Sichuan Provincial People's Hospital	2013 to 2017	102	Accreta (29) Increta (58) Percreta (15)	NR	79	10-F	25	3.2	600	17	1.5	One case of hematoma at puncture sites eight cases of thrombosis
Zeng, 2017 [19]	China	Department of Obstetrics and Gynecology, Second Xiangya Hospital of Central South University,	January 2014 and March 2017	48	Increta (38) Percreta (10)	40	NR	NR	NR	NR	1467	2	5.4	One Thrombosis of femoral artery
Qiu, 2015 [20]	China	Department of Obstetrics and Gyncology, Third Affiliated Hospital ofFujian Medical University	August 2012 to March 2014	10	Increta (9) Percreta (1)	10	10	NR	NR	NR	1290	3	3.6	no
Wei, 2018 [21]	China	Department of Vascular Interventional Surgery, Liuzhou Works Hospital	January 2015 to August 2017	20	NR	20	NR	NR	NR	NO	850	2	1	Two cases of hematoma at puncture sites
Duan, 2018 [22]	China	Departments of 1Interventional Radiology, The First Affiliated Hospital of Zhengzhou University	Jan 2013 and Jan 2014	22	NR	22	22	8-F	20.5	NR	597	2.49	0	no
Xie, 2017 [23]	China	Department of Obstetrics and Gynecology, Sichuan Provincial People's Hospital	January 2013 to May 2015	30	Accreta/Increta (25) Percreta (5)	NR	25	10-F	24.5	NR	961	5	2	One haematoma at puncture sites

Abbreviations: PAS, placenta accreta spectrum; NR, no reported.

Table 2. The result of the quality assessment for the included studies (Newcastle-Ottawa Scale).

Reference	Case-cohort representative	Selection of non-exposed control	Ascertainment of exposure	Outcome negative at start	Comparability by design	Comparability by analysis	Outcome assessment	Duration of follow-up	Adequacy of follow-up	Score
Cui, 2016 [11]	√	√	√	√	√	√	√	×	×	7
Kui Li, 2018 [12]	√	√	√	√	√	√	√	×	×	7
Na Li, 2018 [13]	√	√	√	√	√	√	√	×	×	7
Panici, 2012 [14]	√	√	√	√	√	√	√	×	×	7
SUN, 2018 [15]	√	√	√	√	√	√	√	√	√	9
Wang, 2017 [16]	√	√	√	√	√	√	√	√	√	9
Wu, 2016 [17]	×	√	√	√	×	√	√	√	√	7
Zheng, 2018 [18]	√	√	√	√	√	×	√	×	×	6
Zeng, 2017 [19]	√	√	√	√	√	√	√	×	×	7
Qiu, 2015 [20]	√	√	√	√	√	√	√	×	×	7
Wei, 2018 [21]	√	√	√	√	×	√	√	×	×	6

3.3.4 Surgical complications and fetal outcomes

Three articles did not report surgical complications [12, 13, 17], and 1 article reported no major surgical complications [21]. The 7 remaining articles did report the outcomes from surgical complications. A total of 431 patients across both groups experienced surgical complications. In the ABO groups, there were 13 cases of bladder injury that required repair [11, 18, 19] and 1 case of pelvic abscess [20]. The surgical complication rate for the ABO group was 6.1% (n = 14/228). While in the control group, 3 patients experienced hemorrhagic shock and DIC [14–16], 10 cases had a bladder injury [18, 19], 4 patients needed further surgery for haemostasis or a hysterectomy [19], and 1 patient developed deep vein thrombosis [20]. One patient had a cardiac arrest but was successfully resuscitated [16]. In the control group the total surgical complication rate was 8.9% (n = 18/203). No maternal deaths were reported in either group. Nine articles compared the neonatal outcomes between the two groups. There was no significant difference in birth weight or Apgar score at 1 or 5 min [12–20].

3.3.5 Evaluation of publication bias

Funnel plots for the studies evaluating ABO versus no ABO intervention in terms of operation duration, hysterectomy rate, and BLV of patients with placenta percreta showed asymmetry on visual inspection (Fig. 5), the gaps suggested that few studies with negative results had been published.

4. Discussion

ABO is a haemorrhage control technique used in caesarean sections and caesarean hysterectomies for patients complicated by placenta previa and/or PAS disorders. This study aimed to assess the safety and efficacy of prophylactic ABO in the conservative management of PAS disorders, especially in the most invasive subtype, placenta percreta. The main finding of this study is that compared with a direct caesarean section, prophylactic ABO was effective at haemorrhage control and fertility preservation during deliveries complicated by PAS disorders. Furthermore, the patients who underwent prophylactic ABO during surgery also had a shorter operation duration and a lower rate of ICU admission. In patients complicated with placenta percreta, ABO was still effective at haemorrhage control, but did not significantly reduce the need for caesarean hysterectomies in this invasive PAS disorder. In addition, the total catheter-related complication rate of 3.36% is noteworthy.

Yousef Shahin *et al.* [10] performed a systematic review that compared the efficacy of different endovascular intervention methods for uterus-preservation in patients with abnormal placental implantation. The results showed that ABO resulted in less blood loss and a lower rate of hysterectomy than the other endovascular interventional methods. Another systematic review from China also focused on the safety and efficacy of prophylactic ABO in patients with placenta accrete, but it included a smaller number of patients and might have included repeated patients from the same research institution [24]. Our study not only verified the conclusions of these previous studies, but had a larger sample size, and more strict inclusion criteria. Also, to the best of our knowledge, this is the first meta-analysis study to evaluate the clinical efficiency of ABO in the conservative management of placenta percreta.

There is limited data on the conservative management of placenta percreta. Most studies were case reports. Pather *et al.* [25] reported on 3 patients with placenta percreta and reviewed 57 cases from the literature, the results demonstrated that a hysterectomy can be avoided in 60% of cases if the patient is managed with the placenta left *in situ*. While the rate of major complications was high at 42%, including sepsis, coagulopathy, haemorrhage, pulmonary embolism, fistula, and arteriovenous malformation. In a different review of 119 cases of placenta percreta, 66 patients (56%) underwent a direct caesarean hysterectomy, 36 cases (30%) were managed with the placenta left *in situ*, and a delayed secondary hysterectomy was required in 18 (58%) cases [26].

As there was nearly always massive obstetric haemorrhaging when forcibly removing a deeply invasive placenta, it was recommended by FIGO that the extirpative approach was abandoned [2]. The efficiency of prophylactic ABO at haemorrhage control was consistent in almost all of the previous studies investigating PAS disorders. However, it still be questioned that should this technique be employed for all three subtypes of PAS disorder for the purpose of uterine preservation. In our study, ABO did not reduce the need for a hysterectomy in patients with placenta percreta; therefore this procedure may not be suitable for patients with this condition. The ABO procedure should be mainly employed for a reduction in blood loss in a planned caesarean hysterectomy, but not for haemorrhage control in those who require an invasive placenta removal as part of the conservative management of placenta percreta. As the policy of Medicare resulted in different payments to different countries and the intention of fertility preservation was also different in different patients, the conservative management approach to placenta percreta should be based on the individual circumstances of the patient including the area and depth of myometrium villi invasion, and if any adjacent organs have been invaded.

There were limitations to this systematic review. The heterogeneity across some of the studies for some of the outcomes was significant and the number of articles that referred to the ABO outcomes in patients with placenta percreta was limited. All 11 articles included in this meta-analysis were retrospective case-control studies. The lack of pathological diagnoses and unclear descriptions regarding the invaded areas and depth of placental implantation were a problem, and constituted the main source of heterogeneity. Additional heterogeneity may have originated from the different subtypes of PAS disorders included in the study, the different surgeons, and blood loss volume estimations.

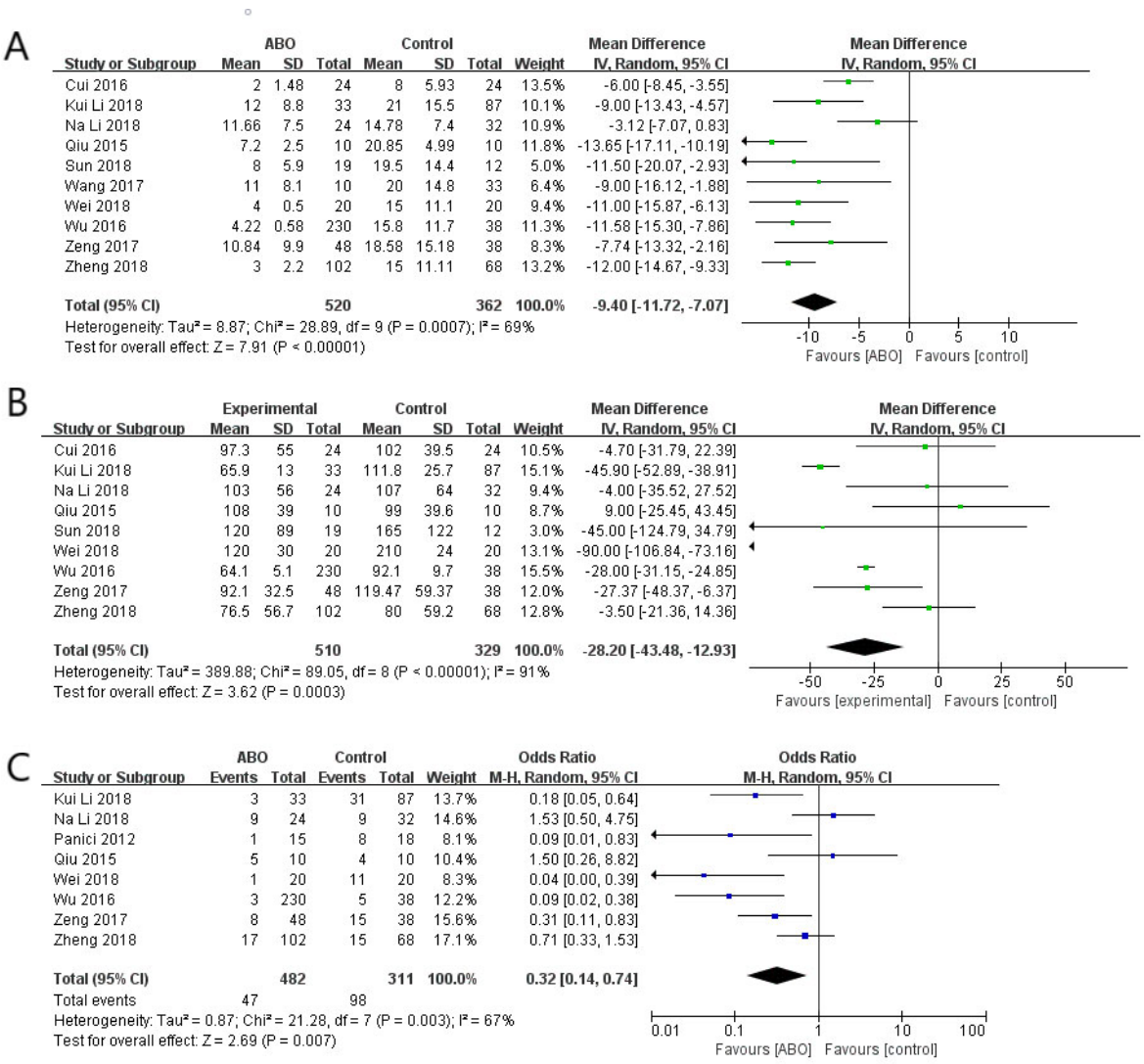

Fig. 3. Forest plot comparing the volume of packed red blood cells transfused (PRBC) in milliliters (A) operation duration (B) and rate of intensive care unit (ICU) admissions (C) between the aortic balloon occlusion (ABO) group and the control group.

As 10 of the 11 articles were from China, this systematic review had a regional limitation. As a matter of fact, ABO in PAS disorders is not accepted across all regions. In the developed European, internal iliac balloon occlusion (IIOB) was more frequently employed in PAS disorders for lower risk and longer data accumulation. But some studies compared different endovascular intervention methods for uterus-preservation in patients with PAS disorders demonstrated that ABO was more effective in controlling haemorrhage than IIOB [10, 12, 27]. This systematic review put forward an optional method of reduce blood loss when conservative management approach for PAS disorders was considered.

5. Conclusions

As there was a lack of high level evidence, such as prospective studies, large multicentre studies, and randomised controlled trials, to assess the efficiency and safety of ABO in patients with PAS disorders. Based on the available evidence, ABO was effective for haemorrhage control and uterine preservation in patients with PAS disorders. In addition, it was associated with a shorter operation duration and a lower rate of ICU admissions. The significant incidence rate of catheter-related complications indicates that patients should be selected cautiously. Among patients with placenta percreta, although prophylactic ABO may reduce intraoperative blood loss, remedial hysterectomy is still almost unavoidable as a result of massive haemorrhaging when the placenta is removed.

Author contributions

YH and FYL designed the study and collected all data. YH was responsible for writing introduction, results and discussion. FYL was responsible for writing materials and methods. YH performed data analysis. All authors read and approved the final manuscript.

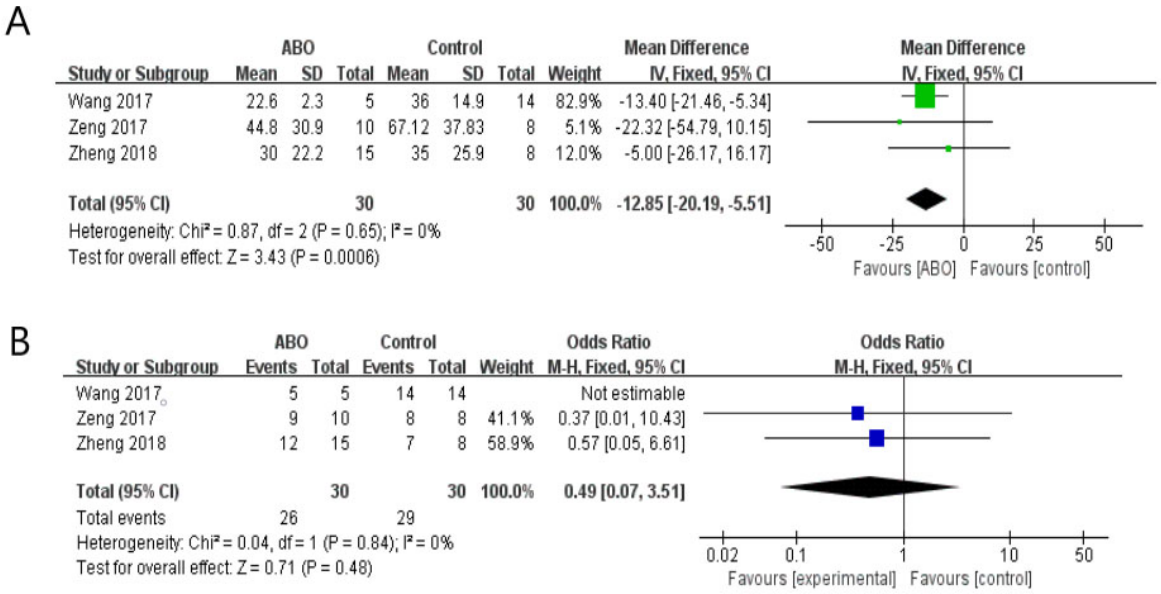

Fig. 4. Forest plot comparing the blood loss volume (BLV) in milliliters (A) and hysterectomy rates (B) between the aortic balloon occlusion (ABO) group and the control group with placenta percreta.

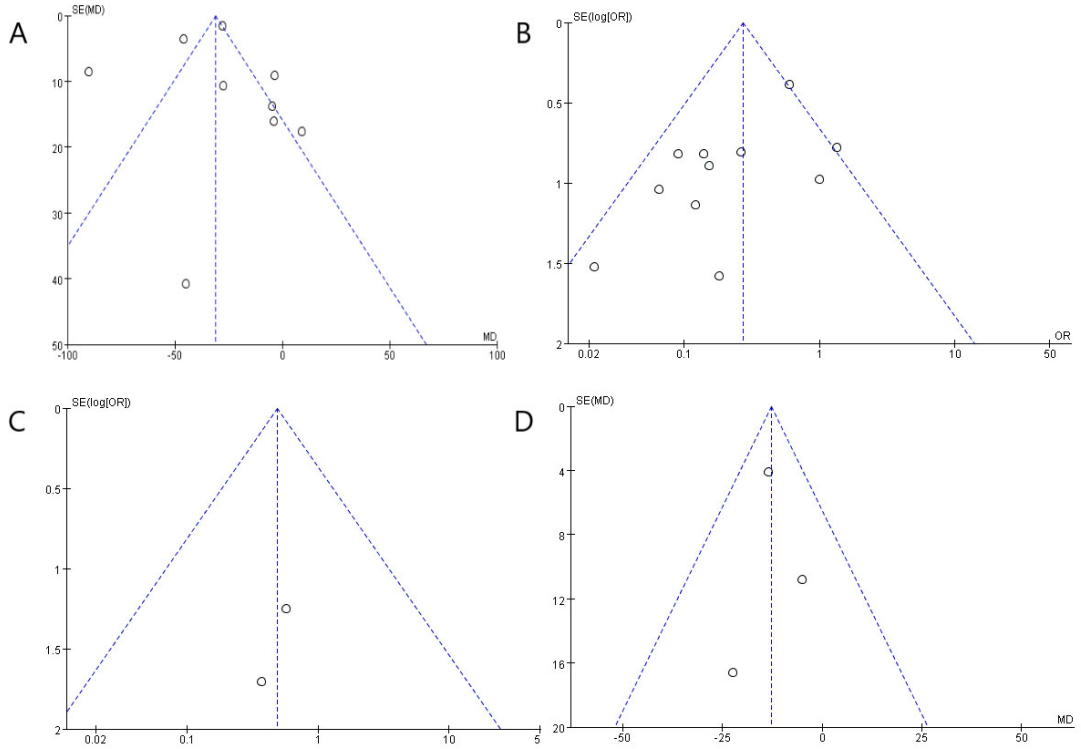

Fig. 5. Funnel plot of the operation duration in 9 studies (A) hysterectomy rate of all 11 studies (B) funnel plot of the hysterectomy rate (C) and the blood loss volume (BLV) according to 3 studies on placenta percreta (D).

Ethics approval and consent to participate

Not applicable.

Acknowledgment

We would like to express our gratitude to Dr. Ying-Lan Wang from The Second Hospital of Jinan University, who generously provided their clinic data to our research.

Funding

This study has received funding by Key projects of Sichuan Science and Technology Department (Grant No. 2018SZ0230).

Conflict of interest

The authors declare no conflict of interest.

Provenance and peer review

Not commissioned, externally peer-reviewed.

References

[1] Luke RK, Sharpe JW, Greene RR. Placenta accreta: the adherent or invasive placenta. American Journal of Obstetrics and Gynecology. 1966; 95: 660–668.

[2] Jauniaux E, Ayres-de-Campos D. FIGO Placenta Accreta Diagnosis and Management Expert Consensus Panel. FIGO consensus guidelines on placenta accreta spectrum disorders: introduction. International Journal of Gynecology & Obstetrics. 2018; 140: 261–264.

[3] Wu S, Kocherginsky M, Hibbard JU. Abnormal placentation: twenty-year analysis. American Journal of Obstetrics and Gynecology. 2005; 192: 1458–1461.

[4] Morlando M, Sarno L, Napolitano R, Capone A, Tessitore G, Maruotti GM, *et al.* Placenta accreta: incidence and risk factors in an area with a particularly high rate of cesarean section. Acta Obstetricia et Gynecologica Scandinavica. 2013; 92: 457–460.

[5] Higgins MF, Monteith C, Foley M, O'Herlihy C. Real increasing incidence of hysterectomy for placenta accreta following previous caesarean section. European Journal of Obstetrics & Gynecology and Reproductive Biology. 2013; 171: 54–56.

[6] Chen D, Xu J, Ye P, Li M, Duan X, Zhao F, *et al.* Risk scoring system with MRI for intraoperative massive hemorrhage in placenta previa and accreta. Journal of Magnetic Resonance Imaging. 2019; 51: 947–958.

[7] Palacios-Jaraquemada JM. Placental adhesive disorders. Berlin/Boston: Walter de Gruyter. 2012.

[8] Shabana A, Fawzy M, Refaie W. Conservative management of placenta percreta: a stepwise approach. Archives of Gynecology and Obstetrics. 2015; 291: 993–998.

[9] Palacios Jaraquemada JM, Pesaresi M, Nassif JC, Hermosid S. Anterior placenta percreta: surgical approach, hemostasis and uterine repair. Acta Obstetricia et Gynecologica Scandinavica. 2004; 83: 738–744.

[10] Shahin Y, Pang CL. Endovascular interventional modalities for haemorrhage control in abnormal placental implantation deliveries: a systematic review and meta-analysis. European Radiology. 2018; 28: 2713–2726.

[11] Cui SH, Zhi YX, Zhang K, Zhang LD, Shen LN, Gao YN. Application of temporary balloon occlusion of the abdominal aorta in the treatment of complete placenta previa complicated with placenta accreta. Zhonghua Fu Chan Ke Za Zhi. 2016; 51: 672–677.

[12] Li K, Zou Y, Sun J, Wen H. Prophylactic balloon occlusion of internal iliac arteries, common iliac arteries and infrarenal abdominal aorta in pregnancies complicated by placenta accreta: a retrospective cohort study. European Radiology. 2018; 28: 4959–4967.

[13] Li N, Yang T, Liu C, Qiao C. Feasibility of infrarenal abdominal aorta balloon occlusion in pernicious placenta previa coexisting with placenta accrete. BioMed Research International. 2018; 2018: 1–6.

[14] Panici PB, Anceschi M, Borgia ML, Bresadola L, Masselli G, Parasassi T, *et al.* Intraoperative aorta balloon occlusion: fertility preservation in patients with placenta previa accreta/increta. Journal of Maternal-Fetal & Neonatal Medicine. 2012; 25: 2512–2516.

[15] Sun W, Duan S, Xin G, Xiao J, Hong F, Hong H, *et al.* Safety and efficacy of preoperative abdominal Aortic balloon occlusion in placenta increta and/or percreta. Journal of Surgical Research. 2018; 222: 75–84.

[16] Wang Y, Su F, Zhang H, Wang F, Zhe R, Shen X. Aortic balloon occlusion for controlling intraoperative hemorrhage in patients with placenta previa increta/percreta. Journal of Maternal-Fetal & Neonatal Medicine. 2017; 30: 2564–2568.

[17] Wu Q, Liu Z, Zhao X, Liu C, Wang Y, Chu Q, *et al.* Outcome of pregnancies after balloon occlusion of the infrarenal abdominal aorta during caesarean in 230 patients with placenta praevia accreta. CardioVascular and Interventional Radiology. 2016; 39: 1573–1579.

[18] Zheng ZR, Hou Y, Xie P, Yu X, Xie L. Intraoperative infrarenal aortic balloon occlusion in pregnancies with placenta accreta, increta, and percreta. Clinical and Experimental Obstetrics & Gynecology. 2018; 5: 704–708.

[19] Zeng C, Yang M, Ding Y, Yu L, Deng W, Hu Y, *et al.* Preoperative infrarenal abdominal aorta balloon catheter occlusion combined with Bakri tamponade reduced maternal morbidity of placenta increta/percreta. Medicine. 2017; 96: e8114.

[20] Qiu Z, Wu J, Hu J. Prophylactic abdominal aorta arteries balloon occlusion in cesarean section for pernicious placenta previa and placenta increta in third trimeste. Chinese Journal of Practical Gynecology and Obstetrics. 2015; 31: 1029–1033.

[21] Wei LC, Gong GY, Chen JH, Hou PY, Li QY, Zheng ZY, *et al.* Application of lower abdominal aorta balloon occlusion technique by ultrasound guiding during caesarean section in patients with pernicious placenta previa. Zhonghua Yi Xue Za Zhi. 2018; 98: 930–934. (In Chinese)

[22] Duan X, Chen P, Han X, Wang Y, Chen Z, Zhang X, *et al.* Intermittent aortic balloon occlusion combined with cesarean section for the treatment of patients with placenta previa complicated by placenta accreta: a retrospective study. Journal of Obstetrics and Gynaecology Research. 2018; 44: 1752–1760.

[23] Xie L, Wang Y, Luo F, Man Y, Zhao X. Prophylactic use of an infrarenal abdominal aorta balloon catheter in pregnancies complicated by placenta accreta. Journal of Obstetrics and Gynaecology. 2017; 37: 557–561.

[24] Chen L, Wang X, Wang H, Li Q, Shan N, Qi H. Clinical evaluation of prophylactic abdominal aortic balloon occlusion in patients with placenta accreta: a systematic review and meta-analysis. BMC Pregnancy Childbirth. 2019; 19: 30.

[25] Pather S, Strockyj S, Richards A, Campbell N, de Vries B, Ogle R. Maternal outcome after conservative management of placenta percreta at caesarean section: a report of three cases and a review of the literature. Australian and New Zealand Journal of Obstetrics and Gynaecology. 2014; 54: 84–87.

[26] Clausen C, Lönn L, Langhoff-Roos J. Management of placenta percreta: a review of published cases. Acta Obstetricia et Gynecologica Scandinavica. 2014; 93: 138–143.

[27] Wang YL, Duan XH, Han XW, Wang L, Zhao XL, Chen ZM, *et al.* Comparison of temporary abdominal aortic occlusion with internal iliac artery occlusion for patients with placenta accreta-a non-randomised prospective study. Vasa. 2017; 46: 53–57.