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REVIEW

Prophylactic abdominal aortic balloon occlusion in patients with pernicious placenta previa during cesarean section: a systematic review and meta-analysis from randomized controlled trials

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Abstract

Purpose Pernicious placenta previa induces severe hemorrhage during cesarean section. Abdominal aorta balloon occlusion (AABO) is considered as an effective operation for patients with pernicious placenta previa. The aim of this study was to investigate the clinical application of abdominal aortic balloon occlusion in the placenta previa and cesarean section by systematic review and meta-analysis.

Methods MEDLINE, EMBASE, Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), WAN-FANG DATA and CQVIP were searched from inception to Jan. 15th, 2019. Operative time, intraoperative blood loss volume, postoperative hospitalization duration, intraoperative blood transfusion volume, hysterectomy rate, lower extremity thrombosis rate, ICU admission rate, adverse reaction rate, neonatal birth weight, Apgar 1-min and 5-min scores were regarded as the endpoints. Randomized controlled trials (RCT) were used for meta-analysis.

Results Fourteen articles were retrieved from total 650 articles, and the results of meta-analysis showed that application of intraoperative AABO had the ability to reduce the operative time (WMD = − 16.581, 95% CI − 26.690 to − 6.472; $P = 0.001$), the intraoperative blood loss volume (WMD = − 1202.69, 95% CI − 1732.25 to − 673.12; $P < 0.001$), the intraoperative blood transfusion volume (WMD = − 1202.69, 95% CI − 1732.25 to − 673.12; $P < 0.001$). The hysterectomy rate (RR = 0.279, 95% CI 0.164–0.474; $P < 0.001$), postoperative hospitalization duration (WMD = − 1.423, 95% CI − 2.070 to − 0.776; $P < 0.001$) and the balloon preset time (WMD = − 13.793, 95% CI − 15.341 to − 12.244; $P < 0.001$; $I^2 = 0.0\%$) were also reduced in AABO group.

Conclusions Application of AABO in patients with pernicious placenta previa is safe and effective, which is worthy of clinical promotion.

Keywords Abdominal aorta balloon occlusion · Pernicious placenta previa · Cesarean section · Placenta accrete · Meta-analysis

Introduction

Pernicious placenta previa (PPP) was first proposed by Chattopadhyay et al. [1] with a definition of the complication of previous cesarean section (CS) while the placenta previa attached uterine scar, usually accompanied by placenta implantation. Fatal post-partum hemorrhage is the main complication of placenta previa during cesarean [2]. Previous studies showed that the rate of severe hemorrhage in patient with PPP was 53.9% [3], and the mortality of massive hemorrhage in patients usually was close to 7% [4, 5]. The risk of placental implantation reached up to 50% in PPP patients who had a history of obstetric cesarean operation with placenta previa [6]. The incidence of placenta accreta (PA) has increased a lot with the increasing rate of cesarean deliveries since 1950s [7]. The risk of severe bleeding is increased by placenta implantation, and the intraoperative blood transfusion or uterus removing is needed to control the blood loss during operation [8].

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Cesarean hysterectomy was used when fatal postpartum hemorrhage occurred during CS in patients with placenta previa to minimize blood loss previously [9], and the incidence of hysterectomy was usually more than 50% [10]. However, hysterectomy has a high risk of massive hemorrhage during surgery [11]. The whole or partial lack of uterus may have negative effects on the endocrine and fertility functions of patients. Therefore, scholars focus on exploring new methods to reduce the risk of cesarean hemorrhage for PPP patients. With the development of interventional techniques, the intravascular interventional therapies are used more widely than before in obstetrics with the aim of reducing the bleeding caused by iliac artery balloon occlusion, uterine artery embolization and bilateral internal iliac artery balloon occlusion, etc. Compared with traditional treatment, more and more transcatheter artery embolization therapies are used to reduce the blood loss and the incidence of hysterectomy [12]. Intravascular intervention therapies can embolize bleeding vessels directly, and it has immediate effects on rescuing acute hemorrhagic patients [13]. As one of these interventional treatments, abdominal aorta balloon occlusion (AABO) is more effective than other interventional methods mentioned before to control bleeding owing to its abundant collateral circulation in pelvis [14, 15]. In this section, the balloon is placed in the abdominal aorta under the guidance of angiography machine, then it will be dilated immediately to block blood during CS [16]. It has been revealed that interventional abdominal balloon occlusion can reduce the intraoperative bleeding effectively, which not only provides a good surgical field of vision, but also achieves satisfactory clinical results. In addition, pervious research found that AABO may have the ability to decrease the hysterectomy rate during CS for patients with placenta implantation [17, 18].

The meta-analysis [16] we retrieved recently contained some blemishes and the literature included in the study was case–control studies. The endpoints only included operative time, blood loss volume, postoperative hospitalization duration, intraoperative blood transfusion volume, hysterectomy rate and adverse reaction rate. As supplements, more studies related to systematic review and meta-analysis should be done in this article to evaluate the safety and efficacy of AABO therapy in PPP patients during CS.

Materials and methods

Search strategy

The literature was retrieved from MEDLINE, EMBASE, Cochrane Library, Web of Science, China National Knowledge Infrastructure (CNKI), WAN-FANG DATA and CQVIP by Mesh terms and entry terms from inception to Jan. 15th, 2019. The following Mesh terms and entry terms were used in literature search: 'Abdominal Aortas' OR 'Aortas' OR 'Abdominal' OR 'Abdominal Aorta' OR 'Aorta, Abdominal'[Mesh] AND 'Utricle' OR 'Saccule' OR 'Saccule' OR 'Saccules' OR 'Utricle' OR 'Utricles' OR 'balloon' OR 'Saccule and Utricle'[Mesh] AND 'Placenta Previa' OR 'Placenta Previa'[Mesh]. The retrieved articles were imported into EndnoteX9 and extracted by screening the titles and abstracts first. After preliminary screening, nonconforming literature was excluded by reading the full text, then the final remaining articles were adopted into this study.

Inclusion and exclusion criteria

In this research, study types designed as randomized controlled trials (RCTs) research were included. The inclusion criteria were listed as follows: (1) patient with PPP; (2) experiment group: PPP patients who adopted AABO before CS; (3) control group: PPP patients who took CS without AABO; and (4) outcome included operative time, blood loss volume, postoperative hospitalization duration, intraoperative blood transfusion volume, hysterectomy rate, lower extremity thrombosis rate, ICU admission rate, adverse reaction rate, neonatal birth weight, intraoperative blood transfusion ratio, postoperative body temperature, neonatal birth height, balloon preset time, bleeding rate at puncture site, sensory disturbance rate, Apgar 1-min and Apgar 5-min scores.

The exclusion criteria were as follows: (1) reviews, meetings or conference abstracts, letters; (2) duplicated reports; (3) animal trials; (4) incomplete data and ambiguous outcome indicators.

Methodological quality appraisal

The articles were screened by two researchers MJ ZHU and YL LI independently, once a disagreement occurred, it would be decided by a third party. The upgraded Jadad scale was used for the quality appraisal of the literature. The scale is divided into 7 points, 1–3 were defined as low quality, and 4–7 were defined as high quality.

Data extraction

The extracted data were listed as follows: first author, year of publication, study type, total number of participants, participant number of treatment group, age range of treatment group, participant number of control group, age range of control group, participants, treatment comparison, outcomes and quality assessment.

Statistical analysis

Meta-analysis was assessed with STATA 15.0 software (Stata Corporation, College Station, TX, USA). The weight mean difference (WMD) and 95% confidence interval (95% CI) were calculated for continuous outcomes, while relative risk (RR) and 95% CI were calculated for dichotomous outcomes. I^2 statistic was conducted to estimate heterogeneity. Random-effects model was used to analyze the outcomes. Begg's test was used to evaluate the publication bias. Sensitivity analysis was performed by removing a single study at a time to evaluate the robustness of the data. $P \leq 0.05$ was considered statistically significant.

Results

After retrieving in Chinese and English databases according to the search strategy, a total of 650 articles were identified. Finally, 14 articles [19–32] were included in this study after screening on the basis of inclusion and exclusion criteria (Fig. 1). A total of 855 patients in 14 articles participated in the study, including 428 in the experimental group and 427 in the control group, details were shown in Table 1.

Subjects of 6 studies were purely PPP among 14 articles, and 8 were PPP complicated by placenta implantation. The assessment of literature quality was evaluated by upgraded Jadad scale and the results are described in Table 2.

Meta-analysis

The results reviewed in this study revealed the difference between AABO group and non-AABO group, involving 855 patients. Subgroup analysis were conducted based on the difference in study objects or literature quality assessment results. The results were listed as follows.

Operative time

Eleven articles reported operative time as one of the end points. Patients who in AABO group spent less time (16.581 min) on operation than those in non-AABO group (WMD = − 16.581, 95% CI − 26.690 to − 6.472; $P = 0.001$; $I^2 = 97.4\%$). PPP patients (WMD = − 25.757, 95% CI − 30.806 to − 20.707; $P < 0.001$; $I^2 = 56.5\%$) or PPP&PA in AABO group (WMD = − 14.065, 95% CI − 27.986 to 0.145; $P = 0.048$; $I^2 = 97.9\%$) spent less operative time in comparison with non-AABO group. The subgroup analysis of literature quality assessment indicated that the operative time of AABO group was equivalent to non-AABO group in high-quality articles (WMD = − 14.497, 95% CI − 30.272 to 1.277; $P = 0.072$; $I^2 = 96.1\%$) and shorter than

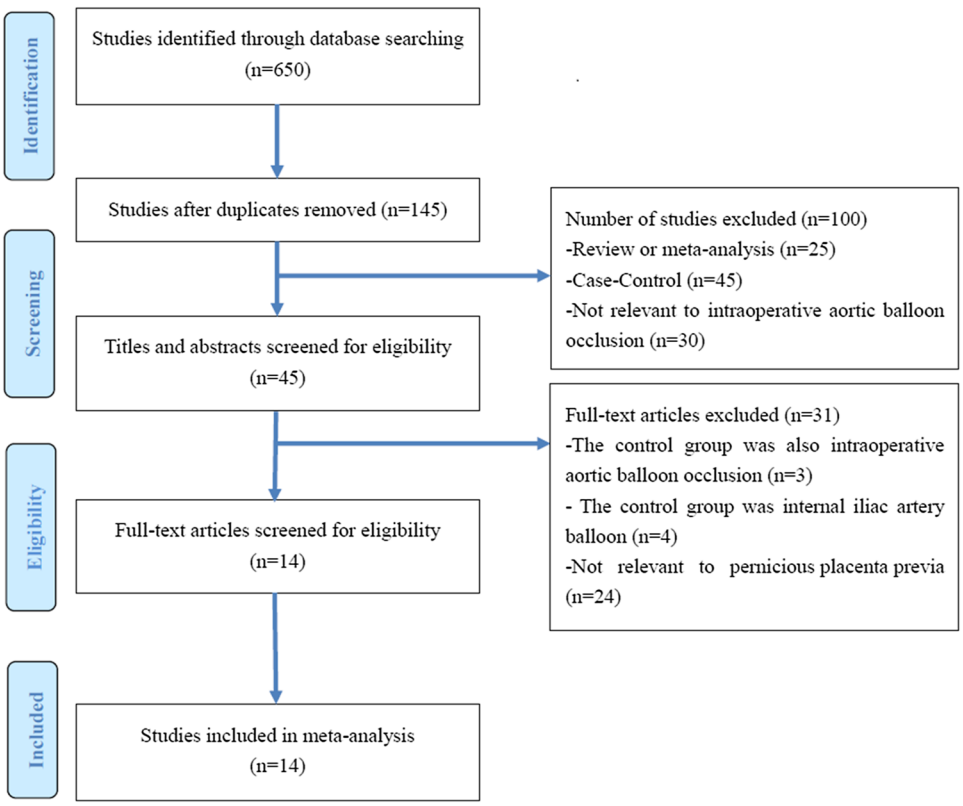

Fig. 1 Study selection process for the meta-analysis

Table 1 Basic information of the literature

References	Year of publication	Study type	Total no	Treatment no	Treat age	Control no	Control age
Zhang et al. [19]	2018	RCT	50	25	33.1 ± 5.2	25	33.6 ± 5.4
Xu et al. [20]	2017	RCT	140	70	34.2 ± 4.5	70	34.0 ± 4.3
Tang et al. [21]	2017	RCT	20	10	–	10	–
Li [22]	2017	RCT	94	47	30.87 ± 3.48	47	29.54 ± 3.26
Xia [23]	2017	RCT	78	39	28.7 ± 3.2	39	28.9 ± 3.0
Liu et al. [24]	2017	RCT	60	30	32.50 ± 1.0	30	31.50 ± 1.0
Cai [26]	2015	RCT	15	8	–	7	–
Xu et al. [27]	2018	RCT	35	18	31.7 ± 5.3	17	31.6 ± 4.4
Huang [28]	2017	RCT	42	21	33.12 ± 3.84	21	32.17 ± 4.16
Lai et al. [25]	2018	RCT	56	21	29.6 ± 2.5	35	30.1 ± 3.3
Mao et al. [29]	2017	RCT	78	45	29.8 ± 3.1	33	30.1 ± 2.9
Duan et al. [30]	2016	RCT	62	32	32.1 ± 6.9	30	31.7 ± 8.5
Li et al. [31]	2018	RCT	56	24	33.75 ± 5.14	32	33.34 ± 3.44
Cui et al. [32]	2017	RCT	69	38	31.2 ± 5.3	31	31.0 ± 4.4

Table 2 Intervention, outcome and quality assessment of literature

References	Year of publication	Participants	Treatment comparison	Outcomes	Quality assessment
Zhang et al. [19]	2018	PPP	AABO vs CS	EFG	2
Xu et al. [20]	2017	PPP&PA	AABO vs CS	BF	3
Tang et al. [21]	2017	PPP&PA	AABO vs CS	ABE	1
Li [22]	2017	PPP&PA	AABO vs CS	ABCEFG	2
Xia [23]	2017	PPP&PA	AABO vs CS	ABCEHIJ	4
Liu et al. [24]	2017	PPP&PA	AABO vs CS	ABE	1
Cai [26]	2015	PPP	AABO vs CS	H	1
Xu et al. [27]	2018	PPP	AABO vs CS	ABCDEHI	4
Huang [28]	2017	PPP	AABO vs CS	ABDEF	4
Lai et al. [25]	2018	PPP	AABO vs CS	ABCEGIJ	1
Mao et al. [29]	2017	PPP&PA	AABO vs CS	ABCDEHIJK	1
Duan et al. [30]	2016	PPP&PA	AABO vs CS	ABCDEIJ	1
Li et al. [31]	2018	PPP&PA	AABO vs CS	ABCEIJK	1
Cui et al. [32]	2017	PPP	AABO vs CS	ABCEHI	1

PPP pernicious placenta previa, *PPP&PA* pernicious placenta previa complicated with placenta accrete, *AABO* intraoperative aortic balloon occlusion, *CS* cesarean section, *A* operative time, *B* intraoperative blood loss volume, *C* postoperative hospitalization duration, *D* intraoperative blood transfusion volume, *E* hysterectomy rate, *F* lower extremity thrombosis rate, *G* ICU admission rate, *H* adverse reaction rate, *I* neonatal birth weight, *J* Apgar 1-min score, *K* Apgar 5-min score

non-AABO group in low-quality articles (WMD = 17.220, 95% CI − 30.673 to − 3.767; $P = 0.012$; $I^2 = 97.4\%$). Results are shown in Fig. 2.

Intraoperative blood loss volume

The intraoperative blood loss volume in AABO group was 1202.69 mL less than non-AABO group, reported in 12 articles (WMD = − 1202.69, 95% CI − 1732.25 to − 673.12; $P < 0.001$; $I^2 = 99.7\%$) (Fig. 3). Subgroup analysis of research objects revealed that the intraoperative blood loss volume of PPP (WMD = − 1283.17, 95% CI − 1731.12 to − 835.23; $P < 0.001$; $I^2 = 89.7\%$) or PPP&PA (WMD = − 1198.55, 95% CI − 1738.03 to − 659.08; $P < 0.001$; $I^2 = 99.5\%$) in AABO group was less than non-AABO group. On the basis of literature quality assessment, blood loss volume in AABO group was less than non-AABO group (high quality: (WMD = − 997.35, 95% CI − 1454.20 to − 540.50;

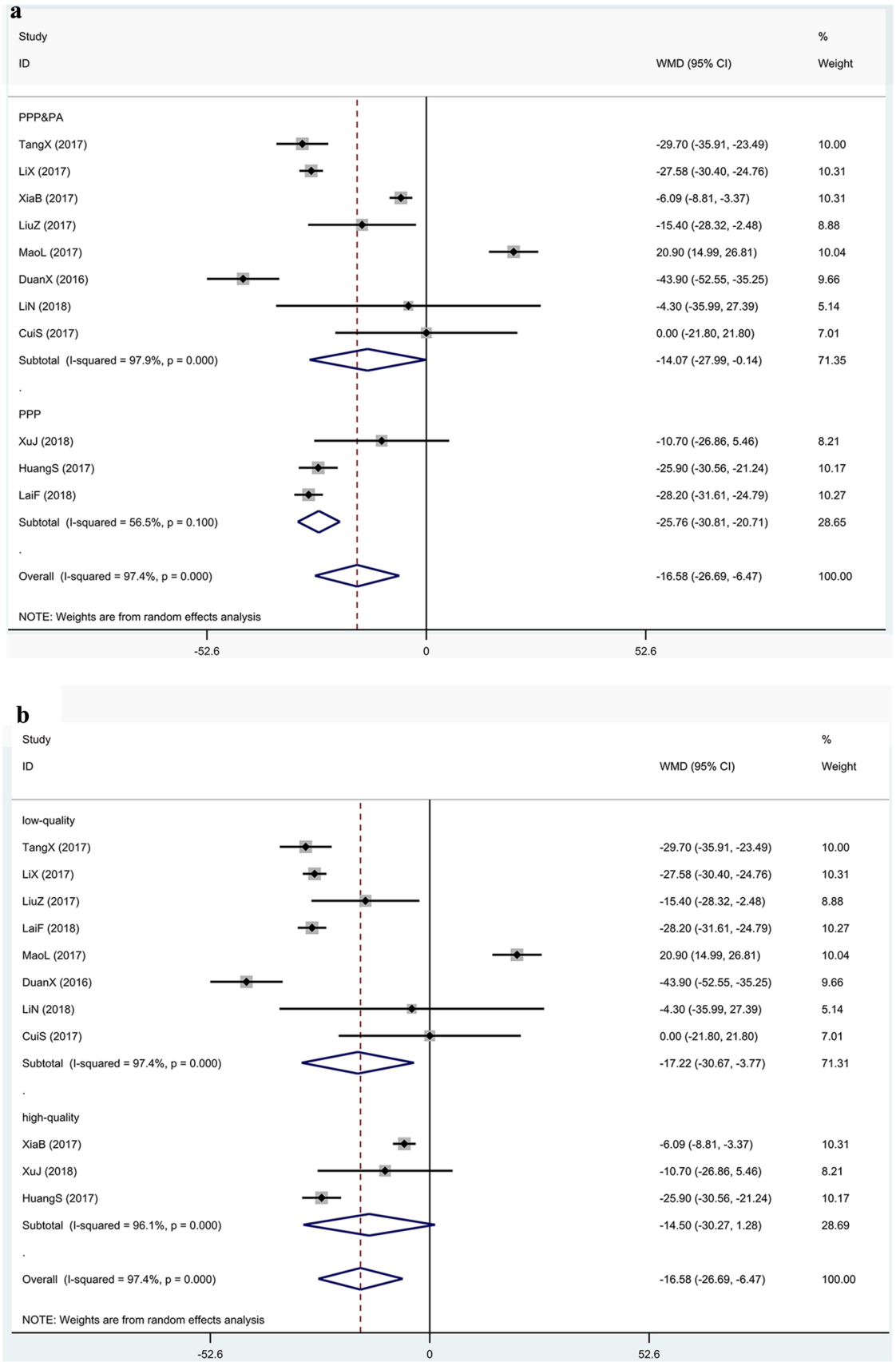

Fig. 2 Subgroup analysis for operative time. **a** Research objects; **b** literature quality assessment results

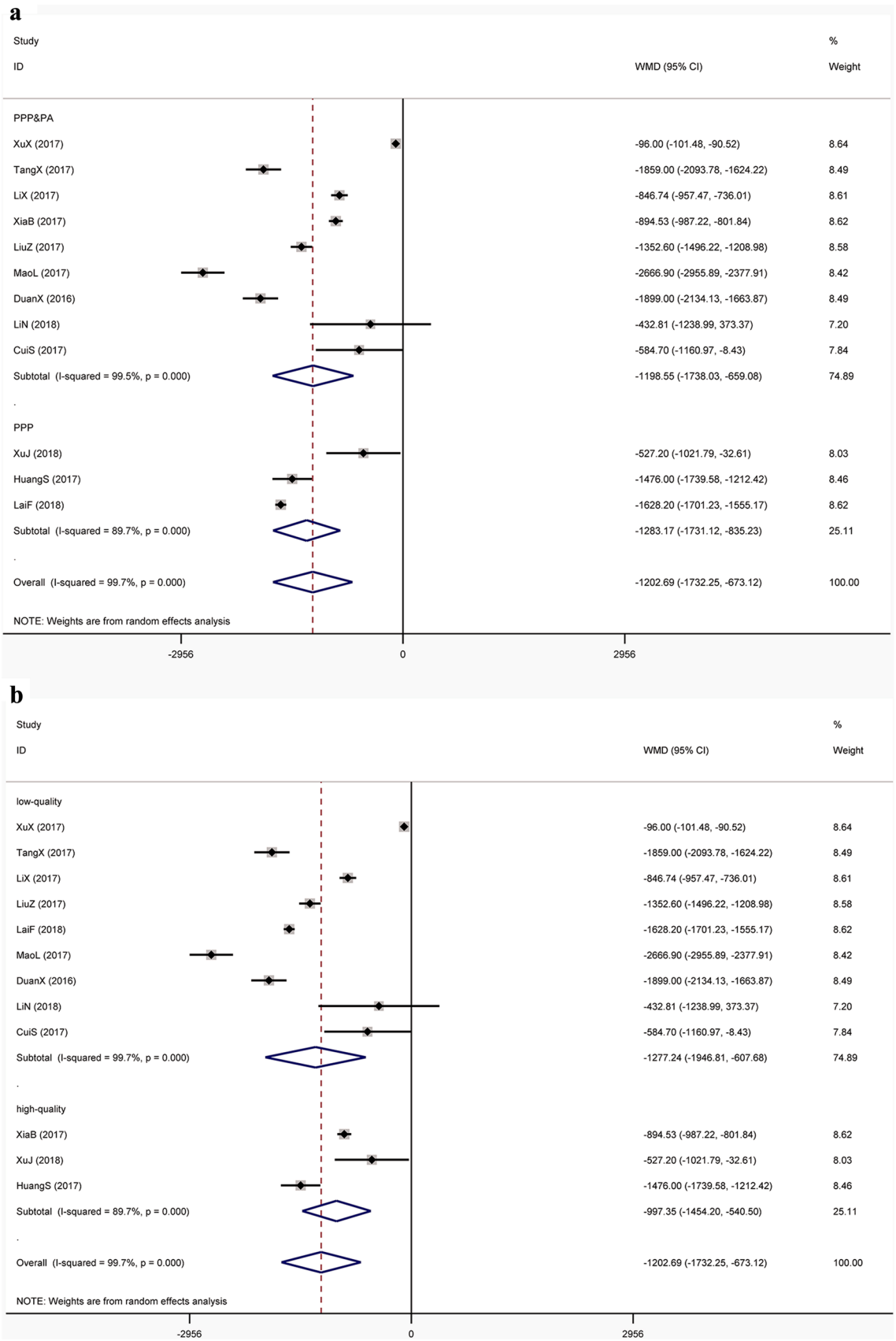

Fig. 3 Subgroup analysis for intraoperative blood loss volume. **a** Research objects; **b** literature quality assessment results

$P < 0.001$; $I^2 = 89.7\%$); low quality: (WMD = − 1277.24, 95% CI − 1946.81 to − 607.68, $P < 0.001$; $I^2 = 99.7\%$).

Intraoperative blood transfusion volume

The intraoperative blood transfusion volume in AABO group was 1450.53 mL less than that in non-AABO group (WMD = − 1450.53, 95% CI − 2139.32 to − 761.75; $P < 0.001$; $I^2 = 99.5\%$), reported in 12 articles. According to different research objects, results of subgroup analysis suggested that the blood transfusion volume in AABO group was less than that in non-AABO group in both PPP patients (WMD = − 1115.92, 95% CI − 2141.18 to − 090.67; $P = 0.033$; $I^2 = 99.8\%$) and PPP&PA patients (WMD = − 1774.24, 95% CI − 1924.57 to − 1623.92; $P < 0.001$; $I^2 = 0.0\%$). Whether in high-quality literature (WMD = − 1115.92, 95% CI − 2141.18 to − 90.67; $P = 0.033$; $I^2 = 99.8\%$) or low-quality literature (WMD = − 1774.24, 95% CI − 1924.57 to − 1623.92; $P < 0.001$; $I^2 = 0.0\%$), blood transfusion volume in AABO group was also less than that in non-AABO group (Fig. 4).

Intraoperative blood transfusion ratio

Four articles reported the intraoperative blood transfusion ration as one of the endpoints. The intraoperative blood transfusion ratio in AABO group was 0.801 times of that in non-AABO group (RR = 0.801, 95% CI 0.370–1.735; $P = 0.573$; $I^2 = 53.9\%$) (Table 3).

Postoperative body temperature

As regard to postoperative body temperature, 3 articles revealed that the postoperative body temperature of patients in AABO group was 0.092 °C lower than that in non-AABO group (WMD = − 0.092, 95% CI − 0.400 - 0.217; $P = 0.560$; $I^2 = 84.3\%$) (Table 3).

Hysterectomy rate

According to hysterectomy rate, 12 articles demonstrated that the hysterectomy rate of AABO group was 0.279 times of non-AABO group (RR = 0.279, 95% CI 0.164–0.474; $P < 0.001$; $I^2 = 0.0\%$) (Table 3).

Postoperative hospitalization duration

Hospitalization duration that patients spent after operation was 1.423 d shorter than in AABO group (WMD = − 1.423, 95% CI − 2.070 to − 0.776; $P < 0.001$; $I^2 = 87.1\%$). The results of subgroup analysis of research objects for postoperative hospitalization duration indicated that PPP (WMD = − 2.369, 95% CI − 2.871 to 1.867; $P < 0.001$; $I^2 = 0.0\%$) or PPP&PA (WMD = − 1.139, 95% CI − 1.851 to − 0.428; $P = 0.002$; $I^2 = 86.7\%$) in AABO group spent less time than non-AABO group. Subgroup analysis of literature quality assessment showed that postoperative hospitalization duration in AABO group was 1.248 d shorter than that in non-AABO group (high quality: WMD = − 1.248, 95% CI − 2.315 to − 0.181; $P = 0.022$; $I^2 = 53.5\%$; low quality: WMD = − 1.452, 95% CI − 2.282 to − 0.621; $P = 0.001$; $I^2 = 88.2\%$). Results are shown in Fig. 5.

Lower extremity thrombosis rate

The outcome of 4 articles indicated that the lower extremity thrombosis rate in AABO group was 0.405 times of non-AABO group (RR = 0.405, 95% CI 0.152–1.079; $P = 0.071$; $I^2 = 11.2\%$) (Table 3).

Adverse reactions

Adverse reaction rate in AABO group showed in 5 articles was 0.611 times of non-AABO group (RR = 0.611, 95% CI 0.194–1.917; $P = 0.398$; $I^2 = 54.7\%$) (Fig. 6). Subgroup analysis results demonstrated that the adverse reaction rate in PPP patients was comparable to in PPP&PA patients (PPP: RR = 0.924, 95% CI 0.065–13.183; $P = 0.954$; $I^2 = 79.5\%$; PPP&PA: RR = 0.473, 95% CI 0.147–1.521; $P = 0.209$; $I^2 = 25.1\%$). Based on the results of the literature quality assessment, the results of subgroup analysis also showed similar rate of adverse reactions (high quality: RR = 1.345, 95% CI 0.212–8.544; $P = 0.753$; $I^2 = 65.6\%$; low quality: RR = 0.335, 95% CI 0.083–1.354; $P = 0.125$; $I^2 = 37.8\%$).

ICU admission rate

As for the rate that patients were sent to the ICU, reported by 3 articles, the ICU admission rate in AABO group was 0.153 times of non-AABO group (RR = 0.153, 95% CI 0.047–0.499; $P = 0.002$; $I^2 = 0.0\%$) (Table 3).

Neonatal birth weight

Meta-analysis of 5 studies showed the rate of neonatal birth weight between two groups. Neonatal birth weight of AABO group was 0.002 kg lighter than that in non-AABO group (WMD = − 0.002, 95% CI − 0.111 to 0.108); $P = 0.976$; $I^2 = 25.5\%$) (Table 3).

Neonatal birth height

The endpoint of neonatal birth height was reported in 2 literatures. Results showed that the neonatal birth height in AABO group was 0.469 cm shorter than that in non-AABO

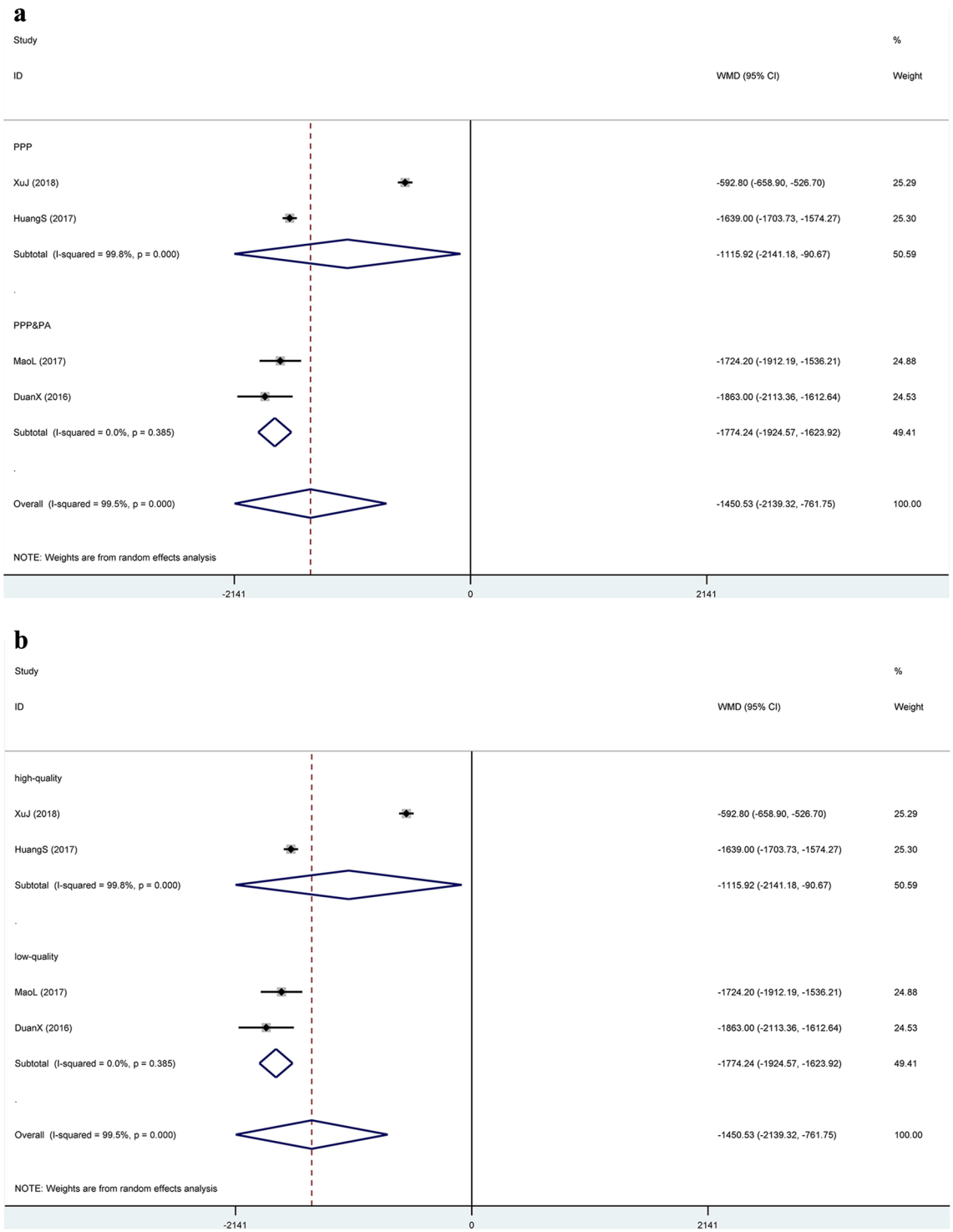

Fig. 4 Subgroup analysis for intraoperative blood transfusion volume. **a** Research objects; **b** literature quality assessment results

group (WMD = − 0.469, 95% CI − 1.787 to 0.850; $P = 0.486$; $I^2 = 18.3\%$) (Table 3).

Apgar 1-min and 5-min scores

Five articles revealed Apgar 1-min scores in AABO group and non-AABO group, the score in AABO group was 0.145 points higher than that in non-AABO group (WMD = 0.145,

Table 3 Clinical evaluation of AABO

Index	WMD/RR (95% CI)	*P*	I^2
Operative time			
Overall	− 12.918 (− 21.962, − 3.874)	0.005	96.6
Participants			
PPP	− 20.523 (− 21.962, − 11.956)	< 0.001	80.4
PPP&PA	− 11.822 (23.796, 0.152)	0.053	97.1
Quality assessment			
High quality	− 14.497 (− 30.272, 1.277)	0.072	96.1
Low quality	− 12.173 (− 23.787, − 0.559)	0.040	96.5
Intraoperative blood loss volume			
Overall	− 1066.28 (− 1278.52, − 854.04)	< 0.001	99.6
Participants			
PPP	− 902.81 (− 2038.36, 232.73)	0.119	99.8
PPP&PA	− 1094.32 (− 1571.95, − 616.69)	< 0.001	99.4
Quality assessment			
High quality	− 997.35 (− 1454.20, − 540.50)	< 0.001	89.7
Low quality	− 1083.95 (− 1312.36, − 855.53)	< 0.001	99.6
Postoperative hospitalization duration			
Overall	− 0.912 (− 1.516, − 0.308)	0.003	89.9
Participants			
PPP	− 1.479 (− 3.222, 0.263)	0.096	92.0
PPP&PA	− 0.727 (− 1.385, − 0.069)	0.030	89.3
Quality assessment			
High quality	− 1.248 (− 2.315, − 0.181)	0.022	53.5
Low quality	− 0.827 (− 1.579, − 0.074)	0.031	91.5
Intraoperative blood transfusion volume			
Overall	− 1556.60 (− 2194.64, − 918.56)	< 0.001	99.3
Participants			
PPP	− 1115.92 (− 2141.18, − 90.67)	0.033	99.8
PPP&PA	− 1783.67 (− 1932.31, − 1635.04)	< 0.001	0.0
Quality assessment			
High quality	− 1115.92 (− 2141.18, − 90.67)	0.033	99.8
Low quality	− 1783.67 (− 1932.31, − 1635.04)	< 0.001	0.0
Hysterectomy rate			
Overall	0.360 (0.213, 0.609)	< 0.001	31.7
Lower extremity thrombosis			
Overall	0.389 (0.130, 1.159)	0.090	16.9
ICU admission rate			
Overall	0.248 (0.054, 1.131)	0.072	55.2
Adverse reaction			
Overall	0.536 (0.133, 2.156)	0.380	58.9
Participants			
PPP	0.807 (0.020, 33.327)	0.910	82.5
PPP&PA	0.428 (0.122, 1.508)	0.187	24.2
Quality assessment			
High quality	1.504 (0.156, 14.498)	0.724	70.0
Low quality	0.241 (0.042, 1.375)	0.109	44.3
Neonatal birth weight			
Overall	− 0.022 (− 0.083, 0.039)	0.476	5.3
Apgar 1 min			
Overall	− 0.184 (− 1.050, 0.683)	0.678	97.2
Apgar 5 min			
Overall	0.095 (− 0.120, 0.311)	0.384	0.0
Balloon preset time			
Overall	− 13.793 (− 15.341, − 12.244)	< 0.001	0.0
Bleeding rate at puncture site			
Overall	0.617 (0.233, 1.635)	0.332	0.0
Sensory disturbance rate			
Overall	1.248 (0.495, 3.147)	0.639	0.0
Intraoperative blood transfusion ratio			
Overall	0.801 (0.370, 1.735)	0.573	53.9
Postoperative body temperature			
Overall	− 0.092 (− 0.400, 0.217)	0.560	84.3
Neonatal birth height			
Overall	− 0.469 (− 1.787, 0.850)	0.486	18.3

PPP pernicious placenta previa, *PPP&PA* pernicious placenta previa complicated with placenta accrete, *IABO* intraoperative aortic balloon occlusion, *CS* cesarean section

95% CI − 0.030 to 0.319; $P = 0.104$; $I^2 = 0.0\%$). Two articles reported that Apgar 5-min score, and the score in AABO group was 0.095 points higher than that in non-AABO group (WMD = 0.095, 95% CI − 0.120 to 0.311; $P = 0.384$; $I^2 = 0.0\%$) (Table 3).

Balloon preset time

The balloon preset time reported by two articles in AABO group was 13.793 min less than that in non-AABO group (WMD = − 13.793, 95% CI − 15.341 to − 12.244; $P < 0.001$; $I^2 = 0.0\%$) (Table 3).

Bleeding rate at puncture site

Bleeding rate at puncture site was recorded by two literatures, and results indicated that the bleeding rate at puncture site in AABO group was 0.617 times of non-AABO group (RR = 0.617, 95% CI 0.233–1.635; $P = 0.332$; $I^2 = 0.0\%$) (Table 3).

Sensory disturbance rate

Two articles reported sensory disturbance rate in two groups, and the sensory disturbance rate in AABO group was 1.248 times of non-AABO group (RR = 1.248, 95% CI 0.495–3.147; $P = 0.639$; $I^2 = 0.0\%$) (Table 3).

Publication bias and sensitivity analysis

Begg's test was used for publication bias in each study, and the results are shown in Fig. 7. The operative time ($Z = 1.09$,

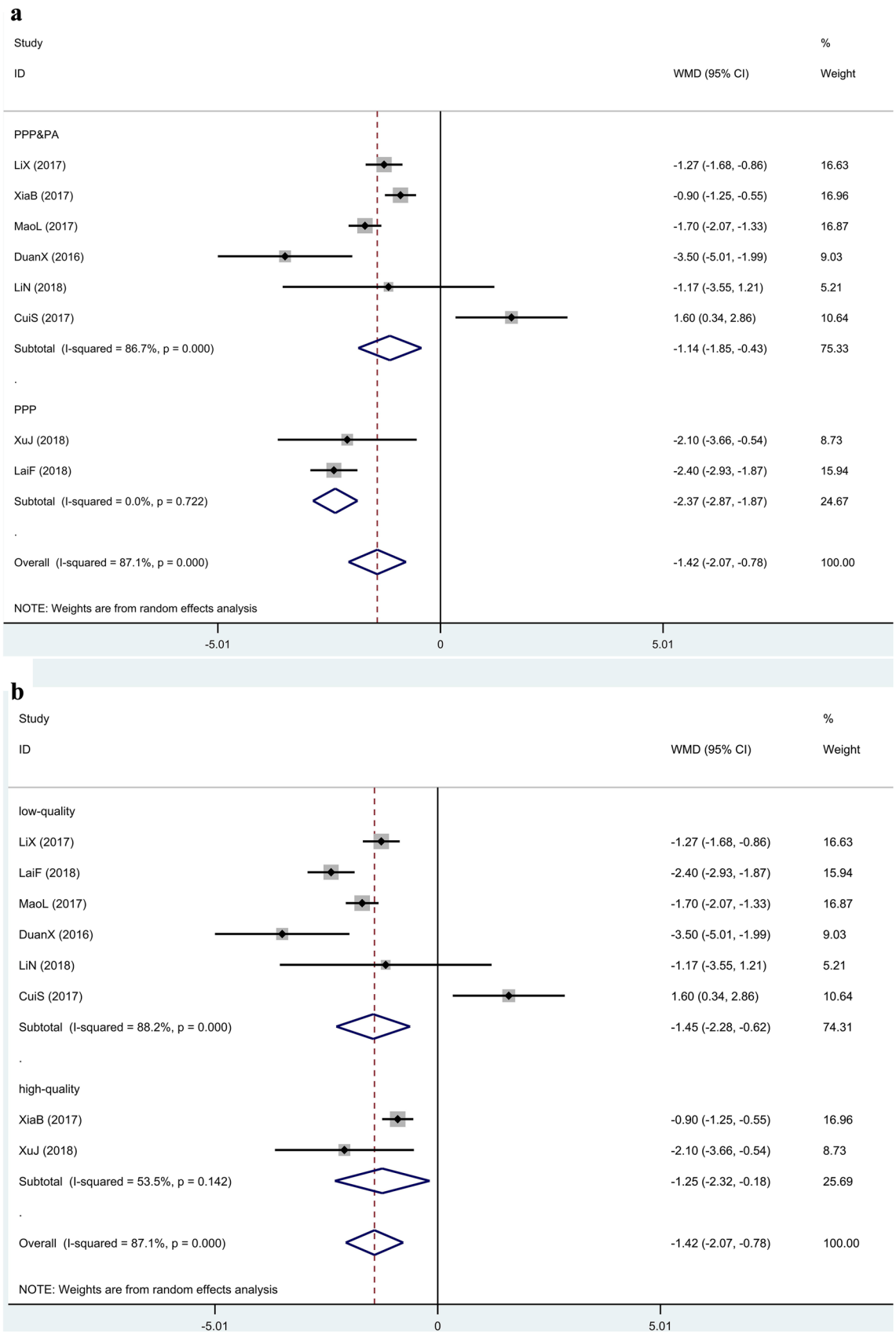

Fig. 5 Subgroup analysis for postoperative hospitalization duration. **a** Research objects; **b** literature quality assessment results

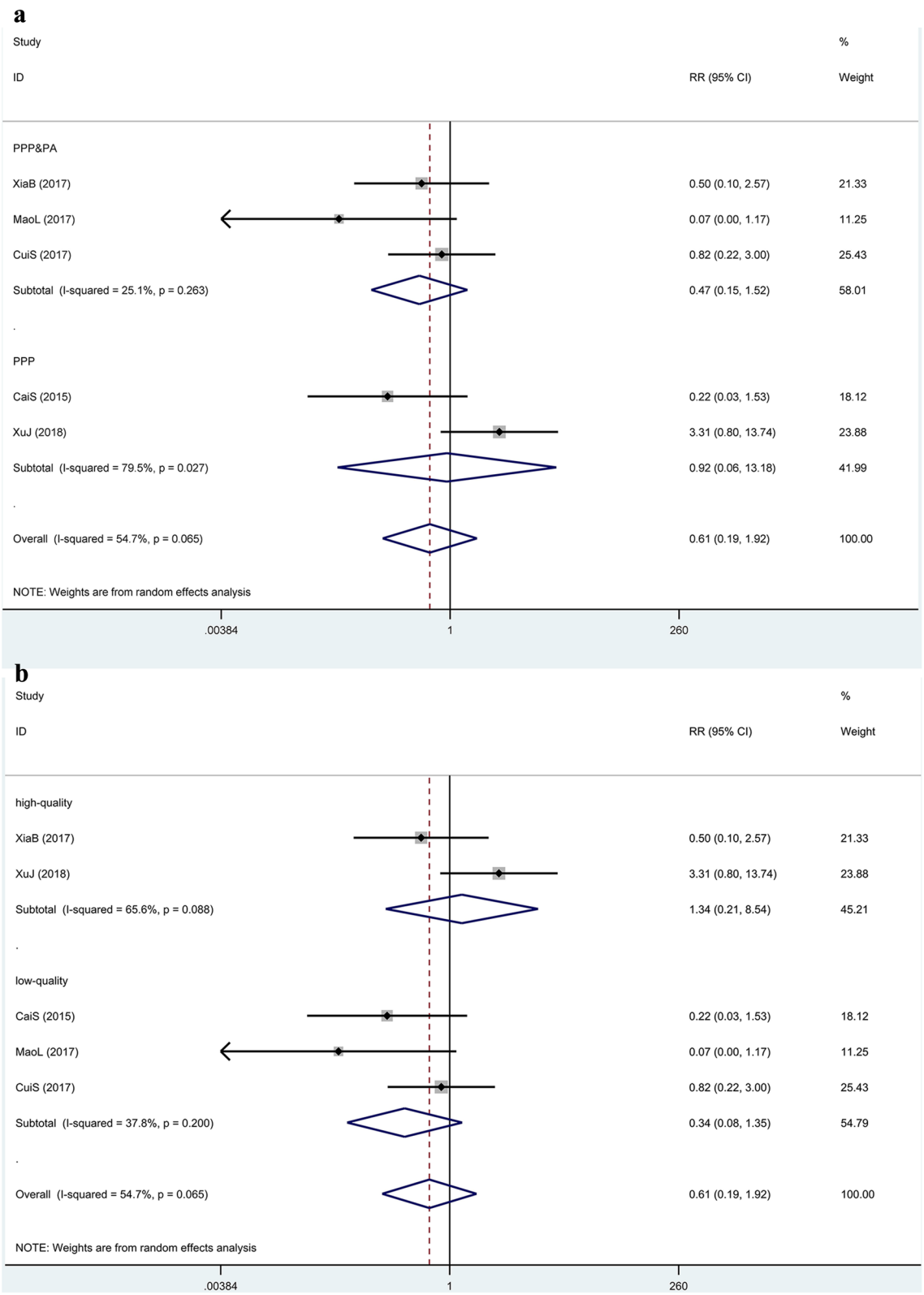

Fig. 6 Subgroup analysis for adverse reaction. **a** Research objects; **b** literature quality assessment results

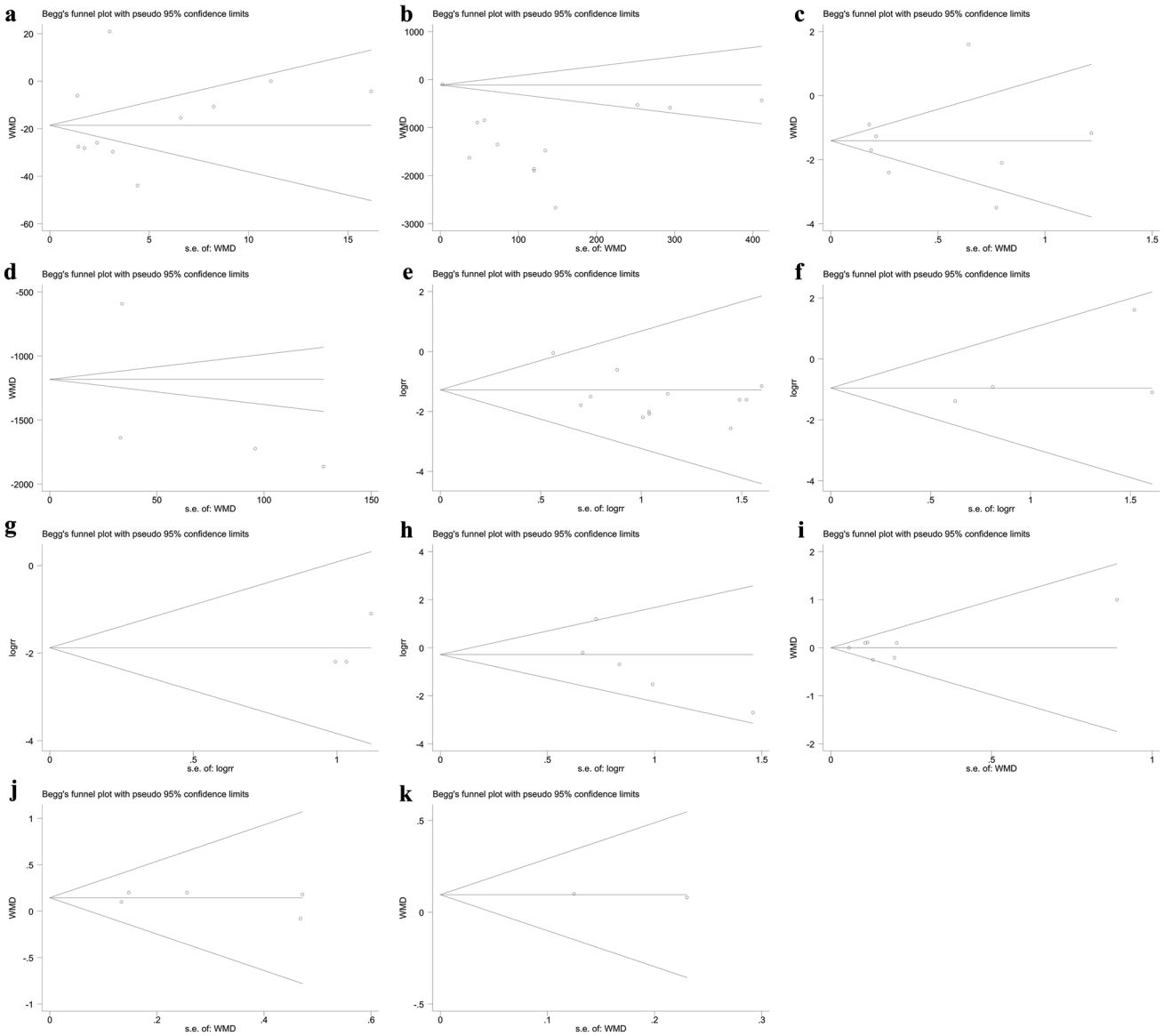

Fig. 7 Publication bias: **a** operative time; **b** intraoperative blood loss volume; **c** postoperative hospitalization duration; **d** intraoperative blood transfusion volume; **e** hysterectomy rate; **f** lower extremity thrombosis rate; **g** ICU admission rate; **h** adverse reaction; **i** neonatal birth weight; **j** Apgar 1-min score; **k** Apgar 5-min score

$P = 0.276$), intraoperative blood loss assessment ($Z = 1.44$, $P = 0.150$), postoperative hospitalization duration ($Z = 0.12$, $P = 0.902$), intraoperative blood transfusion ($Z = 0.34$, $P = 0.734$), hysterectomy rate ($Z = 0.07$, $P = 0.945$), lower extremity thrombosis rate ($Z = 0.34$, $P = 0.734$), ICU admission rate ($Z = 1.04$, $P = 0.296$), adverse reaction rate ($Z = 1.71$, $P = 0.086$), neonatal birth weight ($Z = 0.60$, $P = 0.548$), Apgar 1-min score ($Z = 0.24$, $P = 0.806$) and Apgar 5-min score ($Z = 0.00$, $P = 1.000$) all indicated there was no publication bias in each study ($P > 0.05$). Sensitive analysis was applied to observe the change of merger effects, thus judging the robustness of the results. Sensitive analysis of each endpoints shown in the following figures (Fig. 8) demonstrated that the results of this meta-analysis were stable and credible.

Discussion

AABO is a technique used when severe hemorrhage happens during obstetric cesarean to replace hysterectomy for PPP patients who is willing to preserve fertility. This study aimed to do a systematic review and meta-analysis from RCTs about the AABO application during CS in PPP or PPP&PA patients. Application of AABO in predominant pelvic surgeries and CS for PPP patients has high

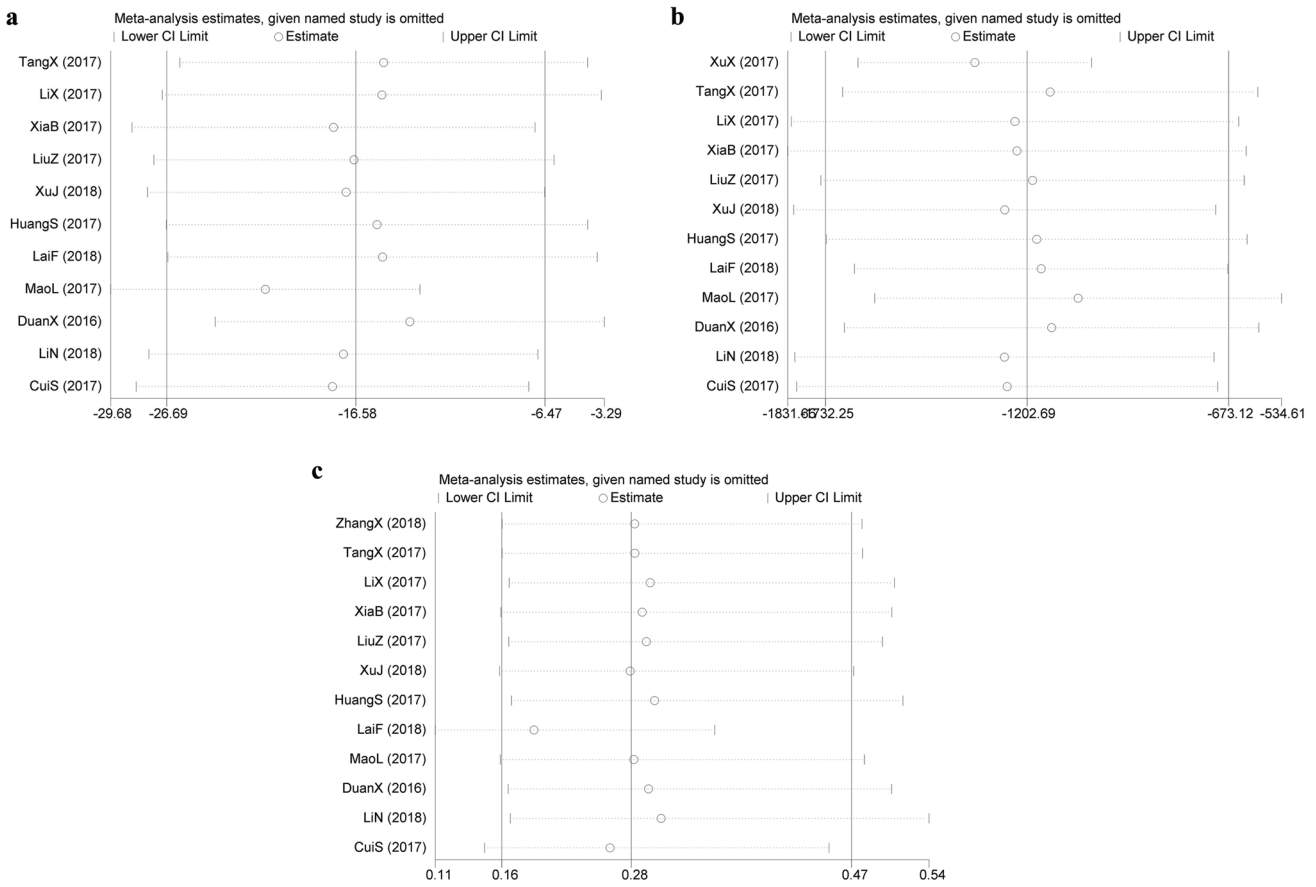

Fig. 8 Sensitivity analysis: **a** operative time, **b** intraoperative blood loss volume, **c** hysterectomy rate

efficiency of devascularization [17, 33]. Analysis of the former studies showed consistent results. Application of AABO in patients was compared with non-AABO group, and the results showed that AABO had positive effects on cesarean delivery. AABO induces intraoperative blood loss volume and transfusion volume of the cesarean operation. The prophylactic AABO may provide a higher degree of pelvic devascularization than iliac or uterine artery occluding collateral circulation [34], and this may be the reason why AABO is more widely used. Sixty minutes are considered to be the limitation of continuous aortic occlusion operation for orthopedic surgeries [33, 35], otherwise human tissues will be injured. In this study, the operative time was decreased by AABO. Under the supervising of abdominal balloon occlusion, the postoperative hospitalization duration was also reduced. Additionally, the rate that patients sent to the ICU was also lower in AABO group than in non-AABO group. Compared with non-AABO group, adoption of AABO during CS almost had no difference in the incidence of maternal lower extremity thrombosis, intraoperative blood transfusion ratio, postoperative body temperature, bleeding rate at puncture site, sensory disturbance rate and adverse reactions.

At present, the position and preset of balloon catheters were placed under the guidance of X-ray, and related research worried about potential harm to patients even the fetal damage caused by radiation [36]. The radiation exposure dose under 100 mGy would not bring obvious fetal damage, proposed by International Radiational Protection Association, which cannot be the reason for termination of pregnancy [37, 38]. The operative time of abdominal aortic balloon preset is much shorter than uterine artery or internal iliac artery catheter preset and the operation of abdominal aortic balloon preset is relatively simple [27, 39], which can reduce the radiation exposure dose of the fetus. Our results showed that the difference of neonate status in two groups can be merely ignored. Even so, the long-term effects of radiation on fetuses are still uncertain.

Table 3 presents the details of clinical evaluation of AABO. Subgroup analysis of research objects revealed that the patients may be the influence factor of the heterogeneity. The heterogeneity changes of operative time, intraoperative blood loss volume, adverse reaction and postoperative hospitalization duration were obvious so that we reviewed the relative articles again in attempt to find out the possible influence of heterogeneity. However,

the basic information of patients mentioned in articles such as ages, times of pregnancy, history of CS and times of delivery tended to be the same, the heterogeneity cannot be found in these articles. Therefore, we presume that the surgery level of surgeon, conditions of patients and type of placenta previa may be the influencing sources of heterogeneity.

P value of literature quality assessments for operative time and adverse reaction changed after subgroup analysis. Significant difference was found in low-quality articles, while no significant difference in high-quality articles. According to the results, high-quality articles were seemed to impact the heterogeneity on intraoperative blood transfusion volume and adverse reactions. Overall, the reasons for the *P* value change may be fewer high-quality articles included in this study. Therefore, more high-quality articles should be recommended to be published in the future.

A lot of endpoints including ICU admission rate, lower extremity thrombosis rate, neonatal birth weight, neonatal birth height and Apgar 1-min and 5-min scores were analyzed in this meta-analysis, which provided more evidences than the former article [16] to prove the efficacy of AABO. However, some shortcomings are still present. For example, low-quality Chinese articles published were included. In light of limited sources, the character of the research cannot be guaranteed.

Conclusions

To summarize, related RCTs demonstrated that the intraoperative blood loss volume, intraoperative blood transfusion volume, hysterectomy rate, operative time, postoperative hospitalization duration, and ICU admission rate were all reduced under the assistant of prophylactic AABO. The systematic review and meta-analysis for prophylactic AABO in patients with PPP complicated by PA during CS provides a good support for clinical practice. Application of AABO in PPP patients during CS are relatively safe, which should be widely promoted in clinic.

Author contributions QH and ZP: conceptualization, data curation, formal analysis, investigation, methodology, supervision, original draft writing, review and editing. YL and MZ: data curation, validation, formal analysis, original draft writing, review and editing. XP: supervision, review and editing. XL: validation, original draft writing, review and editing. HH: supervision, validation, review and editing. ZP acquired and administrated the funding. All the authors have read, reviewed critically and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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