

Endovascular Strategy in Obstetrics

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Post-partum hemorrhage (PPH) requires medical resources to resuscitate hemorrhagic shock patients. The concept of damage control surgery in obstetrics has become widespread, and resuscitative endovascular balloon occlusion of the aorta (REBOA) can be a means of resuscitation in PPH. However, the potential benefits of endovascular strategies in obstetrics are not fully understood. This review aims to share the knowledge and experience of the endovascular strategy in the field of obstetrics among both interventional radiologists and obstetricians through the summary of the literature and multi-specialty expert consensus in the Japanese Society of Diagnostic Interventional Radiology in Emergency, Critical care and Trauma (DIRECT). The endovascular strategies include REBOA, arterial embolization, and common or internal iliac artery balloon occlusion (CIABO or IIABO). Uterine artery embolization achieves rapid definitive hemostasis while leaving fertility with a less invasive procedure. N-butyl-2-cyanoacrylate (NBCA) should be chosen as needed for coagulopathy. The obstetrics team (obstetricians and midwives) and the resuscitation team (doctors from emergency medicine, anesthesiology, interventional radiology, and nurses) would each have to develop a command system, and control and cooperate in parallel. The consensus for the timing of arterial access and the patient's positioning for pelvic examination and femoral arterial access should be established in advance.

Keywords: *Resuscitative Endovascular Balloon of the Aorta; REBOA; Post-Partum Hemorrhage; PPH*

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INTRODUCTION

Post-partum hemorrhage (PPH) puts two young people at risk. Considering the length of life that should have remained, the social loss is enormous if lives cannot be saved. The psychological burden on the bereaved families is usually significant. PPH requires abundant medical and human resources to resuscitate patients with hemorrhagic shock [1]. It is essential that collaboration occurs between obstetricians and emergency doctors, anesthesiologists, intensive care doctors, and interventional radiologists. The anatomy, pathophysiology, and hemostatic strategy of PPH are not fully understood among such multidisciplinary/multi-specialty teams. In many cases, hyperfibrinolysis occurs [2,3], and a large amount of blood is required for transfusion [4,5]. Cooperation with the blood bank is also crucial for a rapid and

massive transfusion protocol. In addition, collaboration with midwives, nurses, and neonatology is required [6]. This kind of multidisciplinary/multi-specialty collaboration is similar to the treatment of polytrauma. This review aims to share the knowledge and experience of endovascular strategies in perinatal resuscitation and hemostasis among both interventional radiologists and obstetricians through a summary of the literature and multi-specialty expert consensus in the Japanese Society of Diagnostic Interventional Radiology in Emergency, Critical care and Trauma (DIRECT).

As with a polytrauma strategy, promptness and certainty should be prioritized over minimal invasiveness in PPH. Bimanual uterine compression massage and Bakri® post-partum balloon are essential and effective hemostatic measures [7]. For maternal lifesaving, it is unavoidable that a total emergency hysterectomy is performed. The concept of damage control surgery in obstetrics has also become widespread. Thus, expedited definitive hemostasis contributes to maternal lifesaving in the most severe PPH. In addition, resuscitative endovascular balloon occlusion of the aorta (REBOA) has also been recognized as a means of resuscitation in PPH [8].

However, endovascular strategies in obstetrics have a wide variety of applications, including emergent versus elective cases [9,10], REBOA versus selective balloon

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Table 1 REBOA placement position and target injury.

	Zone 1	Zone 3
Top	Left subclavian artery	Renal artery
Bottom	Celiac trunk	Aortic bifurcation
Target area	Abdomen (supraceliac)	Pelvis (infrarenal)
Target injury	Spleen	Pelvic fracture
	Bowel and mesentery	Uterus
	Liver	Thigh
	Kidney	
	Impending cardiac arrest	
	Focus unknown	

occlusion [11], and total hysterectomy versus uterine artery embolization (UAE) [12]. The potential benefits may not be fully understood. This article discusses the utility, availability, and feasibility of endovascular strategies in obstetrics.

Ethical Approval and Informed Consent

Ethical approval was not required. Informed consent was not required.

SURGERY AND ENDOVASCULAR STRATEGY IN RESUSCITATION AND HEMOSTASIS

Surgery and interventional radiology (IR) are two sides of the same coin in a trauma hemostatic strategy. The usefulness of a hybrid strategy that combines their merits has been recognized. Arterial bleeding of pelvic fractures is controlled by arterial embolization, and bony and venous bleeding is controlled by external fixation and retroperitoneal packing [13]. For liver injury, portal vein/venous bleeding is controlled by perihepatic packing during emergency laparotomy, and arterial bleeding is subsequently controlled by hepatic artery embolization [14]. The packing can control the low-pressure (portal and venous) system [15], and angioembolization can control arterial hemorrhage [16]. Since both the spleen and uterus are resectable organs, the hemostatic strategy in PPH and spleen injury is similar: resection or preservation with angioembolization [17–19]. There are several similarities between the hemostatic strategies for trauma and PPH. REBOA can increase the proximal arterial pressure in hemodynamically unstable patients and regulate distal bleeding; thus, the patient needs to rush to achieve definitive hemostasis. Zone 1 REBOA is selected for abdominal organ injury such as the spleen, and zone 3 can be chosen anatomically for hemorrhage below the aortic bifurcation such as PPH [20,21] (Table 1). Zone 1 is indicated in impending cardiac arrest by PPH. Zone 3 REBOA cannot occlude the ovarian artery. Since the uterine blood supply in most gravid uteruses can be

regulated by zone 3 REBOA, it is the first choice in the PPH situation when considering the risk of visceral organ ischemia. REBOA is not a hemostatic procedure but an effective and feasible bridge to definitive hemostasis [22]. Bleeding patients need to undergo surgery or IR while using REBOA as a bridge. Surgical hemostasis includes splenectomy or hysterectomy, and angioembolization is most commonly used for endovascular hemostasis, which may preserve the injured organ.

Zone 3 REBOA, which is often chosen in PPH, induces minor ischemia-reperfusion injury compared to zone 1 REBOA in abdominal injury. In most cases of PPH, UAE or internal iliac artery embolization may be completed rapidly. Bilateral non-selective internal iliac artery embolization can be completed within 20–30 minutes, similar to pelvic fracture cases. The uterine artery, which is often enlarged to supply the pregnant uterus, can be cannulated even in an urgent PPH situation. There is a greater chance of selective embolization after stabilization by transfusion and embolization of the main bleeder. Although gelatin sponge particles are usually used in the clinical routine of emergent IR, they can be recanalized in coagulopathy. A liquid embolic agent independent of the coagulation status, such as n-butyl-2-cyanoacrylate (NBCA, Histoacryl®) or ethylene-vinyl alcohol copolymer (Onyx™), may work instantly, even in severe coagulation disorders [23]. When the microcatheter tip can reach the bleeding artery selectively in an obviously coagulopathic patient, a liquid embolic agent may be used as the first choice.

The multidisciplinary consensus among obstetricians, emergency physicians, and IR physicians on the risk of ischemia of the uterus leads to damage control procedures according to hemodynamics and coagulopathy. IR is not only a less invasive procedure but can result in more rapid hemostasis. Endovascular hemostasis may avoid additional injuries during surgery. While fertility becomes null after hysterectomy, preservation of the uterus after angioembolization may lead to subsequent pregnancy. The patient may feel resistance to the uterus's loss, even if the couple no longer hopes to raise a child. Despite the

risks of complications such as amenorrhea, placental malposition, and premature birth, the endovascular strategy has good compatibility with PPH. However, angiographic hemostasis differs from clinical hemostasis. Controlling angiographic arterial bleeding alone may not result in hemostasis. There should be no hesitation to convert to surgical hemostasis if bleeding cannot be controlled, such as persistent oozing due to coagulopathy.

BALLOON OCCLUSION IN OBSTETRICS: PROPHYLACTIC USE AND PROXIMAL CONTROL

REBOA and arterial embolization are not the only options under endovascular strategies in the field of obstetrics. Prophylactic selective balloon occlusion, such as common iliac artery balloon occlusion (CIABO) or internal iliac artery balloon occlusion (IIABO), contributes to reducing intraoperative bleeding in high-risk cesarean sections [11]. Prophylactic use of the balloon catheter in elective cases is a feature and benefit in obstetrics. Prophylactic balloon use makes the surgery safer and more comfortable, before uncontrollable hemorrhage and catastrophic conditions occur.

Both CIABO and IIABO are relatively simple vascular IR procedures. However, the procedure is usually performed by an interventional radiologist in an angiography or hybrid suite, while REBOA could be performed by any trained vascular/trauma or anesthesiologist team without fluoroscopy in the emergency room or operating room. IIABO cannot control the collateral flow from the external iliac artery; thus, previous research reported that it could not reduce bleeding [24,25]. A recent systematic review and meta-analysis, evaluating 29 articles, suggested IIABO in patients with placenta previa contributes to reducing intraoperative blood loss and hysterectomy [26]. Some recommend CIABO because it occludes both internal and external iliac arteries, but it also carries the risk of distal embolism of the leg. Meanwhile, IIABO can be immediately converted to angioembolization of the internal iliac artery in the case of PPH.

The occlusion effect of bilateral CIABO is the same as that of zone 3 REBOA. That is, a REBOA provider who received appropriate training plays the same role as an IR physician who can achieve the temporal arterial occlusion of bilateral CIABO, even if they are not IR physicians. A previous study compared the efficacy of IIABO, CIABO, and zone 3 REBOA. The results suggested that prophylactic balloon occlusion decreased blood loss and blood transfusion, especially in patients with CIABO and zone 3 REBOA compared to IIABO [27]. Moreover, maternal and fetal radiation exposure during REBOA placement requires only one or two images using a portable X-ray device or C-arm. The preoperative procedure can be completed within 30 minutes. REBOA creates a dry operative field, reduces intraoperative bleeding, and may reduce or avoid transfusion, especially in patients with placenta accrete [28–32]. It

reduces the risk of operative injury of the ureter or bladder during the damage control setting, thus helping to achieve delicate surgery is more straightforward.

A REBOA sheath used to be large, such as 10–12 Fr [33,34]. The femoral artery diameter of young women is small. The merits of proximal control and the risk of leg ischemia are compared prior to prophylactic use. Meanwhile, bilateral 5 Fr sheaths are usually placed in CIABO or IIABO. Although the 5 Fr sheath does not induce a significant risk of leg ischemia, both sides of the groin must be continuously compressed for several hours after the sheath is removed. Small-profile REBOA is compatible with a 7 Fr sheath [35]. A 7 Fr sheath is placed on one side, associated with a lower risk of leg ischemia and may be smaller than bilateral 5 Fr sheaths. More recently, 4 Fr-compatible REBOA was launched, and this is expected to provide safer REBOA placement [36].

There is a significant difference in policies depending on the facility or the operator regarding the selection of REBOA in zone 3 or bilateral CIABO/IIABO, and we cannot recommend which is beneficial. However, the potential for maternal and fetal safety during a high-risk cesarean section by the prophylactic placement of balloons is an attractive and valuable option.

MULTIDISCIPLINARY COLLABORATION IN PPH

Multidisciplinary collaboration among multiple departments and professions is essential for PPH. However, this is not an event that occurs every day. Perinatal health care providers cannot train themselves while undertaking daily routine work, even in high-volume centers. Simulation training is required to establish the perinatal critical care system, including regional transportation, command and control, resuscitation and definitive care, massive transfusion protocol, inter-departmental communication among obstetrics, emergency medicine, anesthesiology, and IR.

The obstetrics team (obstetricians and midwives) and the resuscitation team (doctors from emergency medicine, anesthesiology, interventional radiology, and nurses) would each have to develop a command system, and control and cooperate in parallel. Pelvic examination in the lithotomy position and obtaining femoral arterial access cannot be performed simultaneously when considering endovascular treatment. The order of pelvic examination and access may vary depending on the hemodynamics or assumed cause of PPH. These two procedures can proceed simultaneously at a hip abduction supine position with knee flexion, that is, ultrasound-guided femoral artery puncture at the right groin and left knee up for pelvic examination. Interruption of obtaining arterial access by lithotomy position without consensus should be avoided.

The Bakri balloon is a fundamental and practical device that provides temporary compression hemostasis and monitors genital bleeding. Its combination with

endovascular balloon occlusion contributes to temporary hemorrhage control. Placing a folded towelette under the patient's waist for smooth insertion of the Bakri balloon can be considered. The patient's posture can be adjusted for an easy and safe procedure by close communication between the obstetrician and emergency physician (who obtains arterial access) until the moment of puncture. Similar to trauma cases, the arterial sheath can be used for upsizing to the REBOA sheath or as access for embolization even when urgent REBOA deployment is no longer needed. Sharing the importance of early arterial access among emergency physicians, obstetricians, nurses, and midwives would result in a rapid response to PPH.

The balloon can be inflated longer in zone 3 than in zone 1 if it is placed correctly. When transporting a PPH case to a higher-level medical institution, zone 3 REBOA can be a good stabilization option for inter-hospital transport. Partial REBOA is also used in combination to avoid cardiac arrest and regulate arterial bleeding. The education of REBOA providers is crucial for the safe use of REBOA. However, early hemorrhagic shock detection, an early transport decision, and early definitive hemostasis are fundamental processes to save PPH patients. The power of REBOA should never be overestimated; it should always be remembered that it does not achieve hemostasis but is just a bridge.

CONCLUSION

There are various types of endovascular strategies used in the field of obstetrics. The use of REBOA includes resuscitative use to avoid cardiac arrest (zone 1 or zone 3), proximal control for hysterectomy (zone 3), and prophylactic use in high-risk cesarean sections (zone 3). It is essential to share the hemostatic strategy among resuscitation and obstetric teams in resuscitative use. The hip abduction supine position and knee flexion provide simultaneous pelvic examination and arterial access. Proximal control provides a dry operative field, especially in high-risk hysterectomies. Prophylactic REBOA use requires preoperative risk evaluation, but it has the advantages of less radiation exposure, shorter procedure time, and less patient burden than bilateral CIABO or IIABO. UAE achieves rapid definitive hemostasis while leaving fertility, with a less invasive procedure. NBCA should be chosen as needed for coagulopathy. Multidisciplinary collaboration and sharing of strategies would save two young lives in obstetrics.

Ethics Statement

- (1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.

- (2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

Yosuke Matsumura was a clinical advisory board member of Tokai Medical Products (2015–2017). The other author declares that they have no conflicts of interest.

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REFERENCES

- [1] Bienstock JL, Eke AC, Hueppchen NA. Postpartum hemorrhage. *N Engl J Med*. 2021;384(17):1635–45.
- [2] James AH, Grotegut C, Ahmadzia H, Peterson-Layne C, Lockhart E. Management of coagulopathy in postpartum hemorrhage. *Semin Thromb Hemost*. 2016;42(7):724–31.
- [3] Collaborators WT. Effect of early tranexamic acid administration on mortality, hysterectomy, and other morbidities in women with post-partum haemorrhage (WOMAN): an international, randomised, double-blind, placebo-controlled trial. *Lancet*. 2017;389(10084):2105–16.
- [4] Jackson DL, DeLoughery TG. Post-partum Hemorrhage: management of massive transfusion. *Obstet Gynecol Surv*. 2018;73(7):418–22.
- [5] Kogutt BK, Vaught AJ. Post-partum hemorrhage: blood product management and massive transfusion. *Semin Perinatol*. 2019;43(1):44–50.
- [6] Higgins N, Patel SK, Toledo P. Postpartum hemorrhage revisited: new challenges and solutions. *Curr Opin Anaesthesiol*. 2019;32(3):278–84.
- [7] Said Ali A, Faraag E, Mohammed M, et al. The safety and effectiveness of Bakri balloon in the management of post-partum hemorrhage: a systematic review. *J Matern Fetal Neonatal Med*. 2021;34(2):300–7.
- [8] Sovik E, Stokkeland P, Storm BS, Asheim P, Bolas O. The use of aortic occlusion balloon catheter without fluoroscopy for life-threatening post-partum haemorrhage. *Acta Anaesthesiol Scand*. 2012;56(3):388–93.
- [9] Masamoto H, Uehara H, Gibo M, et al. Elective use of aortic balloon occlusion in cesarean hysterectomy for placenta previa percreta. *Gynecol Obstet Invest*. 2009;67(2):92–5.
- [10] Ordonez CA, Manzano-Nunez R, Parra MW, et al. Prophylactic use of resuscitative endovascular balloon occlusion of the aorta in women with abnormal placentation: a systematic review, meta-analysis, and case series. *J Trauma Acute Care Surg*. 2018;84(5):809–8.
- [11] Carnevale FC, Kondo MM, de Oliveira Sousa W, Jr., et al. Perioperative temporary occlusion of the internal iliac arteries as prophylaxis in cesarean section at risk of

- hemorrhage in placenta accreta. *Cardiovasc Intervent Radiol*. 2011;34(4):758–64.
- [12] Aoki M, Tokue H, Miyazaki M, et al. Primary post-partum hemorrhage: outcome of uterine artery embolization. *Br J Radiol*. 2018;91(1087):20180132.
- [13] Coccolini F, Stahel PF, Montori G, et al. Pelvic trauma: WSES classification and guidelines. *World J Emerg Surg*. 2017;12:5.
- [14] Coccolini F, Coimbra R, Ordonez C, et al. Liver trauma: WSES 2020 guidelines. *World J Emerg Surg*. 2020;15(1):24.
- [15] Cothren CC, Osborn PM, Moore EE, et al. Preperitoneal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. *J Trauma*. 2007;62(4):834–9; discussion 9–42.
- [16] Metsemakers WJ, Vanderschot P, Jennes E, et al. Transcatheter embolotherapy after external surgical stabilization is a valuable treatment algorithm for patients with persistent haemorrhage from unstable pelvic fractures: outcomes of a single centre experience. *Injury*. 2013;44(7):964–8.
- [17] van den Akker T, Brobbel C, Dekkers OM, Bloemenkamp KWM. Prevalence, indications, risk indicators, and outcomes of emergency peripartum hysterectomy worldwide: a systematic review and meta-analysis. *Obstet Gynecol*. 2016;128(6):1281–94.
- [18] Coccolini F, Montori G, Catena F, et al. Splenic trauma: WSES classification and guidelines for adult and pediatric patients. *World J Emerg Surg*. 2017;12:40.
- [19] Chen C, Lee SM, Kim JW, Shin JH. Recent update of embolization of postpartum hemorrhage. *Korean J Radiol*. 2018;19(4):585–96.
- [20] Stannard A, Eliason JL, Rasmussen TE. Resuscitative endovascular balloon occlusion of the aorta (REBOA) as an adjunct for hemorrhagic shock. *J Trauma*. 2011;71(6):1869–72.
- [21] Brenner M, Hoehn M, Pasley J, et al. Basic endovascular skills for trauma course: bridging the gap between endovascular techniques and the acute care surgeon. *J Trauma Acute Care Surg*. 2014;77(2):286–91.
- [22] Manzano-Nunez R, Escobar-Vidarte MF, Naranjo MP, et al. Expanding the field of acute care surgery: a systematic review of the use of resuscitative endovascular balloon occlusion of the aorta (REBOA) in cases of morbidly adherent placenta. *Eur J Trauma Emerg Surg*. 2018;44(4):519–26.
- [23] Obata S, Kasai M, Kasai J, et al. Emergent Uterine arterial embolization using n-butyl cyanoacrylate in postpartum hemorrhage with disseminated intravascular coagulation. *Biomed Res Int*. 2017;2017:1562432.
- [24] Shih JC, Liu KL, Shyu MK. Temporary balloon occlusion of the common iliac artery: new approach to bleeding control during cesarean hysterectomy for placenta percreta. *Am J Obstet Gynecol*. 2005;193(5):1756–8.
- [25] Hishikawa K, Koshiyama M, Ueda M, et al. Exchange of intraoperative balloon occlusion of the internal iliac artery for the common iliac artery during cesarean hysterectomy in a patient with placenta percreta. *Am J Case Rep*. 2013;14:409–11.
- [26] Nankali A, Salari N, Kazeminia M, et al. The effect prophylactic internal iliac artery balloon occlusion in patients with placenta previa or placental accreta spectrum: a systematic review and meta-analysis. *Reprod Biol Endocrinol*. 2021;19(1):40.
- [27] 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. *Eur Radiol*. 2018;28(12):4959–67.
- [28] Wu Q, Liu Z, Zhao X, et al. Outcome of pregnancies after balloon occlusion of the infrarenal abdominal aorta during caesarean in 230 patients with placenta praevia accreta. *Cardiovasc Intervent Radiol*. 2016;39(11):1573–9.
- [29] Panici PB, Anceschi M, Borgia ML, et al. Intraoperative aorta balloon occlusion: fertility preservation in patients with placenta previa accreta/increta. *J Matern Fetal Neonatal Med*. 2012;25(12):2512–6.
- [30] Riazanova OV, Reva VA, Fox KA, et al. Open versus endovascular REBOA control of blood loss during cesarean delivery in the placenta accreta spectrum: a single-center retrospective case control study. *Eur J Obstet Gynecol Reprod Biol*. 2021;258:23–8.
- [31] Ioffe YJM, Burruss S, Yao R, et al. When the balloon goes up, blood transfusion goes down: a pilot study of REBOA in placenta accreta spectrum disorders. *Trauma Surg Acute Care Open*. 2021;6(1):e000750.
- [32] Chen L, Wang X, Wang H, et al. Clinical evaluation of prophylactic abdominal aortic balloon occlusion in patients with placenta accreta: a systematic review and meta-analysis. *BMC Pregnancy Childbirth*. 2019;19(1):30.
- [33] Saito N, Matsumoto H, Yagi T, et al. Evaluation of the safety and feasibility of resuscitative endovascular balloon occlusion of the aorta. *J Trauma Acute Care Surg*. 2015;78(5):897–904.
- [34] DuBose JJ, Scalea TM, Brenner M, et al. The AAST prospective Aortic Occlusion for Resuscitation in Trauma and Acute Care Surgery (AORTA) registry: data on contemporary utilization and outcomes of aortic occlusion and resuscitative balloon occlusion of the aorta (REBOA). *J Trauma Acute Care Surg*. 2016;81(3):409–19.
- [35] Teeter WA, Matsumoto J, Idoguchi K, et al. Smaller introducer sheaths for REBOA may be associated with fewer complications. *J Trauma Acute Care Surg*. 2016;81(6):1039–45.
- [36] Power A, Parekh A, Scallan O, et al. Size matters: first-in-human study of a novel 4 French REBOA device. *Trauma Surg Acute Care Open*. 2021;6(1):e000617.