Review

https://doi.org/10.23934/2223-9022-2022-11-4-637-644

Uterine Artery Embolization in the Treatment of Postpartum Hypotonic Bleeding

M.A. Kurtser[1], I.Y. Breslav[2], B.A. Konoplyov[3] ✉, A.G. Konoplyannikov[1]

Department of Obstetrics and Gynecology, Faculty of Pediatrics
[1] N.I. Pirogov Russian National Research Medical University
1, Ostrovityanova St., Moscow, 117997, Russian Federation
[2] Clinical Hospital MD GROUP of the group of companies Mother and Child
24-1, Sevastopolsky Prospect, Moscow, 117209, Russian Federation
[3] Clinical hospital Lapino of the group of companies Mother and Child (HAVEN, OOO)
111, 1st Uspenskoye Highway, Moscow region, 143030, Russian Federation

✉ **Contacts:** Boris A. Konoplyov, Obstetrician-gynecologist, General Director of HAVEN (Lapino Clinical Hospital) of the Mother and Child group of companies.
Email: b.konoplev@mcclinics.ru

ABSTRACT Postpartum hemorrhage is a serious obstetric complication due to the threat to the life and health of a woman. One of the common causes of bleeding in the postpartum period is uterine hypotension. If conservative methods of treating hypotonic bleeding are ineffective, hemostatic compression sutures are applied to the body of the uterus, ligation/clipping of the main vessels of the uterus and (or) ligation of the internal iliac arteries. If available, endovascular uterine artery embolization (UAE) is performed. The review is devoted to the efficacy and safety of UAE in pregnant women with postpartum hypotonic bleeding, as well as to the long-term results of follow-up.

Keywords: postpartum hemorrhage; atony of the uterus; embolization of uterine arteries; long-term results; fertility

For citation Kurtser MA, Breslav IY, Konoplyov BA, Konoplyannikov AG. Uterine Artery Embolization in the Treatment of Postpartum Hypotonic Bleeding. *Russian Sklifosovsky Journal of Emergency Medical Care.* 2022;11(4):637–644. https://doi.org/10.23934/2223-9022-2022-11-4-637-644 (in Russ.)

Conflict of interest Authors declare lack of the conflicts of interests

Acknowledgments, sponsorship The study has no sponsorship

Affiliations

Mark A. Kurtser	Academician of the Russian Academy of Sciences, Doctor of Medical Sciences, Professor, Head of the Department of Obstetrics and Gynecology, Faculty of Pediatrics, N.I. Pirogov Russian National Research Medical University; https://orcid.org/0000-0003-0175-1968, m.kurtser@mcclinics.ru; 30%, development of the concept and design of the article, verification of critical intellectual content, final approval of the manuscript
Irina Yu. Breslav	Doctor of Medical Sciences, Obstetrician-gynecologist, Head of the Obstetric Department of Pregnancy Disorders, MD GROUP Clinical Hospital; https://orcid.org/0000-0002-0245-4968, irina_breslav@mail.ru; 25%, coordination of the material and structure of the review, editing the text, final approval of the manuscript
Boris A. Konoplyov	Obstetrician-gynecologist, General Director of HAVEN (Lapino Clinical Hospital) of the Mother and Child group of companies; https://orcid.org/0000-0001-6347-4375, b.konoplev@mcclinics.ru; 25%, literature selection, manuscript drafting, bibliography design
Aleksandr G. Konoplyannikov	Doctor of Medical Sciences, Professor of the Department of Obstetrics and Gynecology, Faculty of Pediatrics, N.I. Pirogov Russian National Research Medical University; https://orcid.org/0000-0001-9923-8833, npo.med@gmail.com; 20%, checking critical intellectual content, text editing

CBV - circulating blood volume
PPH - postpartum hemorrhage
UAE - uterine artery embolization
PES - post-embolization syndrome
PR - pregnancy rate

INTRODUCTION

About 300,000 women die worldwide due to complications of pregnancy and childbirth annually [1, 2]. In the Russian Federation in 2020, the maternal mortality rate was 11.2 per 100,000 live births [3]. In the structure of maternal deaths in 2020 in the Russian Federation, bleeding (6.4%) took 3rd place after extragenital diseases (71.4%) and septic complications (8.1%) [3]. According to the literature, the global average of the share of obstetric

bleeding in maternal mortality reaches 16–27%, exceeding 50% in Asia and Africa [4–8]. In the Russian Federation, in 2020, the maternal mortality rate from hemorrhages during childbirth and the postpartum period was 0.28 per 100,000 live births [3].

One of the most common causes (64–80%) of postpartum hemorrhage (PPH) is uterine hypotension, a condition in which the tone and contractility of the uterus are sharply reduced with a preserved reflex response [9–14]. The lack of adequate and timely assistance leads to massive blood loss — a simultaneous loss of more than 1,500 ml of blood (25–30% of circulating blood volume — CBV) or more than 2,500 ml of blood (50% of CBV) in 3 hours [13, 14].

The Clinical Guidelines "Postpartum hemorrhage" (2021) draws attention to the importance of determining the volume of blood loss exclusively by the gravimetric method, using the weighing of the surgical material, and, if conditions are available, the hardware reinfusion of the autoerythrogenic suspension. In addition to a clear understanding of the nominal volume of blood loss in milliliters, its calculation as a percentage of the initial CBV of a pregnant woman is of great importance, which determines the volume and composition of infusion-transfusion therapy and surgical tactics [13].

1. CHOICE OF METHOD OF SURGICAL TREATMENT OF POSTPARTUM HYPOTONIC BLEEDING

In obstetric practice, in order to prevent hypotonic bleeding, the tactics of “active management of the third stage of delivery” are used, including the introduction of uterotonics (oxytocin, carbetocin, methylergometrine), prostaglandins immediately after delivery, early clamping and cutting of the umbilical cord, the use of controlled traction for the umbilical cord to isolate the placenta [5 , 13, 15, 16].

The Clinical Guidelines “Postpartum Hemorrhage” (2021) developed a consistent algorithm of actions for bleeding [13]. At the first (non-surgical) stage, external massage and manual examination of the uterus are used, with continued bleeding, an intrauterine balloon is inserted, if it is ineffective, they switch to ligation of the internal iliac arteries or embolization of the uterine arteries (UAE), depending on the equipment of the institution, in the absence of a hemostatic effect, hysterectomy is performed [13, 16, 17].

Balloon tamponade of the uterus (balloons *Bakri*, *Folli*, *Sengstaken-Blekmor Rush* and others) has found its place in postpartum hypotonic bleeding. The method is easy to use, helps stop bleeding in uterine hypotension in 78–90% of cases, and is characterized by a minimal number of complications [5, 6, 12].

A.A. Askerov et al. it has shown that the use of uterine balloon tamponade in the treatment of hypotonic PPH contributed to a decrease in blood loss, the frequency of surgical interventions, and the need for blood transfusion [18]. In the study of T.V. Legalova and I.I. Kukarskaya hysterectomy was avoided and reproductive function was preserved in all patients with hypotonic PPH due to the use of controlled balloon tamponade of the uterus [12].

With the ineffectiveness of conservative methods of hemostasis, the choice of the type of surgical treatment is determined by the characteristics of the obstetric situation, the volume of blood loss, the equipment of the hospital, and the qualifications of the surgeon. The simplest methods are uterine ischemia by applying clamps to the uterine and ovarian arteries, as well as hemostatic compression sutures to the uterus (B-Lynch, Pereira, etc.) [4, 5].

The important role of bilateral ligation of the internal iliac arteries is not denied. This technique is effective in almost all patients with hypotonic bleeding [4, 7, 9].

Kurtser M.A. et al. in their study showed that after ligation of the internal iliac arteries, 56.4% of patients additionally lost up to 300 ml of blood. The authors confirmed that vascular ligation can be undertaken when embolization is ineffective and does not require laparotomy, while the reverse sequence of measures is extremely difficult or impossible [9].

Wang C.Y. et al. conducted a comparative analysis of the effectiveness of bilateral ligation of the internal iliac arteries and UAE in 40 patients with hypotonic postpartum hemorrhage. It was found that the efficiency of vessel ligation was 88.9%, there were no postoperative complications. At the same time, two patients who underwent UAE died of DIC (disseminated intravascular coagulation). The authors concluded that ligation of the internal iliac arteries is safer for massive blood loss accompanied by consumption coagulopathy and should be performed as soon as possible when an indication for emergency obstetric care appears [19].

If organ-preserving surgical methods are ineffective, hysterectomy is performed, which additionally increases the volume of intraoperative blood loss by 500-1000 ml. The frequency of emergency postpartum hysterectomy performed for PPH in the world is from one to three cases per 1000 births [5, 20], in Russia it is 1.11 and 1.07 per 1,000 births in 2019 and 2020, respectively, in Moscow it is 0.15 and 0.11 per 1,000 births, respectively [3].

Dahlke J.D. et al. compared 4 protocols for the treatment of massive postpartum hemorrhage: *American College of Obstetricians and Gynecologists (ACOG)*, *Royal Australian and New Zealand College of Obstetricians and Gynecologists (RANZOG)*, *Royal College of Obstetrician and Gynecologists (RCOG)* and *Society of Obstetricians and Gynecologists of Canada (SOGC)*. All experts emphasized the need for minimal aggression and preservation of fertility, although representatives of the UK considered it appropriate to switch to hysterectomy earlier under the motto "better sooner than later" [21].

Kurtser M.A. et al., on the contrary, recommended to avoid hysterectomy in PPH if possible, which increases total blood loss and can lead to the death of a woman [9].

2. UTERINE ARTERY EMBOLIZATION AS AN ALTERNATIVE TO HYSTERECTOMY FOR OBSTETRIC BLEEDING

2.1. Efficacy and safety of uterine artery embolization

For more than 30 years, the UAE method has been used in emergency obstetrics for the treatment of postpartum hemorrhage [10, 22–24]. This minimally invasive and effective intervention, which requires additional equipment and qualified personnel, is used in case of failed conservative hemostasis, allows bleeding to be controlled and avoid hysterectomy [10, 25, 26].

Uterine artery embolization is successfully used not only for hypotonic postpartum hemorrhage, but also for placental anomalies, injuries of the soft birth canal, arteriovenous malformation of the uterine body. The indication for selective UAE may be the ineffectiveness of hemostasis after hysterectomy due to coagulopathy [19, 23, 24, 27–29].

In Russia, in order to arrest postpartum hemorrhage, UAE was first used by M.A. Kurtser in 2006 at the Family Planning and Reproduction Center. In the study of M.A. Kurtser et al. it was shown that vascular embolization is an effective and safe way to stop postpartum hemorrhage, as well as a method of choice that promotes rapid hemostasis. The authors proved that UAE is the method of choice for hypotonic postpartum hemorrhage, refractory to conservative therapy, and only in the absence of the effect of UAE is it reasonable to attempt bilateral ligation of the internal iliac arteries [9].

In the domestic literature, there are only a few works on the role of UAE in the treatment of hypotonic bleeding, which forced us to resort to the analysis of foreign studies on this topic [10].

According to *Ikeda A. et al*., patients with postpartum hemorrhage before surgery needed a comprehensive examination, including computed tomography (CT), which makes it possible to judge the need for UAE by the presence of arterial bleeding, its location, and the shape of the uterine cavity [30]. As shown in the study, if signs of bleeding from a blood vessel (extravasates) were dobserved in the lower segment of the uterus, it is possible to perform balloon tamponade; and when the source of bleeding is located in the upper part of the uterus, UAE is required [30]. At the same time, the Clinical guidelines "Postpartum hemorrhage" (2021) clearly indicate that patients with PPH as an instrumental examination are sufficient to conduct an ultrasound examination [13].

Angiography is an accurate diagnostic method that allows assessing the characteristics of the blood supply to the pelvic organs and identifying the source of bleeding [24, 27]. According to *Dinc G. et al*., vascular extravasation was the most common (100%) angiographic sign of postpartum hypotonic bleeding [28]. At the same time, *Aoki M. et al*. did not consider contrast agent extravasation to be the main angiographic sign of PPH, as it was observed only in 15 patients with uterine atony and bleeding (45%) [31].

An analysis of literature data on the technical aspects of X-ray endovascular intervention showed that for the purpose of hemostasis in postpartum hypotonic bleeding, the authors more often used gelatin sponges with a diameter of 500 to 1000 microns, dry particles of polyvinyl alcohol, gel foam, N-butyl-2-cyanoacrylate (NBCA), glue and *Gelfoam* [24, 27, 32]. The uterine artery, internal iliac and inferior mesenteric arteries were more often embolized [27, 28, 33].

According to modern concepts, emergency UAE is a safe and highly effective method of hemostasis in life-threatening postpartum hypotonic bleeding. According to various authors, the clinical success rate was 72.7–91.3% [19, 26–29, 31, 33, 34].

Liu Z. et al., in a meta-analysis of 14 studies involving 956 patients with hypotonic postpartum hemorrhage, showed that UAE significantly reduced blood loss during labor (893.39 ml; 95% CI: 581.13–1205.65), reduced operation time (37.19 min; 95% CI: 29.96–44.42) and length of hospital stay (5.36 days; 95% CI: 4.97–5.76) compared with patients who underwent hysterectomy: 1255 ml; 56.12 min; 7.13 days, respectively (p <0.001) [35].

Spreu A. et al. managed to preserve the uterus in all 16 patients who underwent UAE for hypotonic bleeding, while hysterectomy was inevitable in 2 out of 22 women with PPH (9.1%) who received uterine compression sutures and did not undergo UAE. The levels of hemoglobin, fibrinogen and platelet count after treatment were higher in the UAE group (96.73±2.78 g/l, 149.67±17.23×10 ^{9}/l and 4.67±0.42 g/l, respectively) than in the group of patients who did not undergo UAE: 90.77±3.22 g/l (p =0.19), 109.00±11.84×10 ^{9}/l (p =0.01) and 4.04±0.40 g/l (p =0.31) [26].

The ineffectiveness of the interventional technique is often associated with the peculiarities of the vascular anatomy of the small pelvis. According to *Aoki M. et al*., the presence of anastomosis of the uterine and ovarian arteries (blood flow type *A*) was the cause of ongoing hypotonic bleeding after UAE. The authors concluded that patients with type A require selective embolization of the ovarian branches of the uterine arteries in addition to UAE [31].

Lee S. M. et al. showed that the inefficiency of UAE may also be associated with the type of embolizing agent, for example, the effect is often absent when using a gelatin sponge in patients with severe coagulopathy [22].

Lai B.M. et al. revealed other significant factors of failed embolization in postpartum hemorrhage: platelet count before embolization (84.5±21.2×10 ^{9}/l; p =0.036) and maternal age (37.0±3.7 years; p =0.019). Since a low platelet count before intervention and a late reproductive age of the mother are associated with a higher likelihood of embolization failure, these patients, according to the authors, require careful post-embolization monitoring [33].

Re-bleeding after successful UAE may be caused by recanalization of a previously embolized artery due to restoration of hemodynamics and occurrence of episodes of increased blood pressure [24]. According to *Choi W. et al*., recanalization is the main source of recurrent bleeding after UAE (60.6%) performed for hypotonic bleeding [34].

Along with the evaluation of effectiveness, the question of the safety of endovascular intervention is always raised.

According to *Zhang X.Q. et al*., the main complication after UAE performed for postpartum hypotonic bleeding is post-embolization syndrome (PES) [27]. Post-embolization syndrome (PES) is a complex of subjective and laboratory abnormalities that occurred after UAE (pain, nausea and/or vomiting, fever, fatigue, discomfort, leukocytosis, hypertransaminasemia) [36].

The main pathogenetic mechanism for the development of PES is myometrial ischemia [37]. Ischemic damage to the muscular layer of the uterus after UAE is similar to myocardial ischemia, in which chemical mediators such as lactate and adenosine are released, stimulating sensitive receptors. To avoid myometrial ischemia in recent years, doctors are increasingly abandoning the aggressive technique, which is characterized by embolization until complete stasis of contrast in the uterine artery [36].

Ruiz Sanchez E. et al. described a case of uterine necrosis after UAE performed for hypotonic bleeding in a 37-year-old female patient. On the 16th day, she sought a consultation due to a recurrence of fever. According to magnetic resonance imaging, a diagnosis of uterine necrosis was established. An abdominal hysterectomy was performed [38].

Wang C.Y. et al. reported two deaths in patients with hypotonic uterine bleeding [19]. It is well known that in patients with massive blood loss after childbirth and unstable hemodynamic parameters, when choosing a method of treatment, preference should be given to ligation of the internal iliac arteries, rather than embolization of the uterine vessels.

2.2. The results of dynamic monitoring of patients with hypotonic postpartum hemorrhage who underwent uterine artery embolization

The next step in studying the role of UAE in the treatment of obstetric bleeding was the study of its effect on the possibility of the onset and bearing of subsequent pregnancies [25, 27, 39].

With regard to reproductive function, the opinion of most authors is the same: UAE does not affect fertility and pregnancy outcomes in women in the future [26, 39, 40]. However, data on the pregnancy rate (PR) after UAE are very contradictory and do not reveal the features of the gestation period.

Lai B.M. et al. reported that only 2 patients (6.1%) became pregnant after UAE, but one of them had an ectopic pregnancy [33]. In a study by *Aguilar-Crespo A. et al*. normal menstruation was restored in 21 patients (64%) who underwent UAE due to hypotonic bleeding; became pregnant in subsequent years 6 (18.2%) [29].

Sentilhes L. et al. analyzed reproductive function in 68 patients who underwent UAE for hypotonic bleeding. In 17 patients (25%), one ectopic and 25 uterine pregnancies were observed, the latter ended in 4 miscarriages, 2

abortions and 19 births. Pregnancies (in 19 patients) proceeded without complications. PR and pregnancy outcomes did not differ between patients undergoing embolization and uterine-sparing surgery [40].

A review of the literature by *Soro M.P*. found that UAE performed for postpartum hypotonic hemorrhage did not adversely affect the menstrual cycle, fertility, and subsequent pregnancies, and the PR, according to the literature, was high and reached 70–80% [25] . *Toguchi M. et al*. confirmed a high PR (60.9%; 14 of 23) after UAE, the birth rate was 71.4% (10 of 14) [41].

At the same time, it is impossible not to ignore the deviations of reproductive function and adverse outcomes of subsequent pregnancies identified after UAE by a number of foreign authors. Thus, *Toguchi M. et al*. found that patients who underwent UAE for postpartum hemorrhage were later diagnosed with ovarian dysfunction (4.9%), endometritis (16.2%), and Asherman's syndrome (1.6%) [41].

Imafuku H. et al. conducted an analysis of the course of subsequent pregnancies and outcomes of childbirth in patients with postpartum hemorrhage and blood loss of more than 2,000 ml, treated with and without UAE. It was found that in patients with a history of UAE due to hypotonic bleeding, compared with the group of women in labor who had PPH in the past, but UAE was not used, during childbirth there were significantly more: the volume of blood loss (1,581 ml and 1,021 ml, respectively; p <0.01) and the frequency of rebleeding (35.7% and 9.4%, respectively; p <0.05). At the same time, there were no significant differences between the two groups in the incidence of preterm birth, hypertensive disorders, and fetal growth retardation [42].

A high risk of developing abnormal placentation and/or recurrence of massive postpartum hemorrhage in subsequent pregnancies after the use of UAE for hypotonic bleeding was also noted by other authors [25, 27, 41, 42].

Thus, according to *Imafuku H. et al*., placenta ingrowth occurred in 7 out of 14 patients who underwent UAE (50%), while none of the 32 observed in whom standard surgical methods were used for the treatment of PPH had this complication did not develop [42]. In a study by *Toguchi M. et al*. the incidence of placenta ingrowth after UAE performed for PPH was lower, accounting for 17.7% (11 of 62) [41].

Saiga A. et al. found that the frequency of intrauterine synechia was significantly higher in the group of patients in whom a gelatin sponge suspension was used as an embolizing agent (83.3%), compared with those observed who received the same substance, but in the form of a filling material (0%; p <0.001) [43].

CONCLUSION

Hypotonic hemorrhage, being the most common and most formidable complication of the postpartum period, remains the focus of attention of obstetricians around the world.

The search for modern methods of hemostasis, corresponding to the principles of efficiency, safety and expediency is of greatest interest. The similar criteria are met by uterine artery embolization, which has taken its rightful place in the treatment of hypotonic bleeding. Further efforts of scientists will be aimed at analyzing the long-term results of the use of endovascular organ-preserving techniques, their impact on the reproductive potential and quality of life of women.

REFERENCES

1. Olenev AS, Novikova VA, Radzinsky VE. World conceptual approaches to reduce maternal mortality. *Obstetrics and Gynecology. News. Views. Education.* 2018;6(3):5–17. (In Russ.). https://dx.doi.org/10.24411/2303-9698-2018-13901
2. Ziganshin AM, Mudrov VA, Pekarev OG, Kulavsky EV. Possibilities of 3D modeling of the uterine cavity the diagnosis of early hypotonic bleeding. *Obstetrics and Gynecology*. 2021;2:113–118. (In Russ.). https://dx.doi.Org/10.X8565/aig.2021.2.H3-118
3. Kotova EG, Kobyakova OS, Starodubov VI, Aleksandrova GA, Golubev NA, Ogryzko EV, et al. *Osnovnye pokazateli zdorov'ya materi i rebenka, deyatel'nost' sluzhby okhrany detstva i rodovspomozheniya v Rossiyskoy Federatsii: statisticheskie materialy* . Moscow: TsNIIOIZ Minzdrava Rossii Publ.; 2021. (In Russ.).
4. Buianova SN, Mgeliashvili MV, Puchkova NV, Gukasian SA. The results of initial complex hemostatic therapy for postpartum hemorrhage. *Russian Bulletin of Obstetrician-Gynecologist* . 2019;19(5):72–76. (In Russ.). https://doi.org/10.17116/rosakush20191905172
5. Fadel MG, Das S, Nesbitt A, Killicoat K, Gafson I, Lodhi W, et al. Maternal outcomes following massive obstetric haemorrhage in an inner-city maternity unit. *J Obstet Gynaecol.* 2019;39(5):601–605. https://dx.doi.org/10.1080/01443615.2018.1534814
6. D'Alton M, Rood K, Simhan H, Goffman D. Profile of the Jada® System: the vacuum-induced hemorrhage control device for treating abnormal postpartum uterine bleeding and postpartum hemorrhage. *Expert Rev Med Devices.* 2021;18(9):849–853. https://dx.doi.org/10.1080/17434440.2021.1962288
7. Win SS, Lasimbang HB, Lynn AUng SN, Yeap TB. How B-Lynch suture and bilateral internal iliac artery ligation saved the uterus of a young patient with severe postpartum haemorrhage. *BMJ Case Rep*. 2021;14(8):e244226. https://dx.doi.org/10.1136/bcr-2021-244226
8. Ramavhoya TI, Maputle MS, Lebese RT, Makhado L. Midwives' challenges in the management of postpartum haemorrhage at rural PHC facilities of Limpopo province, South Africa: an explorative study. *Afr Health Sci.* 2021;21(1):311–319. (In Russ.). https://dx.doi.org/10.4314/ahs.v21i1.40

9. Kurtser MA, Breslav IYu, Kutakova YuYu, Lukashina MV, Panin AV, Bobrov BYu. Postpartum hypotonic bleeding. Use of internal iliac artery ligation and uterine artery embolization in the early postpartum period. *Obstetrics and Gynecology*. 2012;7:36–41. (In Russ.).
10. Ageeva UYu, Gaidukov SN, Komissarov MI, Aleshin IU. Clinical and economic efficiency of endovascular and surgical hemostatic methods in patients with high risk of early postpartum bleeding. *The Journal of Scientific Articles Health and Education Millennium*. 2018;3:9–12. (In Russ.). http://dx.doi.org/10.26787/nydha-2226-7425-2018-20-3-9-12
11. Ahmadzia HK, Grotegut CA, James AH. A national update on rates of postpartum haemorrhage and related interventions. *Blood Transfus*. 2020;18(4):247–253. https://dx.doi.org/10.2450/2020.0319-19
12. Legalova TV, Kukarskaya II. The Current Approach to Conservative Treatment of Hypotonic Postpartum Hemorrhage Using Intrauterine Balloon Tamponade. *Doctor.Ru*. 2017; 9(138): 52–57.(In Russ.).
13. *Poslerodovoe krovotechenie. Klinicheskie rekomendatsii*. Moscow, 2021. (In Russ.). Available at: https://www.arfpoint.ru/wp-content/uploads/2021/05/poslerodovoe-krovotechenie.pdf [Accessed Feb 10, 2022]
14. Ries JJ, Jeker L, Neuhaus M, Vogt DR, Girard T, Hoesli I. Implementation of the D-A-CH postpartum haemorrhage algorithm after severe postpartum bleeding accelerates clinical management: A retrospective case series. *Eur J Obstet Gynecol Reprod Biol*. 2020;247:225–231. PMID: 31980289 https://dx.doi.org/10.1016/j.ejogrb.2020.01.001
15. Idrisova HS. Modern technologies in treatment of postnatal bleedings. *Russian Journal of Human Reproduction*. 2017;23(3):101–107. (In Russ.). https://doi.org/10.17116/repro2017233101-107
16. Evensen A, Anderson JM, Fontaine P. Postpartum Hemorrhage: Prevention and Treatment. *Am Fam Physician*. 2017;95(7):442–449. PMID: 28409600
17. Gonzalez-Brown V, Schneider P. Prevention of postpartum hemorrhage. *Semin Fetal Neonatal Med.* 2020;25(5):101129. https://dx.doi.org/10.1016/j.siny.2020.101129
18. Askerov AA, Nazaralieva SB, Osmonova SK. Experience with uterine balloon tamponade in postpartum hypotonic bleedings. *Obstetrics and Gynecology*. 2018;(3):52–56. (In Russ.) https://dx.doi.org/10.18565/aig.2018.3.52-56
19. Wang CY, Pan HH, Chang CC, Lin CK. Outcomes of hypogastric artery ligation and transcatheter uterine artery embolization in women with postpartum hemorrhage. *Taiwan J Obstet Gynecol*. 2019;58(1):72–76. https://dx.doi.org/10.1016/j.tjog.2018.11.014.
20. Barinov SV, Tirskaya YuI, Medyannikova IV, Zhilin AV, Shavkun IA, Shamina IV. Procedure for stopping postpartum hemorrhage with a hemostatic external uterine assembly supraplacental suture. *Russian Bulletin of Obstetrician-Gynecologist*. 2017;17(1):53–61. (In Russ.). https://dx.doi.org/10.17116/rosakush201717153-61
21. Dahlke JD, Mendez-Figueroa H, Maggio L, Hauspurg AK, Sperling JD, Chauhan SP, et al. Prevention and management of postpartum hemorrhage: a comparison of 4 national guidelines. *Am J Obstet Gynecol*. 2015;213(1):76.e1–76.e10. PMID: 25731692. https://dx.doi.org/10.1016/j.ajog.2015.02.023
22. Lee SM, Shin JH, Shim JJ, Yoon KW, Cho YJ, Kim JW, et al. Postpartum haemorrhage due to genital tract injury after vaginal delivery: safety and efficacy of transcatheter arterial embolisation. *Eur Radiol*. 2018;28(11):4800–4809. PMID: 29808429. https://dx.doi.org/10.1007/s00330-018-5490-3
23. Kellie FJ, Wandabwa JN, Mousa HA, Weeks AD. Mechanical and surgical interventions for treating primary postpartum haemorrhage. *Cochrane Database Syst Rev*. 2020;7(7):CD013663. PMID: 32609374 https://dx.doi.org/10.1002/14651858
24. Perkins S, Drews E, Li G, Martin J. Endovascular treatment of postpartum haemorrhage in a woman with genitourinary and vascular congenital malformations. *BMJ Case Rep*. 2021;14(3):e240608. PMID: 33758047 https://dx.doi.org/10.1136/bcr-2020-240608
25. Soro MP, Denys A, de Rham M, Baud D. Short & long term adverse outcomes after arterial embolisation for the treatment of postpartum haemorrhage: a systematic review. *Eur Radiol*. 2017;27(2):749–762. PMID: 27229338. https://dx.doi.org/10.1007/s00330-016-4395-2
26. Spreu A, Abgottspon F, Baumann MU, Kettenbach J, Surbek D. Efficacy of pelvic artery embolisation for severe postpartum hemorrhage. *Arch Gynecol Obstet*. 2017;296(6):1117–1124. https://dx.doi.org/10.1007/s00404-017-4554-y
27. Zhang XQ, Chen XT, Zhang YT, Mai CX. The Emergent Pelvic Artery Embolization in the Management of Postpartum Hemorrhage: A Systematic Review and Meta-analysis. *Obstet Gynecol Surv*. 2021;76(4):234–244. https://dx.doi.org/10.1097/OGX.0000000000000887
28. Dinc G, Oğuz Ş. The efficacy of pelvic arterial embolisation for the treatment in massive vaginal haemorrhage in obstetric and gynaecological emergencies: a single-centre experience. *J Obstet Gynaecol*. 2019;39(6):774–781. https://dx.doi.org/10.1080/01443615.2019.1586858
29. Aguilar-Crespo A, Morales-Roselló J, Sánchez-Ajenjo C, Valle-Tejero A, García-Marcos R, Perales-Marín A. Postpartum hemorrhage with pelvic arterial embolization, study of 33 cases. *J Matern Fetal Neonatal Med*. 2019;32(4):573–578. https://dx.doi.org/10.1080/14767058.2017.1387527
30. Ikeda A, Kondoh E, Chigusa Y, Mogami H, Kameyama Nakao K, Kido A, et al. Novel subtype of atonic postpartum hemorrhage: dynamic computed tomography evaluation of bleeding characteristics and the uterine cavity. *J Matern Fetal Neonatal Med*. 2020;33(19):3286–3292. https://dx.doi.org/10.1080/14767058.2019.1571033
31. Aoki M, Tokue H, Miyazaki M, Shibuya K, Hirasawa S, Oshima K. Primary postpartum hemorrhage: outcome of uterine artery embolization. *Br J Radiol*. 2018;91(1087):20180132. PMID: 29641227 https://dx.doi.org/10.1259/bjr.20180132
32. Dabrowiecki A, Newsome J, Bercu ZL, Martin JG. Postpartum haemorrhage requiring embolisation of a hypertrophied round ligament artery. *BMJ Case Rep*. 2019;12(8):e230071. PMID: 31473635 https://dx.doi.org/10.1136/bcr-2019-230071
33. Lai BM, Shum JS, Chu CY, Lo SS, Lau KY. Predictors of the success and failure of emergency pelvic artery embolisation for primary postpartum haemorrhage: a 12-year review. *Singapore Med J*. 2017;58(5):272–278. PMID: 27090601 https://dx.doi.org/10.11622/smedj.2016079
34. Choi W, Shin JH, Kim PH, Han K, Ohm JY, Kim JH, et al. Clinical outcomes of 23 patients who had repeat pelvic arterial embolisation for uncontrolled post-partum haemorrhage at a single centre. *Clin Radiol*. 2018;73(7):665–671. PMID: 29622362 https://dx.doi.org/10.1016/j.crad.2018.02.019
35. Liu Z, Wang Y, Yan J, Li J, Liu X, Zhang L, et al. Uterine artery embolization versus hysterectomy in the treatment of refractory postpartum hemorrhage: a systematic review and meta-analysis. *J Matern Fetal Neonatal Med*. 2020;33(4):693–705. PMID: 30354858 https://dx.doi.org/10.1080/14767058.2018.1497599
36. Kalmykov EL, Rakhimov FR, Umarzoda SG, Baratov AK. Uterine artery embolization for uterine leiomyoma: the state of the problem. *Obstetrics and gynecology*. 2020;9:18–26. (In Russ.). https://dx.doi.org/10.18565/aig.2020.9.18-26
37. Syutkina IP, Khabarov DV, Rakitin FA, Kochetkova MV, Ineshina AD. Integrated assessment of perioperative changes in the blood coagulating system during uterine artery embolization. *Obstetrics and gynecology*. 2019;12:133–139. https://dx.doi.org/10.18565/aig.2019.12.133-139

38. Ruiz Sanchez E, Peinado Rodenas J, Gil Martinez-Acacio L, Arones Collantes M, Villar Garcia M, Garcia de la Torre JP. Uterine necrosis. A rare complication of embolization due to postpartum haemorrhage. *J Gynecol Obstetrics Hum Reprod* . 2021;50(2):1 PMID: 32325270 https://dx.doi.org/10.1016/j.jogoh.2020.101773
39. Corvino F, Giurazza F, Vallone M, Mosca S, Fischer MJ, Corvino A, et al. Postpartum Hemorrhage: Rescue. *Semin Ultrasound CT MR* . 2021;42(1):75–84. PMID: 33541591 https://dx.doi.org/10.1053/j.sult.2020.09.001
40. Sentilhes L, Gromez A, Clavier E, Resch B, Verspyck E, Marpeau L. Fertility and pregnancy following pelvic arterial embolisation for postpartum haemorrhage. *BJOG*. 2010;117(1):84–93. https://dx.doi.org/10.1111/j.1471-0528.2009.02381.x
41. Toguchi M, Iraha Y, Ito J, Makino W, Azama K, Heianna J, et al. Uterine artery embolization for postpartum and postabortion hemorrhage: a retrospective analysis of complications, subsequent fertility and pregnancy outcomes. *Jpn J Radiol*. 2020;38(3):240–247. PMID: 31811462 https://dx.doi.org/10.1007/s11604-019-00907-2
42. Imafuku H, Yamada H, Morizane M, Tanimura K. Recurrence of post-partum hemorrhage in women with a history of uterine artery embolization. *J Obstet Gynaecol Res*. 2020;46(1):119–123 PMID: 31608524 https://dx.doi.org/10.1111/jog.14129
43. Saiga A, Yokota H, Higashide T, Takishima H, Omoto A, Kubota Y, et al. The Relationship Between Gelatin Sponge Preparation Methods and the Incidence of Intrauterine Synechia Following Uterine Artery Embolization for Postpartum Hemorrhage. *Cardiovasc Intervent Radiol*. 2019;42(2):195–204. PMID: 30238332 https://dx.doi.org/10.1007/s00270-018-2078-x

Received on 29.04.2022

Review completed on 26.08.2022

Accepted on 27.09.2022