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VASCULAR-INTERVENTIONAL

Endovascular management of massive post-partum haemorrhage in abnormal placental implantation deliveries

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Abstract
Objectives To retrospectively evaluate safety and efficacy of pelvic artery embolisation (PAE) in post-partum haemorrhage (PPH) in abnormal placental implantation (API) deliveries.
Methods From January 2009 to November 2013, 12 patients with API and intractable intraoperative PPH underwent PAE after caesarean delivery to control a haemorrhage (in four of these cases after hysterectomy). Arterial access was obtained prior to the delivery; PAE was performed in the obstetrics operating room by an interventional radiologist that was present with an interventional radiology (IR) team during the delivery.
Results PAE was successful in preventing bleeding and avoid hysterectomy in four cases (group A). Uterine atony and disseminated intravascular coagulation caused failure of PAE requiring hysterectomy in four patients (group B). PAE prevented bleeding post-hysterectomy in the remaining four cases (group C). Technical success (cessation of contrast extravasation on angiography or occlusion of the selected artery) was 100 %. Maternal and foetal mortality and morbidity were 0 %.
Conclusions PAE is a minimal invasive technique that may help to prevent hysterectomy and control PPH in API pregnancies without complications. Embolisation should be performed on an emergency basis. For such cases, an IR team on

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standby in the obstetrics theatre may be useful to prevent hysterectomy, blood loss and limit morbidity.

Key Points

- *Endovascular treatment is a validated technique in post-partum haemorrhage.*
- *Abnormal placental implantation is a risk factor for post-partum haemorrhage.*
- *We propose an interventional radiologist standby in the delivery room.*

Keywords Uterine Artery Embolisation · Placenta accreta · Placenta previa · Post-partum haemorrhage · Intraoperative procedures

Introduction

Post-partum haemorrhage (PPH) continues to cause significant morbidity and mortality in the Western world [1]. PPH is defined as a blood loss of more than 500 ml for vaginal delivery or more than 1,000 ml if a caesarean section is performed or as a reduction of the haematocrit higher than 10 % during the delivery [1]. Approximately 2 % of deliveries are complicated by PPH, and in 3 % maternal death occurs, due to maternal age and education (years of school attendance), previous deliveries, gestational age, uterotonic drugs and anaemia [2]. Also, referring from another facility has shown to correlate to severe maternal outcomes [2]. Moreover, PPH is linked with severe morbidity: disseminated intravascular coagulation (DIC), respiratory distress syndrome, Sheehan's syndrome and hypovolemic shock may occur [3]. The main causes of obstetric haemorrhage are: uterine atony (UA); placental abnormalities; retained placental tissue; vessel malformations; ruptured uterus; laceration of the perineum, vagina or cervix; non-correctable coagulopathy [4].

Abnormal placentation occurs in one of 540–70,000 deliveries (mean of 1/7,000) [5]. However, these numbers are increasing due to the rise caesarean deliveries. APIs are burdened by a massive PPH, more than other deliveries, with a blood loss that might exceed 5,000 ml [6]. Abnormal placental implantation (API) includes both abnormal placental attachment in the lower uterine segment, overlying or near the anatomical internal os of the uterus (placenta previa) and abnormal uterine wall invasion (placenta accreta). According to the depth of invasion we may recognise: placenta accreta (limited to a superficial invasion of basalis layer), increta (myometrium invasion) and percreta (serosa or adjacent pelvic organs invasion).

The main risk factors for placental abnormalities are previous damage or fibrosis of the myometrium and endometrium, such as previous caesarean sections or uterine trauma (artificial delivery, curettage, etc.), maternal age older than 35 years or previous multiple births [7].

PPH treatment includes conservative or surgical therapy. Surgical treatment consists in hysterectomy or uterine vessels ligation and is associated with a significant risk of bleeding and loss of fertility. Conservative treatments consists in the administration of drugs that increase the tonicity of the uterus, use of packing gauzes, haemostatic square sutures, B-Lynch suture, insertion of Bakry balloon, and arterial embolisation [3]. The success rates for controlling PPH are for balloon tamponade and for pelvic devascularisation (including uterine or internal iliac artery ligation) in the range of 85 % and for arterial embolisation in the range of 90 % [1, 5]. The identification of patients with API through imaging techniques [8, 9] is of paramount importance for the prevention and treatment of this condition. The purpose of this study is to report the experience with our multidisciplinary protocol in the management of massive PPH due to API and to evaluate the clinical outcome. The protocol adopted implies an interventional radiologist standby in the operating room in order to allow a prompt embolisation in case of massive haemorrhage in haemodynamically unstable patients, who cannot be transferred to the angiography suite.

Materials and methods

We collected data for this retrospective study from the clinical records of our institution, where a mean of 2,000 deliveries are performed every year. The study protocol was approved by our Institutional Review Board. Inclusion criteria were (1) presence of API that required potential vascular intervention and (2) intractable intraoperative PPH that required immediate embolisation in the obstetrics operating room.

A specific protocol was developed in our institution to manage API deliveries. The protocol provides that once an API pregnancy is identified by the gynaecologist, the interventional radiology unit may be alerted. The obstetric operating room is prepared for both surgical and embolisation procedures. The interventional radiologist may be standing by during delivery in the operating room, so as to be prompt to attend PAE.

Between January 2009 and November 2013, a total of 76 patients with imaging-confirmed diagnosis (magnetic resonance imaging [MRI] or ultrasound) of API were managed with our protocol for API deliveries. A 5-F introducer sheath was positioned in the common femoral artery in the angiographic suite at least 2 h before prior to the delivery [8]. An informed consent for embolisation was obtained from all the patients at this stage. A portable angiographic (OEC-9800; GE Healthcare, Milwaukee, WI, USA) system and an emergency angiographic tray were transferred to the obstetrics operating room and the interventional radiologist was on standby. Pelvic artery embolisations (PAEs) were performed by one of three

interventional radiologists with 10–30 years of clinical experience, and at least 5 years of experience of our protocol.

Twelve of these 76 patients, experienced an intractable intraoperative PPH after caesarean delivery and underwent PAE to control a massive haemorrhage were enrolled in this study. Patient's characteristics and risk factors are shown in Table 1 and pre- and post-procedure information in Table 2.

The indication to PAE was the development a severe PPH not responding to conservative manoeuvres, causing a life-threatening blood loss with hemodynamic consequences, needing unusual therapy [10]. The decision on whether to proceed to PAE before the hysterectomy or not was decided by the obstetrician surgeon for each individual case, after a prompt consult with the anaesthesiologist and the interventional radiologist in the operating room. Usually, patients were initially treated with uterotonic drugs and obstetric manoeuvres including: massage of the uterus, packing gauze and manual exploration of the uterine cavity. Once conservative manoeuvres failed to control haemorrhage most patients underwent balloon tamponade and suturing (B-Lynch and squared sutures). If bleeding was not controlled, decision for hysterectomy or PAE was made according to operator's preference; PAE was performed for patients that were haemodynamically unstable (systolic blood pressure lower than 90 mm/Hg and heart rate greater than 120 beats/min despite adequate medical management or the need for continuous administration of a vasopressor). Initially, pelvic angiograms were obtained to identify the uterine artery and the other potential sites of bleeding from the pelvic arteries (Fig. 1). Selective catheterisations were performed using 4- to 5-F catheters with different shapes (Cobra, RIM or RC2 catheter; Cordis, Miami, FL, USA) and an 0.035" hydrophilic guide wire (Glidewire; Terumo Europe, Leuven, Belgium). Embolisation was performed with the use of gelatine sponge particles (Spongostan; Ferrosan, Søborg, Denmark) and 4- to 10-mm coils (MReye; Cook, Bloomington, IN, USA).

In all cases, the embolisation was performed on at least one uterine or anterior division of the internal iliac artery; additional arteries were embolised only when identified as the bleeding foci. Technical success was defined as angiographically successful target vessel occlusion after embolisation. Embolisation was either performed according to contrast extravasation or in the case of no visible extravasation, empirically as previously described [11] and following the indication of the obstetric surgeon that observing the surgical field guided the interventional radiologist to embolise the right or left side.

The parameters that were analysed were: number of embolised vessels, type of embolic agents used, intraoperative blood loss and supportive fluids (blood, crystalloids and colloids as plasma expander, saline solution, potassium chloride, lactated Ringer's, albumin) used, blood haemoglobin before and after the procedures, complications associated with the PAE procedure. Data were expressed as mean±standard deviation (SD), fractions, and percentages. The Mann-Whitney *U* test was used to test for significant differences between continuous variables. Statistical analysis was performed using MedCalc software (version MedCalc 12.5.0.0; MedCalc Software, Ostend, Belgium). Clinical success was defined as the ability to avoid hysterectomy applying the interventional standby protocol.

Complications from procedures were classified according to guidelines established by the Society of Interventional Radiology (SIR) Standards of Practice Committee [12].

Table 1 Patients' characteristics

Patient number	Age	Previous pregnancies	Miscarriage	Voluntary pregnancy interruption	Curettage	Previous caesarean deliveries	Previous vaginal deliveries	Endometriosis	Primiparous	API	Diagnosis API pre-post delivery (US/MRI)	
1	36	1	-	1	-	-	-	No	Yes	Previa	US + MRI	Group
2	36	3	1	-	1	2	-	No	No	Previa	US	A
3	37	2	1	-	1	1	-	No	No	Previa	US + MRI	
4	33	6	-	2	-	-	4	No	No	Previa	US	
5	31	4	-	3	-	1	-	No	No	Accreta	US + MRI	Group
6	32	2	-	1	-	1	-	No	No	Previa	US	B
7	41	1	1	-	-	-	-	No	Yes	Previa	US + MRI	
8	36	-	-	-	-	-	-	Yes	Yes (twin)	Previa	US	
9	40	4	4	-	2	-	-	No	Yes (twin)	Accreta	US	Group
10	38	2	1	-	-	1	-	No	No	Accreta	US	C
11	38	2	1	-	-	1	-	No	No	Percreta	US + MRI	
12	30	4	-	-	2	1	1	No	No	Increta	US + MRI	

API abnormal placental implantation, *US* ultrasound, *MRI* magnetic resonance imaging

Table 2 Preoperative and postoperative procedures

Patient number	Delivery	Uterotonic drugs	Colloids/ cristalloids	Blood/ haemoderivative	Obstetrical procedures	Intraop. estimated blood loss	WBC rise	Fever	Day/ night shift	
1	Scheduled	Oxytocin	1,200	400	Massage of uterus, packing gauze Bakry balloon, B-Lynch	1,400	Yes	No	D	Group A
2	Scheduled	Oxytocin	1,000	700	Massage of uterus, packing gauze	1,800	Yes	Yes	D	
3	Scheduled	Carbetocin	1,500	300	Massage of uterus, Bakry balloon, Square sutures	1,200	No	Yes	D	
4	Scheduled	Oxytocin	4,000	1,800	Massage of uterus, packing gauze	1,500	Yes	No	D	
5	Scheduled	Carbetocin	5,300	1,200	Packing gauze	5,000	No	Yes	D	Group B
6	Scheduled	Oxytocin	3,500	1,350	Massage of uterus	1,500	Yes	No	D	
7	Scheduled	Carbetocin, Methylergometrine, Sulprostone	6,100	1,650	Massage of uterus, Bakry balloon, B-Lynch, Square sutures	2,770	No	No	D	
8	Scheduled	Carbetocin , Methylergometrine, Sulprostone	4,800	950	Massage of uterus, packing gauze, Bakry balloon	1,800	Yes	Yes	D	
9	Scheduled	Carbetocin , Duratocine	1,500	600	packing gauze , Bakry balloon	3,000	No	Yes	D	Group C
10	Scheduled	Carbetocin	5,950	7,600	Bakry balloon, B-Lynch, Square sutures	2,700	Yes	No	D	
11	Urgency	Carbetocin	5,800	3,700	Packing gauze	4,200	Yes	No	D	
12	Scheduled	Oxytocin	3,600	620	Packing gauze	1,800	Yes	No	D	

D day

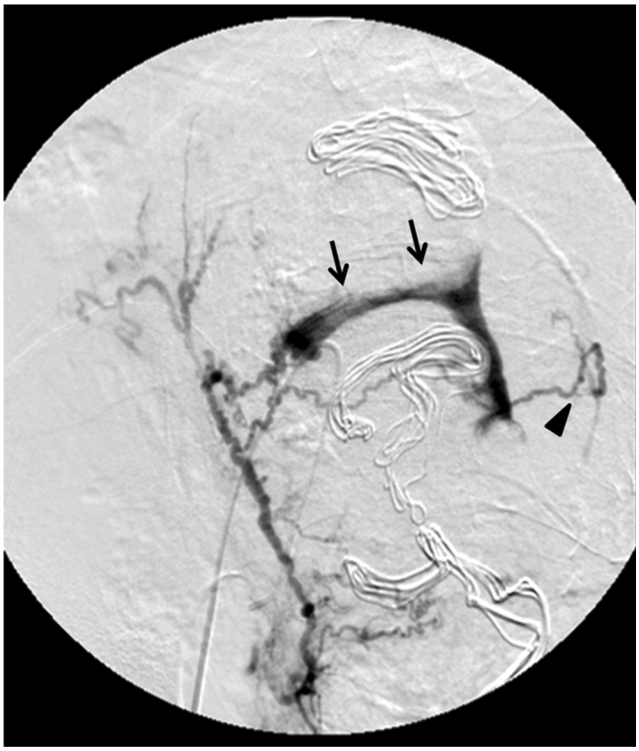

Fig. 1 Massive haemorrhage. Patient 5, right uterine catheterisation showing a massive contrast extravasation (*arrow*) from the body of uterus; the left uterine artery is visible, suggesting bleeding also from this side (*black arrowhead*)

Results

Seven patients had placenta previa, three placenta accreta, one placenta increta and one placenta percreta were included in the study. The mean intraoperative blood loss was 2,389 ml. The mean blood haemoglobin (Hb) before the delivery was 10.77 g/dl and dropped to 6.27 g/dl during the delivery. Supportive therapy consisted in a mean infusion of 3,688 ml of crystalloid and colloids, and 1,739 ml of blood transfusion; uterotonic drugs were given to all patients. A statistically significant difference (p value=0.0183) was detected between the mean estimated intraoperative blood loss in placenta previa (1,710±513 ml) and placenta accreta (3,340±1,264 ml). No statistically significant difference was detected among blood or fluid infusion in the two subgroups. Results are shown in detail in Table 3.

In 8/12 patients contrast extravasation was confirmed, indicating active haemorrhage. In four of the 12 cases the PAE was performed unilaterally and a total of 24 arteries were embolised: 14 uterine arteries, 1 inferior epigastric artery and 9 anterior division of the internal iliac arteries (Table 4). We used gelatine sponges in all cases, injecting piecemeal with cutting sponges; coils were also used in eight cases.

PAE was able to control the haemorrhage in four cases, avoiding hysterectomy (group A; Table 1). In four cases the PAE was not able to control haemorrhage and to prevent the hysterectomy (group B), and in one of these a second embolisation session was necessary to control the haemorrhage (patient 8). Patient 8, as well as patient 7, despite a successful first embolisation of left uterine artery, experienced a UA and underwent hysterectomy. A persistent bleeding was identified in the Pouch of Douglas of patient 8 after hysterectomy, probably due to a severe endometriosis, and a second embolisation of anterior division of the internal iliac arteries was necessary after 30 min from the first embolisation. In four patients (group C) the initial decision was to undergo the

Table 3 Results

Haemoglobin (mean)			
Before delivery	10.77 g/dl (min 8.5-max 12)		
Before PAE and hysterectomy	6.27 g/dl (min 4.8-max 8.1)		
24 h after the procedures	10.05 g/dl (min 7.7-max 12.7)		
72 h after the procedures	9.9 g/d (min 8.3-max 11.9)		
Colloid/crystalloid infusion (mean)	3,688 ml (min 1,500-max 6,100)		
Blood infusion (mean)	1,739 ml (min 300-max 3,700)		
Intraoperative blood loss (mean)	2,389 ml (min 1,200-max 5,000)		
	Previa (n=7)	Accreta (n=5)	p value
Blood infusion (mean)	1,021±595 ml	2,722±2,999 ml	0.4649
Colloid/crystalloid infusion (mean)	3,157±1,975 ml	4,430±1,885 ml	0.2556
Intraoperative blood loss (mean)	1,710±513 ml	3,340±1,264 ml	0.0183
WBC increase	8 patients		
Fever	5 patients		
Elapsed time (delivery-menses)	4 months		
Procedure time	38 min (min 19-max 61)		

WBC white blood cells, *PAE* pelvic artery embolisation

Table 4 PAE procedure details

Patient number	Coils	Spongostan	Angiographic contrast pooling	Embolisation of uterine artery	Embolisation of anterior division of internal iliac artery	Embolisation of epigastic artery	Necessity of hysterectomy (pre or post embolisation)	
1	No	Yes	Yes	R and L			No	Group
2	No	Yes	Yes	R			No	A
3	Yes	Yes	No	R [a]			No	
4	Yes	Yes	Yes	R [a] and L [a]			No	
5	Yes	Yes	No	R [a]			Yes: post-emb	Group
6	No	Yes	No	R and L	R and L		Yes: post-emb	B
7	Yes	Yes	Yes	L [a]	R		Yes: post-emb	
8	Yes	Yes	Yes	L	R [a] and L [a]		Yes: post-emb (PAE performed also after hysterectomy)	
9	No	Yes	Yes		R and L		Yes: pre-emb	Group
10	Yes	Yes	Yes		R [a] and L [a]	R [a]	Yes: pre-emb	C
11	Yes	Yes	No	R [a] and L [a]			Yes: pre-emb	
12	Yes	Yes	Yes	L [a]			Yes: pre-emb	

R right, *L* left

[a] Embolised by coil

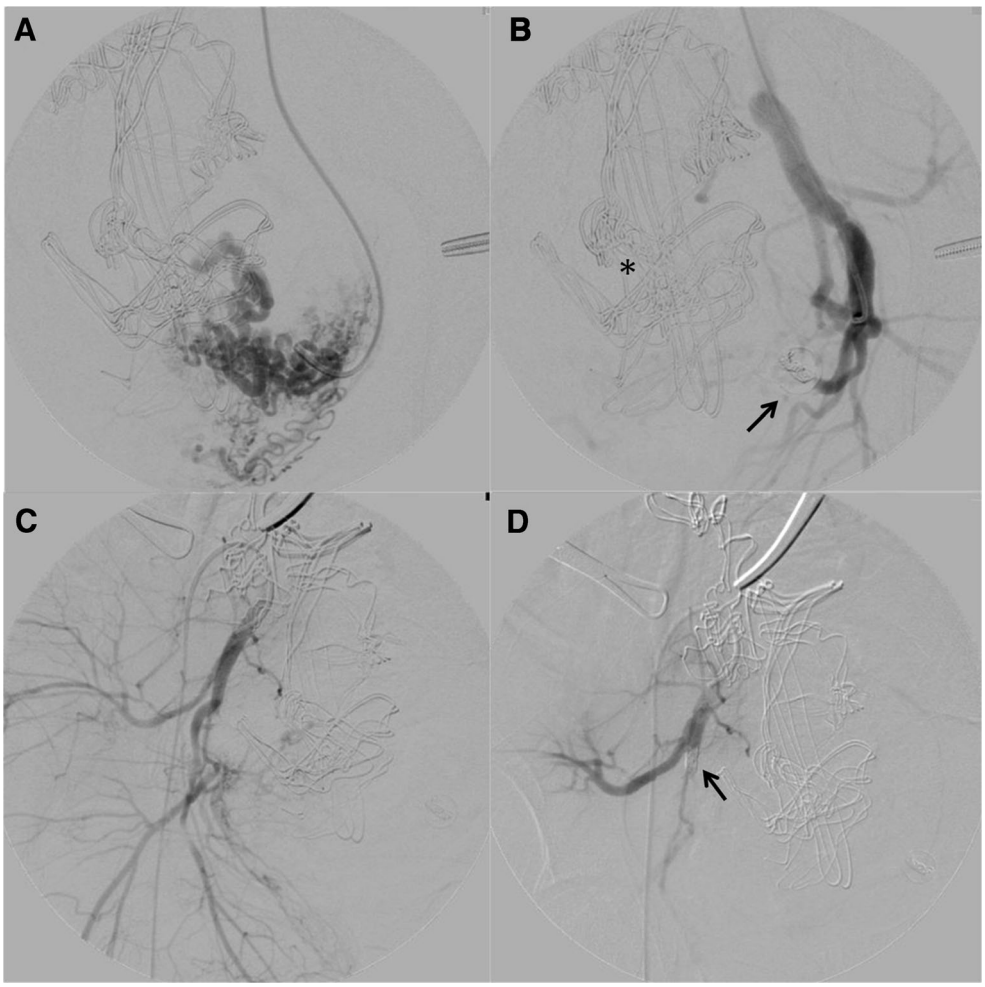

Fig. 2 Bilateral uterine artery coiling. Patient 11: selective catheterisation of the left uterine artery and angiography post subtotal hysterectomy without evidence of contrast extravasation (**a**); super-selective catheterisation with microcatheter of the left uterine artery and release of coils (*arrow*); the angiogram shows the complete occlusion of the uterine artery; note the intra-abdominal surgical gauzes that hinder the angiographic visualisation (*asterisk*) (**b**); right internal iliac catheterism with no evidence of bleeding (**c**); due to a persistent haemorrhage the right uterine artery was embolised with absorbable gelatine sponge and coils (*arrow*) (**d**)

hysterectomy; however, bleeding was not controlled, therefore PAE was retained as the last resort for haemostasis. In these patients the radiologist and the surgeon, in accord with the anaesthesiologist, decided to attempt the hysterectomy immediately, thus because of the sudden onset of haemorrhage and the profuse blood loss. In patient 11 a persistent bleeding was observed from cervical arteries; after that, a subtotal hysterectomy was necessary because a uterine fibroid hampered clamping the uterine arteries, so PAE was performed on the cervical uterine arteries (Fig. 2). Even patient 12 with an increta placenta developed a bleeding from the cervix arteries after a subtotal hysterectomy requiring PAE. In patient 10 the hysterectomy was immediately performed because of a massive bleeding of vescico-uterine pouch; then an adnexal bleeding was observed causing DIC, so embolisation of the anterior division of internal iliac arteries and of the right inferior epigastric (Fig. 3) were performed.

The technical success rate of embolisation (among all groups) was of 100 %, accompanied by a clinical success of 33 %, defined as the ability to avoid hysterectomy applying the interventional standby protocol. Foetal and maternal mortality was of 0 %. Twenty-four and 72 h after the procedures the mean Hb improved to 10.05 and 9.9 g/dl, respectively. The embolisation procedure lasted an average of 38 min (range, 19-61 min), with a mean fluoroscopy time of 11 min. Eight patients had a rise in white blood cells and five had fever after the procedure. No transient or persistent ovarian failure was noted at follow-up. Regarding the SIR classification [12] no minor or major complications due to embolisation, were noted after the procedure. All patients who did not undergo hysterectomy experienced regular menses at a mean of 4 months after delivery, but none had new pregnancies.

Discussion

The early identification of placental abnormalities is essential to avoid risk of mortality and morbidity associated with delivery [2]. In all patients of our series the diagnosis was suspected by symptoms and risk factors; abnormalities were identified by ultrasound and MRI and confirmed by histopathology analysis. Surgical hysterectomy is still the first choice treatment of API deliveries complicated by PPH [13]. However, PAE in PPH showed promising results in several studies, with good bleeding control and few complications [13, 14]. PAE is a suitable alternative to hysterectomy because it allows a better control of bleeding, blocking also small haemorrhage foci, and gives the possibility of preserving fertility, avoiding major surgery and general anaesthesia.

The role of PAE in API deliveries remains unclear due to a high risk of failure (up to 50 %) [4]; multiple risk factors are involved, such as myometrial injury during vaginal delivery,

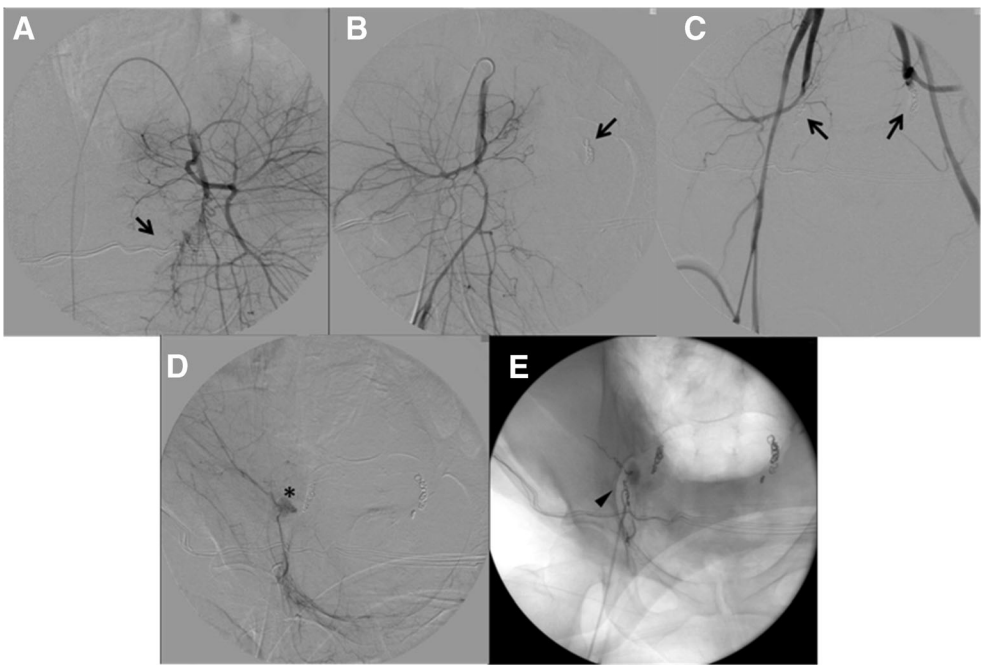

Fig. 3 Coiling of right inferior epigastric and internal iliac arteries. Patient 10: selective catheterisation of left internal iliac artery showing a faint contrast pooling in the cervical branches of uterine artery (head) (**a**); angiogram of the right internal iliac artery; note the coiling of the anterior branch of the anterior division of the left internal iliac artery (*arrow*) (**b**); angiogram with pig tail in the aorta showing occlusion of the bilateral anterior division of internal iliac arteries (*arrows*); note the reduced diameter of right external iliac artery (spasm) due to persistent haemorrhage (**c**); selective catheterisation of the right inferior epigastric artery with angiogram showing contrast extravasation (*asterisk*) (**d**); coiling in the right inferior epigastric artery (*arrowhead*) and in the anterior branch of internal iliac arteries (**e**)

placental removal, DIC, incomplete embolisation of the arteries due to an insufficient ability in identifying bleeding foci [15].

Despite the development of new tools and catheterisation techniques, the improvement of supportive and conservative care procedures, few articles have reported successful treatment of PPH in API deliveries with success rates up to 90 % [16, 17]. However, in the aforementioned reports, patients did not have massive bleeding; in fact, the authors were able to transfer the patients in the angiographic suite. In our series, all patients had a massive haemorrhage and haemodynamic instability not responding to supportive care and other conservative manoeuvres.

In group C, PAE was performed for a persistent haemorrhage after hysterectomy, achieving technical success and bleeding control. The persisting bleeding probably was due to the onset of DIC and caused a worsening of haemodynamic parameters and patients' conditions. Moreover, finding the haemorrhagic focus and performing vascular ligations of small pedicles after hysterectomy in such patients could be extremely difficult for the surgeon [18]. All these causes of persistent bleeding after hysterectomy support the usefulness of PAE after hysterectomy to reduce maternal mortality, even if reports in the literature are still few.

In group B, PAE allowed a safer and easier hysterectomy to be performed, although it was clinically unsuccessful: reducing bleeding, making the field bloodless, improving the possibility of the surgeon to identify the pelvic structures, as well as aiding to avoid DIC. Blood loss and the type of placentation abnormality seem to correlate with the possibility of preserving the uterus. In fact, it is interesting to note that all the patients of group C and one of group B had a placenta accreta and were not able to avoid hysterectomy. All the patients of group A suffered from placenta previa and were successfully managed with PAE only. Moreover, placental accretism was associated with a significantly higher estimated intraoperative blood loss than placenta previa (Table 3).

UA and DIC are the most threatening PPH complications that could affect the success of embolisation. In case of UA, the absence of myometrial contraction does not allow the occlusion of spiral arteries of endometrium; compressive sutures and Bakry balloon are often not sufficient to compress arteries of the fundus of uterus, and the PAE cannot stop bleeding from all foci, even if there is no evidence of active pooling. Moreover, vascular spasm in the shock or impending shock due to massive blood loss could cause PAE failure because it hampers the selective vascular catheterisation and the delivery of embolic agents to the bleeding focus [17]. Contrast pooling was visible in eight cases (67 %); in the remaining four patients (33 %), no active contrast medium extravasation was visible, probably due to vascular spasm or hypotension. In these cases, we opted for a unilateral or bilateral (performed in 7 of 12 patients; 58 %) embolisation of uterine artery or anterior division of internal iliac artery according to the obstetric surgeon indications that are essential to identify the bleeding site; observing the surgical field, the surgeon could guide the interventional radiologist to embolise the right or left side.

In only one case did we find an unusual site of bleeding (patient 10) from the right inferior epigastric artery. In this case probably the presence of CID associated with a traumatism by surgical retractor caused the artery damage. Another potential source of bleeding is the ovarian artery. The interventional radiologist should be aware of this possibility, especially in the case of persistent bleeding after uterine or anterior division branch of internal iliac artery embolisation and a juxtarenal arteriography should be performed to exclude blood supply from these arteries [18, 19].

Many embolisation agents were described as useful agents performing PAE and other uro-genital and pelvic interventional procedures [20, 21]. Absorbable gelatine sponge is the embolic material of choice because of its ease of delivery and duration of effect [22]; nevertheless, it might be insufficient due to hypervascularisation [16, 17]. Some authors recommend the use of absorbable sponge as first choice absorbable embolic agent and PVA in case of failure with sponge alone [23]. In all cases, we attempted to achieve success with absorbable gelatine sponge only (Fig. 4). Since the speed of stopping bleeding is paramount in patients with such a massive acute bleeding and haemodynamic instability, we associated metallic coils in 67 % of patients to achieve a prompt technical success. In patients in whom hysterectomy would be avoided (groups A and B) coils were used as the last chance to achieve procedure success. We preferred to avoid small-sized particles because they could cause necrosis and distal occlusions due to permanent ischaemia. The use of PVA (size range from 150 to 1,200 μm) particles is not recommended as they may cause uterine necrosis. Moreover, micro-particles may pass through arteriovenous shuntings due to accretism and cause distal dissemination [24]. Other authors recommend NBCA glue (*N*-butyl cyanoacrylate) as embolic agent, to have a definitive occlusion of arteries; hence, NBCA should be considered for definitive devascularisation as well as coils. This embolic agent should be used particularly when the bleeding derives from pseudoaneurysm or lacerated arteries because has demonstrated effectiveness in such indications [10, 25]. In our series, no patient underwent ovarian insufficiency or uterine/bladder necrosis. Some authors suggest the use of balloons catheters positioned in the common iliac arteries before the procedure, to control bleeding after delivery [26]. With this procedure the ischaemic risk increases; indeed some authors reported a lower-limbs ischaemia [26].

Prophylactic balloon occlusion of the pelvic arteries was proposed by several authors in the management of PPH, especially in the API subgroup and showed to be an effective technique [27, 28]. Balloons are usually placed before the

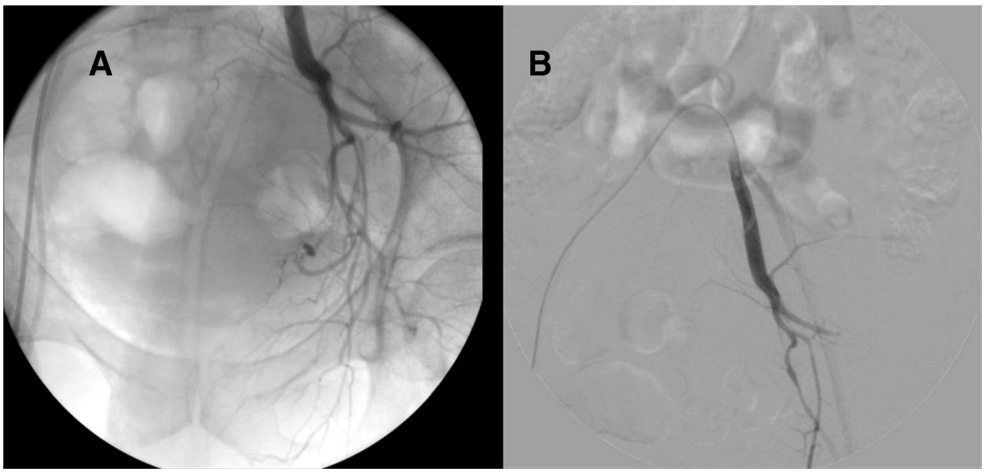

Fig. 4 Embolisation with absorbable sponge. Patient 1: left internal iliac artery angiogram before (**a**), and after (**b**) embolisation with an absorbable gelatine sponge showing complete occlusion of the anterior division; PAE avoided hysterectomy in this patient

delivery in the iliac common artery, in the internal iliac artery or in its anterior division [27, 28]; some authors reported a temporary occlusion of the abdominal aorta distally to renal arteries [29]. Evidence suggest that positioning the balloon in the common iliac arteries should be preferred in the elective setting [27], while infrarenal aortic occlusion should be reserved for the acute setting, which proved safe even when occlusion lasted up to 80 min [29]. Balloon occlusion effectiveness did not show to be more effective than PAE [1, 5]; moreover, it provides preventive treatment of all the patients with a consequent increase in costs and risks.

Patient transfer from the obstetric suite to the angiographic one could be an issue because it variably increases morbidity and mortality [30], and, above all, is unsafe in haemodynamically unstable patients. Several complications could occur during transfer, such as cardio-respiratory events or equipment failure. In fact, the American College of Obstetricians and Gynecologists (ACOG) guidelines recommended the use of embolisation only in haemodynamically stable patients when the rate of loss is not excessive [1]. However, the possibility of performing embolic procedures without patient transfer is becoming popular in many cardiovascular or neurovascular [31, 32] as well as in obstetric procedures [33].

Prophylactic catheterisation with intraoperative embolisation, compared with emergency vascular access and embolisation in the angiography room allows a significant reduction of the delay between the onset of bleeding and the embolotherapy. In our series the mean blood loss was considerably less with respect to the value reported in the literature (2,389 ml vs 4,500 ml) [6], although hysterectomy cannot be avoided in all cases. According to the literature, accretism has a statistically significant influence on the estimated blood loss only [6]. Some authors suggest considering PAE or surgical ligation of uterine arteries within 30-60 min from failure of other approaches [34]. The portable angiographic system and the emergency angiographic tray allows operation on haemodynamically unstable patients, not only stable ones, because of the impossibility to move these high-risk patients to the angiographic suite or to another hospital [35].

Maternal fertility can be preserved after uterine embolisation and multiple new pregnancies have been reported after embolisation [36]. The hysterectomy rate after caesarean delivery, reported in the literature, can vary from 5 % [37], among placenta previa, up to 23-35 % in placenta accreta [38]. Only the 10 % (eight patients; groups B and C) of the 76 patients managed with our protocol required hysterectomy. In our series, 4 of 12 patients avoided hysterectomy, resulting in a clinical success of 33 %; none of these four patients, who did not undergo a hysterectomy, had a new pregnancy at a mean follow-up time of 3.6 years, but all of them experienced regular cycles. Moreover, one patient underwent a salpingectomy, due to the patient's wish for sterilisation. No minor or major complications due to embolisation were noted. Caesarean delivery is usually accompanied by increased WBC and fever, and did not cause any difference in patients' care, so we did not consider these signs as a procedure complication.

This study has several limitations: the small number of patients enrolled at one institution; the retrospective nature of the study. The small number of patients does not allow a proper comparison with other protocols, thereby preventing to understand the true value of IR standby. Moreover, performing PAE in the obstetric suite with the portable angiographic C-arm is burdened by some technical limitations. Firstly, there are many surgical tools in the field of view; secondly, compared with the angiographic suite, the absence of the mobile table and the reduced field of view do not allow an optimal visualisation of the operating field.

Applying our protocol, joined by the obstetrical and radiological department, foreseeing the intervention in the operating room of an interventional radiologist with mobile equipment, maternal and foetal mortality of massive PPH in API

deliveries was reduced to zero. Moreover, hysterectomy was avoided in four patients suffering from placenta previa, preserving their menses and potentially their fertility.

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