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The role of endovascular treatment of pelvic fracture bleeding in emergency settings

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Abstract

Purpose To evaluate the role of endovascular treatment for controlling haemorrhage in haemodynamically unstable patients with pelvic bone fractures and to relate clinical efficacy to pre-procedural variables.

Materials and Methods From March 2009 through April 2013, 168 patients with major pelvic trauma associated with high-flow haemorrhage were referred to our emergency department and were retrospectively reviewed. Pelvic arteries involved were one or more per patient. Embolisation was performed using various materials (micro-coils, Spongostan, plug, glue, covered stent), and technical success, complications, treatment success, clinical efficacy, rebleeding, and mortality rates were assessed. Factors influencing clinical efficacy were also evaluated.

Results The technical success rate was 100 %; no complications occurred during the procedures. Treatment was successful in 94.6 % cases, and clinical efficacy was 85.7 %. Three patients had to undergo a second arteriography due to recurrent haemorrhage. Fifteen patients died. Pre-embolisation transfusion demand was significantly associated with clinical efficacy.

Conclusions Percutaneous embolisation of pelvic bleeding may be considered a safe, effective, and minimally invasive therapeutic option. As haemodynamic stability is the first objective with traumatic haemorrhagic patient, arterial embolisation can assume a primary role. On the basis of our results, pre-procedural transfusion status may be considered a prognostic factor.

Key Points

- *The series presented is one of the largest in a single centre.*
- *Arterial embolisation is a life-saving procedure in patients with pelvic haemorrhage.*
- *In pelvic traumas associated with haemorrhage, prognosis is dependent upon prompt treatment.*
- *Transfusion status is significantly related to clinical efficacy.*

Keywords Pelvic arterial bleeding · Endovascular treatment · Emergency treatment · Life-saving embolisation · Pelvic fractures

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Introduction

Arterial haemorrhage is one of the most serious problems associated with pelvic fractures, and it remains the leading cause of death attributable to pelvic fracture [1]. Common mechanisms for all types of pelvic fractures include motor vehicle accidents (57 %), pedestrians hit by motor vehicles (18 %), motorcycle accidents (9 %), falls (9 %), crush injuries (4 %) and sports mechanisms (3 %) [2], and they range in severity from low-energy stable fractures to high-energy injuries with unstable fracture patterns.

The rate of mortality among patients with all types of pelvic fracture is approximately 16 % [2]. Focusing only on patients with closed pelvic fractures and haemodynamic instability, the mortality rate rises to approximately 27 %, and further increases to approximately 55 % for open pelvic fractures. These rates remain the greatest of any skeletal injury, with haemorrhage the major reversible contribution to mortality in around 42 % of pelvic trauma patients. In patients who die from haemorrhage, 62 % of deaths are due to pelvic haemorrhage and 38 % to associated external intrathoracic and intra-abdominal haemorrhage sources [2]. The origin of post-traumatic pelvic bleeding can be arterial, venous, or bone-related. Arterial injuries are the most severe, and are predominantly observed in anterior–posterior pelvic compression type 2 and 3 injuries, type 3 lateral compression injuries, vertical compression injuries, and combined injury mechanisms. The instability of pelvic bone fractures is a good predictor of the need for haemostatic embolisation, and prompt, rapid orthopaedic fixation [3].

Contrast-enhanced CT has been reported to be an accurate non-invasive technique for identifying ongoing arterial haemorrhage in patients with pelvic fractures [2]. Transcatheter angiographic embolisation (TAE) and external fixation have been applied to control haemorrhage. As reported in several studies, TAE in particular may be a rapid, safe, and effective technique for treatment of haemorrhage caused by pelvic fractures [4]. Any site of contrast extravasation, false aneurysm, occlusion of a main stem artery, or vasospasm with complete vessel occlusion should be embolised.

The purpose of this study was to evaluate the role of endovascular treatment for controlling haemorrhage in haemodynamically unstable patients with pelvic bone fractures and to relate clinical efficacy to pre-procedural variables.

Material and methods

Written informed consent was obtained from patients whenever possible. The study was performed in accordance with the Declaration of Helsinki, the International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH) Guideline for Good Clinical Practice, and relevant local laws and regulations. Independent data and safety monitoring committees were established to monitor efficacy and safety data.

Patients

From March 2009 through April 2013, 168 patients (112 men and 56 women, average age 58 years, range 19–95 years) with major pelvic trauma associated with high-flow haemorrhage were referred to our emergency department. On the basis of multidisciplinary evaluation in accordance with literature data [5,6], 105 patients had previously undergone external fixation; an orthopaedic external fixator was used for 47 patients, while in 61 patients a T-POD was used (Trek-Tech, Portland, OR, USA). The T-POD is a pelvic circumferential compression device that has been shown to provide pelvic stability and closely re-approximate the symphyseal diastasis.

A total of 101 patients were victims of car or motorbike accidents, and 47 had suffered falls from great heights; the remaining were involved in pedestrian or bicycle accidents (15 patients) or falls on stairs (5 patients).

All patients arriving at our trauma centre were evaluated by the emergency team, and their Revised Trauma Score (RTS) was calculated. The RTS is a scoring system that utilizes a combination of the results from three data sets: Glasgow Coma Scale (GCS), systolic blood pressure (SBP), and respiratory rate (RR) (Tables 1, 2, and 3).

All of the results can be quickly assessed. The range of scores is 0–12. With the simple triage and rapid treatment (START) method, a patient with an RTS score of 12 is labelled delayed, 11 is urgent, and 10–3 is immediate. The lowest possible label is morgue, which is given to seriously injured people with an RTS score of 3 or lower. These people should not receive certain care because they are unlikely to survive.

In this study, RTS was 12 (delayed) in 24 cases, 11 (urgent) in 80 cases, 10 (immediate) in 32 cases, and 6 (immediate) in 32 cases. All cases are summarised in Table 4.

Baseline imaging

All examinations were performed with a 64-slice CT system (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan), with the following parameters: beam collimation 64×0.5 mm, gantry rotation time 0.5 s, tube voltage 120 kV, automatic exposure control (AEC, standard deviation 12), field of view (FOV) L, pitch factor (PF) 0.8, slice thickness 1.0 mm, reconstruction interval 0.8 mm. All examinations were performed before and after IV injection of 100–120 ml of iodinated contrast material (iomeprol 350 mgI/ml, Iomeron, Bracco Imaging, Milan, Italy), at an injection rate of 3.5 ml/s, followed by a saline chaser of 40 ml at the same rate, using a dual-head injector (Stellant D, Medrad Inc., Warrendale, PA, USA), with arterial, venous (delay 90 s), and late-phase acquisitions (delay 5 min).

Table 1 Glasgow coma scale (GCS)

GCS	Points
15–13	4
12–9	3
8–6	2
5–4	1
3	0

Table 2 Systolic blood pressure (SBP)

SBP (mmHg)	Points
>89	4
76–89	3
50-75	2
1–49	1
0	0

Haemorrhage was defined as free extravasation of contrast media (blush) at CT imaging; false aneurysm was defined as an encapsulated hematoma communicating with a ruptured wall of a vessel and large vessel occlusion interpreted as interruption of the blood flow.

Pretreatment workup

Pretreatment evaluation was completed using a preliminary angiographic study (Allura Xper FD20C, Philips Healthcare, Best, Netherlands), which was carried out at the time of the operative procedure. All procedures were performed in the angiographic suite under anaesthesia. The patients received oxygen during the procedures and continuous monitoring of heart rate, electrocardiographic tracing, oxygen saturation, and respiratory rate; blood pressure was measured continuously with arterial monitoring.

The procedures were performed percutaneously through common femoral artery puncture under local anaesthesia (10 ml of mepivacaine 2 %), where a 5 F sheath (Cordis Corporation; Miami, FL, USA) was placed.

In some cases, a first panoramic angiogram was obtained on the aortoiliac region with placement of a 5 F pigtail catheter, and administration of contrast media was performed at a rate of 15ml/s. Selective study of a region of interest (ROI) was performed using a cobra, multipurpose, or vertebral catheter, with injection of a total of 12–15 ml of contrast media at a flow rate of 3 ml/s. Selective arteriography was based on CT and midstream aortography findings. The bleeding site was diagnosed by direct visualization of contrast extravasation or vascular arrest.

Table 3 Respiratory rate (RR)

RR (breaths/min)	Points
10–29	4
>29	3
6-9	2
1–5	1
0	0

Table 4 Revised trauma score (RTS)

Number of patients	GCS	SBP	RR	RTS
24	4	4	4	12
38	4	4	3	11
23	3	4	4	11
19	4	3	4	11
24	4	2	4	10
8	3	4	3	10
16	0	4	2	6
4	2	4	0	6
12	3	2	1	6

GCS Glasgow Coma Scale, *RR* respiratory rate, *SBP* systolic blood pressure

Lesions

Pretreatment DSA detected the source of bleeding in 100 % of cases; findings of DSA were compared with those of CT, and an exact correlation was found for each patient. Arterial injuries involved the following vessels: superior gluteal artery (n=55), lateral sacral artery (n=27), internal pudendal artery (n=44), lumbar arteries (n=19), common femoral artery (n=1), external iliac artery (n=1), inferior gluteal artery (n=10), and obturator artery (n=29).

Pelvic fractures

All pelvic fractures were scheduled according to Tile classification [7], in which injuries are graded according to the stability of the pelvic ring and the integrity of the posterior sacroiliac complex. The classification begins with minor complications, type A fractures, with no major instability of the posterior ring. Type B fractures are partially stable. They may have anterior displacement through the symphysis and/or pubic branches but no vertical or posterior displacement other than that allowed by rotation of the hemipelvis, usually less than 1 cm. Type C fractures are unstable. These fractures are always caused by severe trauma such as a crushing injury, motor vehicle crash, or a fall from a great height. This injury is characterised by complete disruption of the posterior SI complex, involving vertical shear forces. This type of fracture can involve one or both sides of the pelvis [7]. In the present study, 34 cases were a Tile class A, 55 were class B1 (five of them not associated with bone fracture but only with unilateral partial disruption of the posterior arch and external rotation), 24 were B2, 1 was B3, and 54 were class C (Table 5).

Associated lesions

Pretreatment X-ray and CT examinations showed the following: in 44 cases, multiple rib fractures (with pneumothorax or

Table 5 Tile classification

	Tile classification	Number of patients
Type A	Stable pelvic ring injury	34
Type B	Partially stable pelvic ring injury	
	B1 Open book (AP compression, external rotation)	55
	B2 Lateral compression (internal rotation)	24
	B3 Bilateral injuries	1
Type C	Completely unstable (allows all degrees of translational displacement)	54

hemothorax); in 24 cases, renal and liver contusions; in 23 cases, femoral fracture; in 12 cases, retroperitoneal hematoma; in 11 cases, subarachnoid haemorrhage; in 10 cases, tibial plateau fracture; in 14 cases, acetabulum fracture; in 16 cases, vertebral fractures; in 13 cases, multiple bone facial fractures (nasal, orbit, and maxillary bones); and in 1 case, atlas fracture.

Treatment procedures

In 160 cases, embolisation was performed either with micro-coils (VortX, Boston Scientific, Natick, MA, USA) alone (n=82) or in combination with the Spongostan (Johnson & Johnson, New Brunswick, NJ, USA) (n=78) (Fig. 1 (a,b,c,d,e,f)), Fig. 2 (a,b,c)).In 18 cases, embolisation was performed with the Amplatzer vascular plug IV (AGA Medical Corporation, Plymouth, MN, USA) alone (n=6) or in combination with micro-coils, Spongostan, or both (in three, three, and six cases, respectively). In four cases, embolisation was performed with glue (Glubran 2, *N*-butyl-2-cyanoacrylate; GEM S.r.l., Viareggio, Italy), and in two patients only with a Spongostan. In two cases (one external iliac artery and one femoral artery), bleeding was treated using a stent graft (Fluency endovascular stent graft, BARD Peripheral Vascular, Tempe, AZ, USA; Talent thoracic stent graft, Medtronic, Inc., Minneapolis, MN, USA) to preserve vascular continuity (Fig. 3 (a,b,c,d)).

The choice of micro-coil size was directly dependent upon vessel diameter. Embolisation of the most distal branches of the arteries was performed using a dedicated angiographic catheter advanced forward close to the site of bleeding or by superselective catheterization with a microcatheter (Progreat, Terumo Medical, Tokyo, Japan) when vascular anatomy did not permit peripheral catheterization with the angiographic catheter alone (Fig. 4 (a,b,c)). More proximal embolisation was performed in the following situations: multiple extravasations, vasospasm impeding selective catheterization, or excessive duration of procedure. After vessel embolisation, the potential collateral vessels were evaluated to identify additional supply.

Clinical outcomes

Technical success was defined as successful embolisation of the bleeding artery and the absence of extravasation of contrast after arterial embolisation. Treatment success of embolisation was characterised as stabilization of the haemodynamic status of the patient without the need for a surgical procedure for haemodynamic stabilisation (within 30 days). Haemodynamic stability was defined as no clinical signs of ongoing haemorrhage, and haemodynamic instability was defined as decreased ability of blood flow to meet the metabolic demands of the body.

The efficacy of arterial embolisation was defined as the percentage of patients for whom embolisation achieved technical success and treatment success, with control of bleeding after embolisation (one or two sessions). Clinical efficacy was defined as stabilization of laboratory data within 24 hours and within 1 week after the endovascular procedure on the basis of the number of blood bags and liquids received during the days after embolisation (Table 6), the absence of a recurrent decrease in haemoglobin by more than 1.5 g/dL, and circulatory stabilization. Absence of reperfusion of bleeding during follow-up, endovascular repeat treatment, or subsequent surgical intervention were considered.

A nonparametric Mann–Whitney test for independent samples was used with MedCalc statistical software version 13.1.2.0 to identify the factors influencing clinical efficacy (transfusion status, type of pelvic fracture). The same test was applied in order to determine the influence of the volume of replacement fluids administered (colloids, crystalloids, and number of RBC and fresh frozen-plasma bags) before embolisation in the two groups of patients (successful embolisation [group A] and unsuccessful embolisation [group B]).

Results

The technical success rate documented at post-procedural angiography was 100 %; no complications occurred during the procedures. After embolisation, 27 patients (16.1 %) remained haemodynamically unstable. The rate of treatment success was 94.6 %. Seven of the 27 haemodynamically unstable patients died from hypovolemic shock (n=4) or cerebral herniation (n=3), while eight patients died from complications related to massive blood transfusions. Nine of the remaining 12 patients needed additional surgery for haemodynamic stabilisation (i.e., decompression celiotomy and removal of

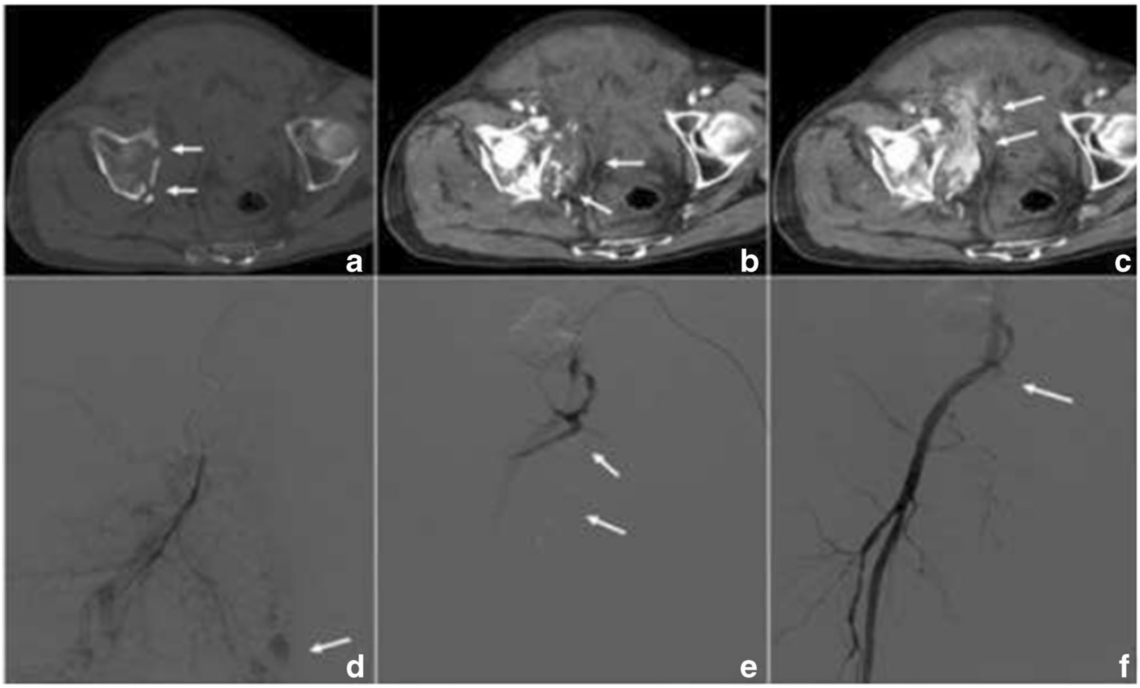

Fig. 1 Polytrauma patient (male, 81 years old) with obturator artery injury. (*a*) Axial CT scan obtained without contrast medium administration shows the right acetabular fracture (*arrows*). (*b*) Axial CT scan in arterial phase shows active bleeding at the level of the medial acetabular wall and the right perineal region (*arrows*). (*c*) Axial CT scan obtained at 120 sec demonstrates a substantial increase of spreading of contrast medium in the site of obturator artery damage (*arrows*). (*d*) Selective angiogram of the right internal iliac artery shows active contrast medium extravasation from the distal branches of the right obturator artery (*arrow*). (*e*) Superselective embolisation of injured vessel with multiple steel coils (3 mm diamond-shaped), followed by Gelfoam suspension embolisation (*arrows*). (*f*) Selective angiogram of the right internal iliac artery shows complete exclusion of bleeding (*arrow*).

pelvic packages). Three patients underwent a second arteriography due to the recurrence of haemorrhage; of these, none needed additional surgery. The rate of clinical efficacy was evaluated excluding patients who died ($n=15$) or who needed surgical stabilization ($n=9$). Patients who underwent a second endovascular treatment ($n=3$) were included. The overall clinical efficacy was 85.7 %. The type of pelvic fracture was not significantly related to clinical efficacy.

A statistically significant difference was found in the correlation between transfusion status and clinical efficacy ($p<0.0001$). The amount of colloids administered in group A (383.8±486.2 ml) was lower than that in group B (1, 250.0±361.2 ml), with a statistically significant difference ($p<0.0001$). The amount of crystalloids administered in group A (1,021.1±678.6 ml) was lower than that in group B (2, 250.0±989.1 ml), with a statistically significant difference ($p<0.0001$). The number of RBC bags administered in group A (3.25±1.61) was lower than that in group B (5.54±0.88), with a statistically significant difference ($p<0.0001$). The number of fresh-frozen plasma bags administered in group A (1.84±0.79) was greater than that in group B (5.54±0.88), with a statistically significant difference ($p=0.0001$). Clinical efficacy was statistically influenced by pre-procedural transfusion status.

Discussion

Arterial haemorrhage is one of the most serious problems associated with pelvic fractures, and it remains the leading cause of death attributable to pelvic fracture [8]. Pelvic haemorrhage associated with traumatic pelvic fracture can lead to life-threatening bleeding, with high rates of morbidity (40–50 %) and mortality (5–30 %), due in part to the inability to surgically control pelvic retroperitoneal bleeding [9, 10]. The reported mortality rate for pelvic fracture patients with haemorrhagic shock ranges from 36.4 % to 54 % [11, 12], and these fractures can result in venous and arterial injury. Pelvic arterial haemorrhage is rarely the result of bleeding from large, named vessels—the iliofemoral arteries, for example [13, 14]. Rather, arterial disruption more often occurs from smaller hypogastric arterial branches that traverse deep through the pelvis. Vascular damage may be caused by a laceration or angulation of an artery or vein, or by a fragment of the pelvic bone. It may also result from a contusion or tear due to the direct application of external force, causing sudden stretching and twisting of the vessels. In penetrating trauma, the vessels are directly damaged from contact with the assaulting object, such as a sharp weapon or bullet [15]. Arteries that are commonly involved include the superior gluteal and the lateral sacral arteries. Posterior dislocation of the pelvic ring (open-book fractures) normally involves injury of the internal iliac arteries or their branches; a “butterfly” fracture involves rupture of the inferior pudendal artery, and anterior compressive forces may damage the external iliac or femoral arteries. Pelvic fractures may produce a wide range of haemorrhages, ranging from self-limited bleed to vascular resection with haemodynamic instability.

The most important aspect in the management of pelvic haemorrhages associated with pelvic fractures is their detection. In the past, the radiological study of "trauma patients" was difficult, with significant diagnostic limitations that could lead to treatment errors [16]. Computed tomography has now become the diagnostic modality of choice in many trauma centres for evaluation of patients with pelvic fractures—even patients with some degree of haemodynamic instability [17]. At our trauma centre, contrast-enhanced CT (Aquilion 64, Toshiba Medical Systems, Tokyo, Japan) is used for initial diagnosis in the evaluation of patients with pelvic fractures. Extravasation of contrast material in the pelvis on contrast-enhanced CT is an accurate indicator of ongoing arterial haemorrhage in these patients. The presence of extravasation of contrast materials on contrast-enhanced CT scans is highly predictive of arterial injury that will require angiographic embolisation. It has also been found to be a reliable indicator of arterial haemorrhage, with sensitivity of 66– 90 %, specificity of 85–98 %, and accuracy of 87–98 % having been reported [18, 19]. The detection of such extravasation on CT can lead to prompt angiographic embolisation, which can be life-saving. Additionally, the site of contrast material extravasation visible on CT corresponds well to the site of bleeding visible on angiography. This correlation enables the interventional radiologist to selectively study the arteries most likely to be injured, and thus to potentially reduce the patient’s risk morbidity and mortality [20]. Pelvic fracture haemorrhage caused by venous injury at the fracture site can be effectively treated with external fixation by reducing the pelvic volume and stabilizing the fracture [21]. Several authors have suggested that external fixation is unlikely to be sufficient to stop arterial bleeding. Urgent angiography and subsequent transcatheter embolisation are currently accepted as the most effective methods for controlling ongoing arterial bleeding in pelvic fractures.

Surgical control of pelvic arterial haemorrhage often fails as a result of uncontrolled haemorrhage from

Fig. 2 Polytrauma patient (male, 76 years old) with right internal pudendal artery injury. (*a*) Axial CT scan in arterial phase shows active bleeding at the level of the right internal pudendal artery. (*b*) DSA (digital subtraction angiography) image shows contrast media blush in the distal brunch of the internal pudendal artery. (*c*) Superselective embolisation of injured vessel with multiple steel coils (3 mm diamond-shaped)

inaccessible vessels. As such, pelvic angiography, which was first reported by Margolies et al. in 1972, has become the gold standard not only for the diagnosis, but also for the treatment, of pelvic arterial haemorrhage [22].

Patient deaths caused by the haemorrhage of a pelvic fracture frequently occur within the first 24 hours of injury. The early identification of patients who might benefit from angiographic embolisation could reduce blood loss, prevent late complications related to transfusion, and improve outcomes [23]. In our study, clinical efficacy results were directly and significantly related to the pre-procedural transfusion status of the patient. The transfusion demand increases with the severity of the trauma and the time elapsed before the arrival to angiography [24]. However, the decision to move a critically injured patient to the angiography suite is not to be made lightly. Several investigators have attempted to define clinical or radiologic predictors for determining which patients with pelvic fractures are at high risk of arterial haemorrhage and thus might benefit from angiography and embolisation. As such, access to angiography varies among institutions [21–23]. There is a delicate balance between risking delayed intervention and performing many unnecessary angiographic procedures [24].

Research has demonstrated the efficacy of TAE for the management of arterial haemorrhage caused by pelvic fractures. The success rate, expressed in terms of haemorrhage control and reduction in transfusion requirements, ranges from 85 % to 100 %. TAE should be performed as early as possible, because effective embolisation must be achieved before severe systemic coagulopathy and multiple organ failure develop [21–23, 25, 26].

Agolini et al. [27] reported a mortality rate of 14 % (1/7) for embolised patients who arrived in the angiography suite within 3 hours of injury, but it rose to 75 % (6/8) in patients who arrived after 3 hours. Eastridge et al. [12] noted a mortality rate of 25 % (1/4) in patients with unstable pelvic fracture patterns who underwent TAE before celiotomy, but the rate increased to 60 % (6/10) for patients who underwent celiotomy before TAE [25]. The authors concluded that angiography should be considered as an initial intervention in patients with unstable pelvic fractures, even in the presence of hemoperitoneum. Tanizaki et al. [24] registered a lower mortality rate among haemodynamically unstable patients who were embolised within 60 minutes of arrival (16 % vs. 64 %), and thus length of time may be a considered a prognostic factor [24, 25]. Our experience during the angiographic study was that selective

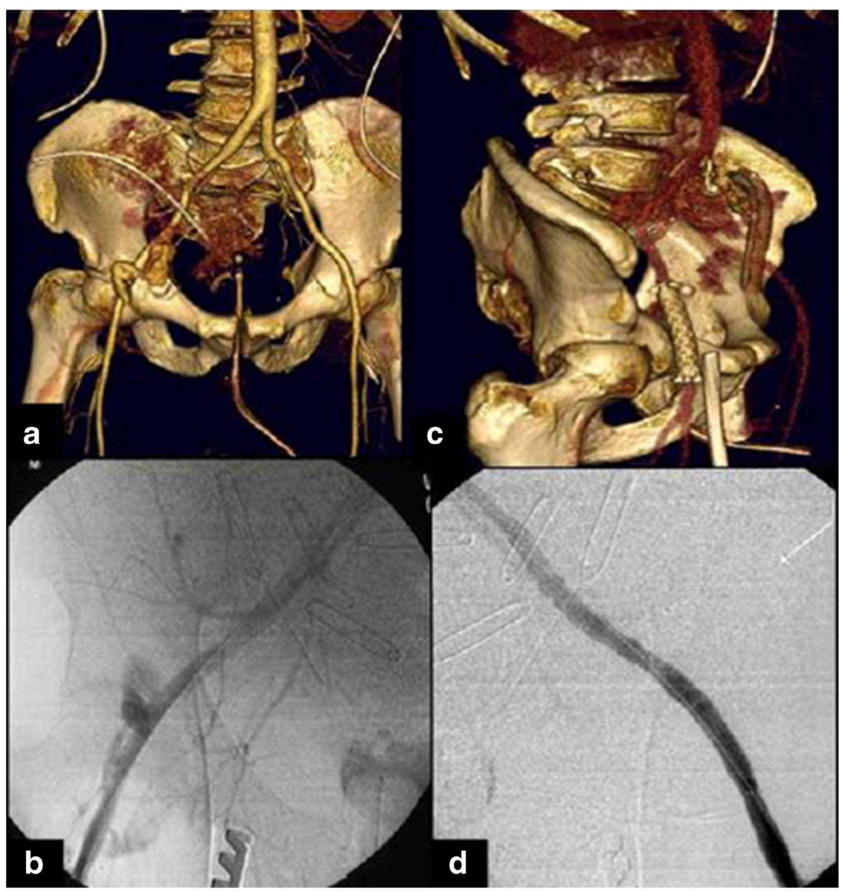

Fig. 3 Polytrauma patient (male, 66 years old) with femoral artery injury. (*a*) Volume-rendering 3D reconstructed image shows contrast media extravasation in the femoral artery. (*b*) DSA image shows a contrast media blush in the right femoral artery. (*c*) Volume-rendering 3D reconstructed image shows bleeding exclusion by covered stent positioning. (*d*) DSA image shows covered stent positioning.

injection of the internal iliac arteries was necessary, as the bleeding may be intermittent, and the characteristics of the arteries that may be injured are more evident.

It is also important to selectively study the contralateral internal iliac artery to search for other potential bleeding sites and collateral flow that may contribute to the original bleeding site. A capillary and venous phase blush in the region of the distal branches of the internal pudendal artery that simulates bleeding can sometimes be seen on arteriograms of male patients who are not bleeding. This normal variation, called the “cavernosal blush,” is characterized by a bilaterally symmetric and homogeneous stain at the base of the penis that washes out, and it should not be confused with active haemorrhage. In general, patients who need angiography tend to be older, require more transfusion before angiography, and have higher injury severity scores than those who do not. Thus, it is not surprising that the mortality rate is still high in patients who undergo angiographic embolisation. Mortality rates among patients who undergo successful TAE have been reported from 17.6 % to 47 % [27–29].

In order to increase the efficacy of the method and reduce complications and costs, the trend has been to combine several materials for embolisation. There are a number of embolisation devices available, each with its own characteristic features: a fibrin sponge is used for temporary (about 48 h) embolisation, and polyvinyl alcohol (PVA) microspheres are commonly used for permanent embolisation, whereas detachable balloons, glue, steel coils, and plugs are used for definitive embolisation. Active bleeding due to a lesion of a small distal vessel responds well to embolisation using particles such as those of PVA (150–300 μm), the Embosphere (300–500 μm), or Gelfoam in small segments (1 mm). Gelfoam is

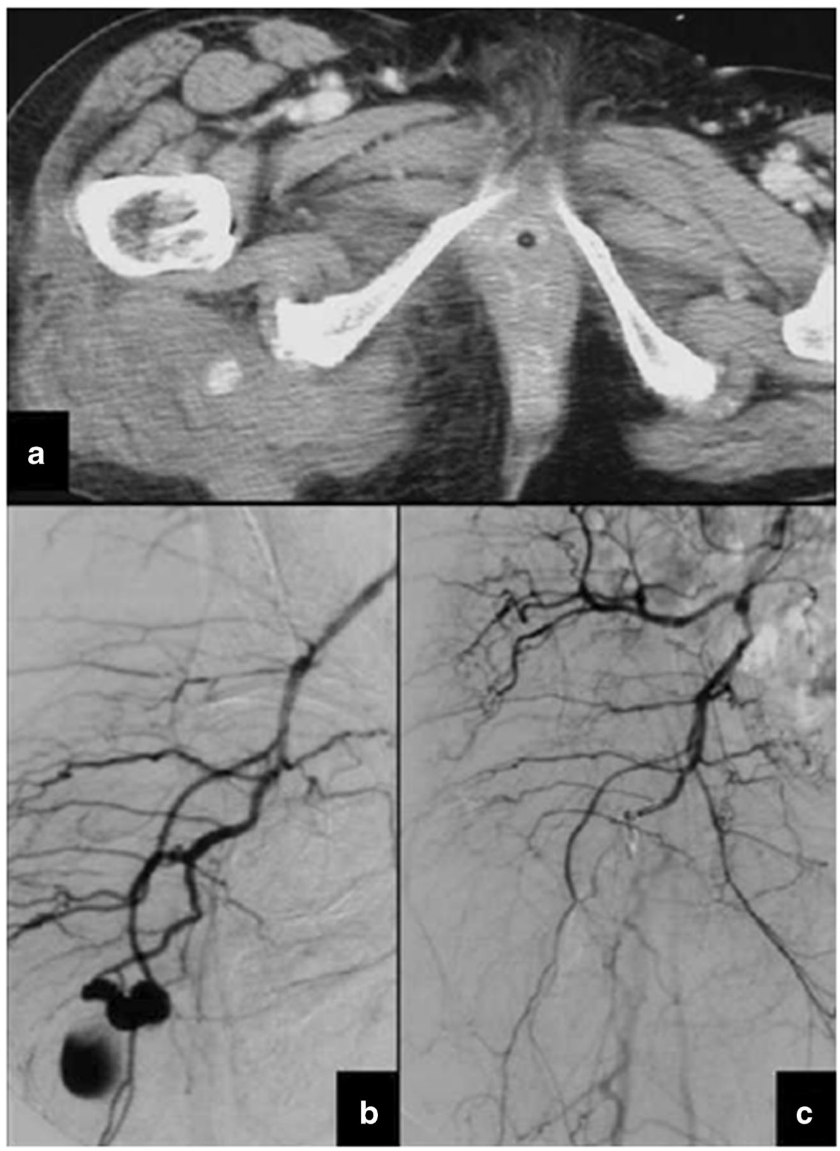

Fig. 4 Polytrauma patient (male, 57 years old) with inferior gluteal artery injury. (*a*) Axial CT scan in arterial phase shows active bleeding at the level of the gluteal muscle. (*b*) DSA image shows a pseudoaneurysm originating from the inferior gluteal artery. (*c*) Superselective embolisation of injured vessel with multiple steel coils (3 mm diamond-shaped) followed by Gelfoam suspension embolisation.

Table 6 Patient hemodynamic and transfusion status

Number of patients	Pre-procedural replacement fluid	Intra-procedural replacement fluid	Post-procedural replacement fluid
21	1,500 ml colloid 3,000 ml crystalloid 6 RBC bags 1 fresh-frozen plasma bag	2 RBC bags 4 fresh-frozen plasma bags	10 RBC bags
22	500 ml colloid 1,000 ml crystalloid 3 RBC bag 2 fresh-frozen plasma bags	1 RBC bag	1,000 ml crystalloid 2 RBC bags
45	1,000 ml crystalloid 5 RBC bags 2 fresh-frozen plasma bags	3 RBC bags	2 RBC bags
18	3 RBC bags 3 fresh-frozen plasma bags	2 RBC bags	
13	2,000 ml crystalloid		
9	2 RBC bags 2 fresh-frozen plasma bags		
32	1,000 ml colloid 3 RBC bags 2 fresh-frozen plasma bags	1 RBC bag	1,000 ml colloid
4	2,000 ml crystalloid 3 RBC bags 2 fresh-frozen plasma bags	1 RBC bag	1,000 ml crystalloid 1 RBC bag
4	1,000 ml colloid 2,000 ml crystalloid	1,000 ml crystalloid	1,000 ml colloid

RBC red blood cells

inexpensive and easy to use; however, it is not permanent, and rebleeding may occur. Superselective catheterization with a coaxial microcatheter of the bleeding vessel is the most important step in the embolisation procedure for obtaining the best results and avoiding multiple complications. In cases such as pseudoaneurysms or fissurations, in order to obtain complete haemostasis, micro-coils have to be placed in both distal and proximal vascular sites of the pseudoaneurysm. When a pseudoaneurysm with or without extravasation of contrast media is identified, a coaxial microcatheter is placed distal to the pseudoaneurysm, followed by placement of micro-coils. Subsequently, the coaxial microcatheter is placed proximal to the pseudoaneurysm, and micro-coils are deployed. Arteriography is repeated immediately after embolisation in order to confirm the exclusion of the pseudoaneurysm and the cessation of extravasation.

The Amplatzer vascular plug (AVP) (AGA Medical Corporation, Golden Valley, MN, USA) can also be used. A relatively new system for definitive embolisation, the AVP is a versatile device that has been successfully used in the closure of arteries (internal iliac and subclavian), pulmonary arteriovenous malformations, haemodialysis fistulae, and gastric varices [30]. The device was approved by the U.S. Food and Drug Administration (FDA) for peripheral embolisation of arteries and veins. It uses the same technology as other Amplatzer devices that are used for occluding interatrial and interventricular defects and patent foramen ovales. It is a cylindrical, self-expandable system made from 144 nitinol mesh wires secured on both ends with platinum marker bands; a stainless steel microscrew is welded to the proximal marker band to allow attachment to a delivery cable 135 cm in length. The system is preloaded inside a 100-cm guiding catheter: 5 Fr for plugs with a diameter of 4–8 mm, 6 Fr for plugs with a diameter of 10–12 mm, and 8 Fr for plugs with a diameter of 14–16 mm. The system ranges in size from 4 mm to 22 mm in diameter, increasing in 2-mm increments. Once the release site has been reached, the catheter may be withdrawn in order to expose the plug and the metallic guide turned counterclockwise to release the device. The manufacturer recommends oversizing the device by at least 20 % with respect to the diameter of the vessel to be treated in order to prevent the risk of distal migration. Positive features include the availability of a wide range of sizes—even very large, the ability to reposition the device before its definitive release, a lower risk of migration compared with coils, and short occlusion times [30] (Fig. 1a–f)).

A multidisciplinary approach is essential for the management of pelvic fracture bleeding. Optimal management is dependent upon the availability of hospital facilities and experienced medical personnel [31]. According to the literature data [32], endovascular treatment should be available at all level I trauma centres on a 24-hour basis. We attribute the high rate of technical success and clinical efficacy that we have experienced to an appropriate multidisciplinary team approach in dealing with traumatic patients and a skilled interventional radiologic team that is available 24 hours a day.

One important limitation of this study should be noted. Other variables including initial haemodynamic stability before and after cardiopulmonary resuscitation (CPR), pelvic X-ray findings, CT findings, and comorbidity status (neurological, etc.) were not analysed and correlated with clinical efficacy.

Conclusions

In summary, the use of CT allows the location and characterisation of haemorrhages associated pelvic fractures, reducing the time to diagnosis, and above all, improving the success of embolisation procedures. Our series, which represents one of the largest over the past few years, demonstrates that percutaneous control of pelvic haemorrhages may be considered an initial therapeutic option. TAE is a rapid, safe, effective, and minimally invasive technique, features that render it very useful in this setting, where the clinical course and prognosis are related to achieving haemodynamic stability. Our study is the first in which a statistically significant correlation was found between clinical efficacy and pre-procedural transfusion demand. On the basis of our results, pre-procedural transfusion status may be considered a prognostic factor.

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