

Transcatheter Embolization for Trauma of the Pelvis

Concepts and techniques for a multidisciplinary treatment approach.

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Trascatheter embolotherapy is well established for the management of hemorrhage and vascular injury.¹ Familiarity with clinical presentation, pretreatment imaging, angiographic findings, and endovascular techniques are all essential components to effective diagnosis and treatment of trauma patients with embolotherapy. Furthermore, pelvic trauma rarely occurs in isolation; as many as 50% of patients with pelvic fracture have additional injuries, so pelvic fracture should be treated as an indicator of polytrauma.² As such, an algorithm approach to the care of the trauma patient, though institution dependent, should weigh the severity of multiple injuries and mandates a multidisciplinary approach.

MECHANISM OF INJURY

Pelvic trauma may be categorized into blunt and penetrating, with blunt trauma being more common. When blunt trauma causes a pelvic fracture, vascular injury may be seen in up to 40% of patients. Hemorrhage is the highest cause of mortality in this patient group (50%–74% of patients).^{3–5}

Motor vehicle collisions and pedestrians hit by motor vehicles account for the majority of blunt arterial injury.⁶ Although domestic falls are a less common cause, the need for pelvic vascular evaluation in this population is well documented.^{6–8} Further, age is an independent predictor of active bleeding and indication for transcatheter arterial embolization (TAE),

regardless of hemodynamic stability.^{6,8} This may be secondary to osteoporosis in elderly women, which results in increased rates of pelvic fracture.⁹ The prevalence of long-term anticoagulation for cerebrovascular and cardiovascular disease in this patient population may also necessitate early intervention. Types of vascular injury seen with blunt pelvic trauma include complete or partial transection, arteriovenous fistula, pseudoaneurysm, dissection, and traumatic thrombosis.

Examples of penetrating pelvic injuries include gunshot wounds, stab wounds, or iatrogenic injury.¹⁰ Penetrating injuries are more likely to result in transection or pseudoaneurysm formation, with or without arteriovenous fistula.¹¹ Traumatic pseudoaneurysms are high risk for rupture and should be treated, preferably with endovascular methods when possible.¹²

TECHNIQUE

Preprocedural Planning

It is essential that the interventionist be familiar with the trauma history and previous imaging in order to assess the appropriateness and timing of angiography. Indications for TAE in the setting of pelvic trauma include pelvic fractures and hemodynamic instability after exclusion of other sources of hemorrhage, active extravasation of contrast on CTA in the presence of pelvic fracture regardless of hemodynamic status, previous TAE for pelvic trauma with ongoing hemodynamic instability after other sources of hemorrhage have been

TABLE 1. ANGIOGRAPHIC APPEARANCE OF TRAUMATIC VASCULAR INJURY

| Type of Injury | Appearance on Angiography |
|---|--|
| Transection | Brisk extravasation of contrast. Partial or complete transection may result in vasospasm. The appearance cannot be distinguished from traumatic thrombosis or vasospasm without transection. |
| Dissection | Luminal irregularity with an intimal flap. |
| Pseudoaneurysm | Contrast filling an irregular outpouching in communication with the vessel lumen. |
| Arteriovenous fistula | Early filling of a vein adjacent to the contrast-opacified artery. This may have an associated pseudoaneurysm. |
| Thrombosis | Abrupt cutoff of the vessel. This cannot be distinguished from vasospasm. |
| Hemorrhage originating from cancellous bone | Group of small round collections of contrast, clustered together. This is seen within the region of osseous or ligamentous injury. |
| Vasospasm | May have several appearances, including contour irregularity of the vessel lumen, abrupt narrowing of the vessel, or abrupt cutoff. |

excluded, and patients older than 60 years with a high-risk pelvic fracture pattern.^{6,8,13,14} It is important to note that disruption of the osseous pelvis ring allows for a large volume of hemorrhage to accumulate rapidly in a surgically inaccessible area; thus, early intervention is necessary to prevent exsanguination.⁷ Rapid response is also important: the literature shows a statistically improved survival rate when TAE is performed within 3 hours of arrival to the hospital.¹⁵

Whereas TAE plays an important role in the treatment of pelvic trauma, pelvic hemorrhage more commonly occurs from venous sources or fractured cancellous bone, and this type of low-pressure hemorrhage is best controlled with external fixation or compression with pelvic binding. The goal of these methods is to reestablish the normal tamponading effect of the retroperitoneum, although some recent studies call into question the overall efficacy with this approach.^{2,13,16} Peritoneal pelvic packing has been introduced as an additional method of treating pelvic hemorrhage.² There are many approaches to this patient population, and interventionists should be familiar with the treatment algorithm employed at their institutions. Regardless, early control of pelvic arterial hemorrhage has a strong association with improved outcomes, and TAE continues to occupy a central role in the treatment of traumatic pelvic hemorrhage.^{1,13,15,17-20}

Site of Access and Diagnostic Imaging

Pelvic binders vary among institutions and can be made of fabric or leather. Depending on the type of material, access may be acquired through a small hole cut into the binder. Otherwise, the binders may have to be undone before obtaining access. Most pelvic

embolizations can be performed via a single common femoral artery access site. If there is known unilateral pelvic or lower extremity injury, contralateral femoral access is preferred. If injuries or external devices preclude the preferred femoral access, the procedure can be performed via a brachial or even popliteal or radial artery access. More recently, dual access has been advocated to allow placement of a temporary occlusion balloon within the infrarenal abdominal aorta while pelvic or lower extremity hemorrhage is treated.^{7,21}

The procedure should begin with nonselective angiography to localize sites of hemorrhage and serve as a roadmap for vessel selection. Additionally, the initial imaging is useful in differentiating traumatic injury from guidewire-induced vasospasm.

Appropriate angiographic imaging of the internal iliac artery requires orthogonal selective views. The anterior division is best imaged with a contralateral oblique view of approximately 45°. An ipsilateral anterior oblique view is important to identify the superior gluteal artery and the internal pudendal artery. Although initial nonselective pelvic angiography is an important part of pelvic or extremity evaluation, selective angiography is also critical to achieving appropriate angiographic sensitivity.

Hemorrhage from pelvic trauma is most often associated with the internal iliac artery, but some have advocated that a selective angiogram of the external iliac artery should also be obtained.²² Although the external iliac artery is not usually a source of pelvic hemorrhage, the external pudendal, deep iliac circumflex, inferior epigastric, and circumflex femoral arteries may be injured.^{1,18,23} The more inferior lumbar arteries,

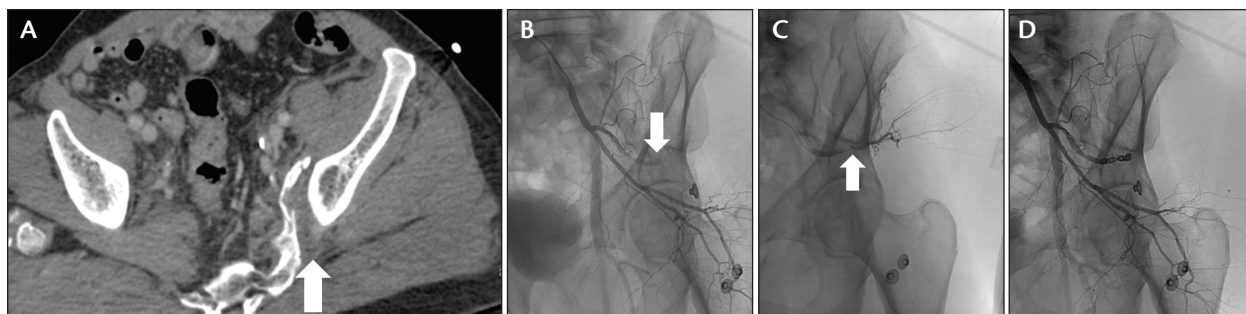


Figure 1. A 74-year-old man involved in a motor vehicle collision. CT showed a vertical shear-type fracture pattern with comminuted fracture involving the left sacral ala (arrow, A). Minimal adjacent contrast blush was identified. The patient was taken emergently to angiography secondary to rapidly decreasing hemoglobin and hemodynamic instability. Angiography with catheter in the left common iliac artery shows abrupt contrast cutoff of the posterior division of the left internal iliac artery (arrow, B). A microcatheter was used to cross the vessel, and contrast injection demonstrated findings consistent with dissection versus transection of the vessel (arrow, C). Multiple coils were placed across the vessel defect. Postembolization arteriogram showed no evidence of continued hemorrhage or filling of the abnormal vessel (D).

as well as the inferior mesenteric or even the gonadal arteries, are other rare sources of pelvic bleeding.

After completion of contralateral pelvic vessel evaluation, selection of the ipsilateral common iliac artery should be performed. Of note, imaging of the bilateral iliac vessels should always be obtained to avoid continued hemorrhage resulting from reperfusion of the injured vessel via anastomoses with the contralateral pelvic arteries. It also rules out additional injury, which may have been occult on initial CT imaging.

Imaging Appearance

The different angiographic appearances of traumatic vascular injury are listed in Table 1.^{1,12,16,24} Vascular injury typically occurs in relationship to adjacent osseous fractures or shearing forces against the ligamentous structures of the pelvis.¹⁶ Historically, fracture patterns were believed to be important diagnostic indicators in pelvic trauma.^{4,16} More recent studies have shown that arterial hemorrhage can occur with any of the fracture patterns, as well as in the less severe subtypes, and may occur in the absence of fracture.²⁵ Vertical shear, type II and III lateral compressions, and anterior-posterior compressions are the most concerning fracture patterns for associated vascular injury.^{4,16,26} It is important that the interventionist recognize these patterns, as they may suggest the culprit vessel in the absence of active extravasation at angiography (Figure 1).

Embollic Material

Embollic material used in trauma is most commonly coils, microcoils, or gelfoam (Pfizer Inc.). Large vessel occlusion devices, such as the Amplatzer vascular plug 4 (St. Jude Medical, Inc.), have seen increasing usage. Alternatively,

liquid embolic agents, such as Onyx (Covidien) and N-butyl cyanoacrylate (Codman Neuro [Johnson & Johnson]), have been used, with the potential advantages of achieving vessel occlusion in patients with coagulopathy while providing distal control.^{27,28} Important considerations when using liquid embolic agents include cost, a steep learning curve, and a narrow safety profile. Small particles, including gelfoam particles, have little or no role in the treatment of acute trauma.^{12,16}

Embollic Delivery

The type of embolic and the site and method of delivery of an embolic agent should be dictated on the basis of angiographic findings of vessel injury. In most cases, superselective embolization at the site of injury is recommended. However, nonselective internal iliac embolization is recommended by some if the patient is hemodynamically unstable or if there are multiple sites of extravasation identified. CT demonstrating acute hemorrhage without active extravasation at angiography may lead the interventionist to nonselectively embolize either the anterior or posterior division of the internal iliac artery.

Gelfoam is an inexpensive temporary embolic agent allowing for potential recanalization within a few weeks. This may allow for reclaimed tissue perfusion once the acute injury has had time to heal. Gelfoam is typically delivered as a slurry mixed in a three-way stopcock with a half-strength mixture of contrast and normal saline. More agitation will create a gelfoam mixture that is smoother and can affect vessels of smaller caliber. If the target of embolization with gelfoam is distal, the gelfoam mixture should be kept coarse to achieve

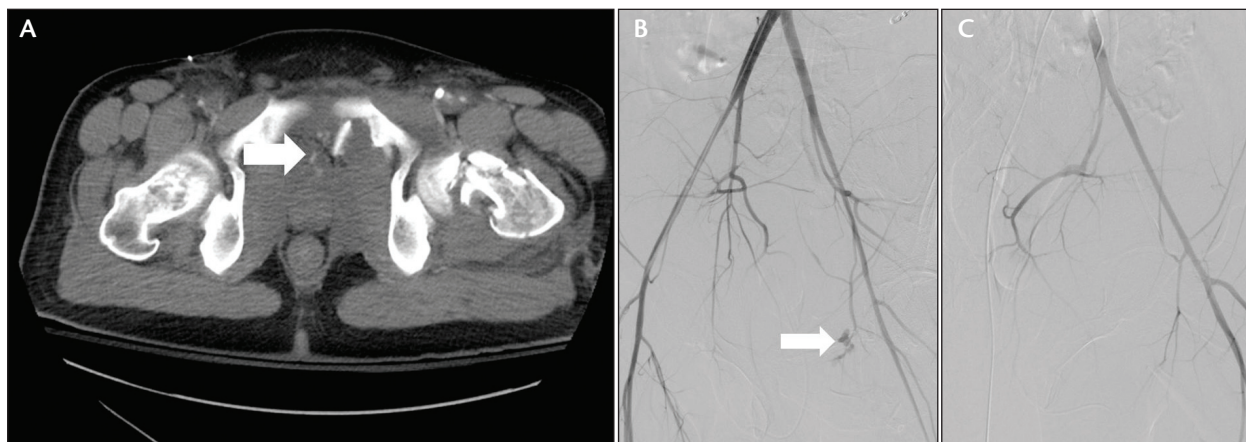


Figure 2. A 66-year-old man involved in a motor vehicle collision. CT showed comminuted fracture involving the left inferior pubic ramus with adjacent active arterial extravasation (arrow) (A). The patient was taken emergently to angiography (B), which showed active extravasation from the left obturator artery (arrow). After administration of Gelfoam slurry and multiple coils, no evidence of continued extravasation was identified (C).

hemostasis through occlusion proximal to the end capillary bed, thereby decreasing the risk of tissue necrosis.^{13,29} Gelfoam can also be delivered in the form of 2- to 3-mm pledgets. This is performed by front-loading a 2- to 3-mm piece of gelfoam into the tip of a 1-mL syringe of half-strength contrast. The torpedoes may be soaked in contrast before injection. This can be used to achieve occlusion of larger-caliber vessels and may reduce the risk of ischemia. The delivery of gelfoam should be followed with a contrast injection after every few 0.1 to 0.3 mL of slurry or after every few torpedoes with the goal of sluggish flow.^{12,30} This technique helps limit reflux of embolic agents into other branches.

The administration of gelfoam into internal iliac artery branches is frequently followed by selective branch occlusion with coils (Figure 2). This method prevents very early recanalization of the vessel but is not proximal enough to cause ischemia. Caution is advised, as coils may block access to bleeding vessels if repeat embolization is needed. Coil selection is often dictated by catheter choice. If a 4- or 5-F catheter has been advanced to the target vessel, then 0.035-inch coils, such as Nester or Tornado (Cook Medical), can be used. These 0.035-inch coils have Dacron fibers to promote thrombogenesis. The 0.035-inch coils should be pushed and not injected. Superselective catheterization of the target vessel is typically accomplished with a 0.021-inch lumen, 3-F microcatheter (eg, Cantata [Cook Medical]). A high-flow microcatheter—which typically has a 0.025-inch lumen, such as the Progreat Omega (Terumo Interventional Systems)—provides the ability to perform rapid-power injection. The larger inner lumen of high-flow microcatheters introduces concerns with

0.018-inch microcoil (eg, Nester or Tornado) compatibility because coils can fold over and become wedged within these larger-lumen microcatheters.

Microcoils can be deployed conventionally by using a pushing wire, such as the Trupush (Cordis Corporation). Alternatively, microcoils can also be injected; this may expedite the procedure, but the safety of this technique requires a stable delivery location (ie, not close to the origin of the vessel) and low risk of refluxing gelfoam.

The proximity of the microcatheter to the vessel origin influences the choice of embolization materials. If the catheter is near the origin of the accessed vessel, detachable coils (eg, the Axiom Concerto coil [Covidien]), although often more expensive, may be considered to help prevent herniation of the coil into the parent vessel.

Attempts should always be made to advance the microcatheter distal to the site of injury (Figure 1). This allows for coils to be first deployed distal to the injury, followed by gelfoam, and then additional coils proximally (gelfoam sandwich technique). Gelfoam—or in very select circumstances, glue or Onyx—and proximal coils without distal coiling may be used if the lesion cannot be crossed. If a traumatic pseudoaneurysm begins expanding subsequent to proximal coiling, endovascular treatment options are limited to percutaneous embolization of the additional branches that are backfilling the pseudoaneurysm. Coils should not be used directly within a traumatic pseudoaneurysm sac due to the potential for rupture as well as re-expansion.¹² However, if the anatomy of the pseudoaneurysm allows, coiling may be performed across the neck of a pseudoaneurysm.

Traumatic arteriovenous fistula may occur when a vein and artery are injured simultaneously, either in the pelvis or extremities. Angiographically, this is appreciated as abnormal early venous return concurrent with the opacification of the arteries. Treatment is similar to pseudoaneurysms, with distal and proximal coil embolization of the artery, but rarely, treatment may require access through both the arterial and venous systems. Although coils may be used in this situation, there is a risk of coil migration in the venous system and subsequent migration centrally. Other options include exclusion of the fistulous connection with an arterial stent graft or use of an Amplatzer vascular plug.³¹ The Amplatzer plug can be particularly useful for the treatment of arteriovenous fistula because of its low risk of migration.

POTENTIAL COMPLICATIONS

Repeat bleeding after pelvic TAE should be considered the most important adverse event, as it occurs in 15% to 20% of patients and is associated with mortality increasing from 15% to 30%.¹⁷ Predictors of recurrent pelvic arterial hemorrhage include hemoglobin < 7.5 mg/dL before the procedure, > 6 units of packed red blood cells after the procedure, or a superselective embolization.¹⁷ Injured vessels may be in vasospasm or otherwise go undetected during angiography. These missed arterial injuries can manifest as delayed hemorrhage after resuscitation restores intravascular volume. Vasospasm or delayed migration/packing of gelfoam may also contribute to repeat bleeding. Aggressive embolization of occluded vessels (which may be due to traumatic thrombosis or vasospasm) is recommended. Leaving the vascular sheath in place should also be considered when there is concern that the embolization is incomplete or the patient still needs resuscitation.

Directly related to embolization is tissue ischemia within the treatment vascular bed or other territories secondary to nontarget embolization. This uncommon complication is manifest in pelvic embolizations as gluteal muscle necrosis, sacral skin breakdown, ischemic necrosis of the bladder wall and rectum, or necrosis of the femoral head.^{23,29,32-34} The choice of embolic agent is the best predictor of tissue ischemia. The agent should be small enough to effectively occlude the site of bleeding but large enough to avoid the capillary bed. As mentioned, the use of nonpermanent embolic agents (gelfoam) may potentially aid in reducing the risk of tissue necrosis.

Nerve injury after TAE for trauma has been reported, but shear injury from the trauma itself, rather than procedure-related ischemic changes, may account for many of these reported pelvic TAE complications.²³ Impotence in the male patient is likewise usually considered a con-

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sequence of the initial traumatic injury rather than nerve injury caused by pelvic TAE.^{35,36}

Nontarget embolization most often occurs when the rate of embolization is too fast and embolic material refluxes proximal to the catheter tip. Anastomotic vessels not appreciated on angiography can also contribute to nontarget embolization. Nontarget embolization of unintended pelvic vessels is typically well tolerated, secondary to pelvic collateral vessels. In contrast, embolic material introduced into the outflow vessels of the extremity or used during an intervention for the extremity can jeopardize the perfusion of the limb. Endovascular coils, if placed within a proximal segment of vessel, can herniate into the parent vessel, thereby resulting in unintended occlusion distal to the point of herniation. Coils can also embolize through arteriovenous fistulae. The operator must have familiarity with coil retrieval if providing arterial embolization services.

CONCLUSION

Hemorrhage from pelvic fracture is a significant source of mortality in the trauma patient and necessitates a multidisciplinary, algorithm-directed protocol. Angiography and transarterial embolization remain highly effective methods of assessing and controlling arterial hemorrhage. The interventionist should be familiar with clinical presentation, pretreatment imaging, angiographic findings, embolization materials, and potential complications to adequately provide these services. ■

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