# Pelvic fracture-related hypotension: A review of contemporary adjuncts for hemorrhage control

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**ABSTRACT:** Major pelvic hemorrhage remains a considerable challenge of modern trauma care associated with mortality in over a third of patients. Efforts to improve outcomes demand continued research into the optimal employment of both traditional and newer hemostatic adjuncts across the full spectrum of emergent care environments. The purpose of this review is to provide a concise description of the rationale for and effective use of currently available adjuncts for the control of pelvic hemorrhage. In addition, the challenges of defining the optimal order and algorithm for employment of these adjuncts will be outlined. (*J Trauma Acute Care Surg.* 2021;91: e93–e103. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

**LEVEL OF EVIDENCE:** Review, level IV.

**KEY WORDS:** Pelvic hemorrhage; hypotension; endovascular; pelvic packing; embolization.

Optimal care of patients with pelvic fractures remains a significant challenge of modern trauma care. While multiple variables have been associated with adverse outcome following these injuries,[1–3] the ability to expediently control ongoing hemorrhage from these fractures represents a modifiable of risk factor. In the largest contemporary multicenter study on the topic to date, Costantini and colleagues[2] identified that 13.3% of trauma victims with pelvic fractures will be in shock at admission and found that hypotension in this setting is associated with a mortality of 32.0%.

Pelvic fracture is associated with hemorrhage from arterial, venous, and bony sources. Available adjuncts for early hemorrhage control include pelvic binders, resuscitative endovascular balloon occlusion of the aorta (REBOA), preperitoneal packing (PPP), angioembolization (AE), external fixation (EF), and open ligation of the internal iliac artery in a damage-control approach. A number of recent publications have examined the effectiveness of these interventions in assisting in the arrest of pelvic hemorrhage.[1–18] Optimal selection, ideal conduct, and order of these interventions, however, remain matters of active investigation.

The purpose of this publication is to review the rationale and technique for each of the available interventions for major pelvic hemorrhage control and provide a succinct synopsis of the contemporary evidence for their use. We conclude this review with a discussion of the key issues related to optimal coordination of these interventions and elements of care requiring additional study.

## PELVIC BINDERS

### Rationale

Pelvic binders are frequently used in the prehospital environment or early hospital course as an inexpensive and expedient temporizing bridge to definitive care of pelvic hemorrhage. Published research suggests that pelvic compression devices reduce hemorrhage by increasing pelvic stability, decreasing hematoma volume, and promoting stable clot formation.[7,19–23] However, evidence regarding their benefit in terms of reducing transfusion requirements and improving hemodynamic and metabolic parameters remains conflicting.[24–29]

### Technique

Optimal utilization of a pelvic binder requires early placement at the level of the greater trochanters and application of effective force to achieve fracture reduction and pelvic immobilization[30,31] (Fig. 1). Multiple studies demonstrate that 40% to 50% of binders are placed improperly and most often too high.[20,31–33] The potential dangers of extreme tightening or prolonged application must be appreciated, including skin and soft tissue damage, and visceral, vascular, and peripheral nerve compromise.[34] There are, however, no reports to date of overreduction causing harm, even in those cases where there is noted increased deformity on imaging.[20,35,36] Skin breakdown occurs most commonly in cases of

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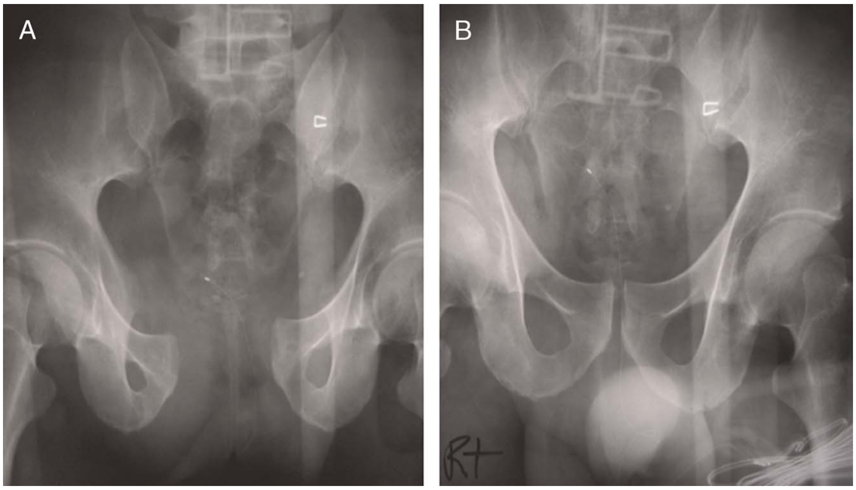

**Figure 1.** Before (*A*) and after (*B*) reduction of an open book pelvic fracture using a pelvic binder.

prolonged application (>24 hours), underlying soft tissue injury, and utilization of sheets instead of commercially available binders.[37–39] Skin damage appears more common when these binders are used in conjunction with prolonged spinal board immobilization for >2 to 3 hours.[40] False-negative imaging as a result of pelvic compression devices has also been described and represents a potential limitation of these devices.[41–44] In these instances, reduction of the fracture can mask the presence of fracture, particularly when the device was placed in the prehospital environment before the fracture could be radiographically characterized.

Pelvic binders may also present challenges for the vascular access required for other hemostatic adjuncts that can be used for pelvic hemorrhage control, including both REBOA and AE. These challenges may be circumvented by the use of sheets or binders that can sustain tailoring with scissors to afford the necessary access to the groin region or even the use of dual binders above and below the inguinal portal required for this access.

## RESUSCITATIVE ENDOVASCULAR BALLOON OCCLUSION OF THE AORTA

### Rationale

An evolution in endovascular technologies and borrowed experience from the use of aortic occlusion balloons in emergent vascular surgery have contributed to the subsequent introduction REBOA for traumatic hemorrhage control applications.[45–54] The expansion of REBOA use in the United States and abroad continues to be an area of active study across different cultures of utilization. Significant international experience using REBOA originates from the Japanese Trauma Data Bank, an environment where REBOA is used by interventional radiology and emergency medicine providers.[50,51] In the United Kingdom, REBOA use has been adopted by highly specialized groups of prehospital providers, who initiate aortic occlusion in the field based on predefined criteria.[52]

In the United States, REBOA has been primarily used at advanced trauma centers, where it remains a practice of active research. As Joseph et al.[4] and others have demonstrated, there remains a need for continued study of optimal patient selection and mitigation of complications such as reperfusion injury and extremity ischemia.[4,55] The most comprehensive experience with REBOA use for trauma in the United States has been collected by the Aortic Occlusion for the Resuscitation in Trauma and Acute Care Surgery (AORTA) registry of the American Association for the Surgery of Trauma (AAST).[49,54] Findings from this registry and other sources demonstrate that REBOA use by trauma surgeons for life-threatening hemorrhage continues to grow.[49,54,55]

The use of endovascular occlusion balloons for major pelvic hemorrhage control was originally described in a small series by Rieger et al.,[56] who placed them in the used internal iliac artery. Martinelli and colleagues[45] later reported the use of an intra-aortic balloon to temporize bleeding in patients presenting with hypotension or cardiac arrest following pelvic fractures. In this series, REBOA resulted in either return of spontaneous circulation or improvement in systolic blood pressure and facilitated transport of all treated patients to the interventional suite for attempted definitive hemorrhage control. Despite these preliminary reports, the 2015 multi-institutional study by Costantini et al.[2] noted that only 1 of 11 participating centers was using REBOA for pelvic indications.

More recently, however, increasing utilization of REBOA for severe pelvic bleeding has been documented. A 2020 AORTA study identified 160 patients undergoing zone 3 REBOA for management of pelvic fractures from 2013 to 2020.[13] In this series, REBOA was used as standalone hemorrhage-control tool in 37.5% of patients but was more commonly used as a bridge to some combination of hemorrhage control interventions that included EF, PPP, and/or AE. The optimal role of REBOA in this setting has also been examined using the Trauma Quality Improvement Program registry,[6,57] with conflicting results. The absence of standardized approaches to utilization of this adjunct and the lack of an ideal data set for examination of this issue continue to confound determination of the optimal role of REBOA for severe pelvic hemorrhage and underscore the need for additional study.

### Technique

Resuscitative endovascular balloon occlusion of the aorta requires arterial access via the common femoral artery and delivery of the occlusion balloon into the aorta above the site of hemorrhage. Access to the common femoral artery is obtained percutaneously or through an open cut-down technique depending on user experience, clinical situation, and the ability to visualize the vessel using ultrasound. The effective deployment of REBOA is dependent on the establishment of early arterial access for this purpose.[55]

Initial modern REBOA experience used Coda balloons (Cook Medical, Bloomington, IN), which required advancement of a compliant balloon over a prepositioned wire through 12-Fr access. Lower profile, trauma-specific devices have since been developed, which obviate the need for over-the-wire techniques. The device most commonly used is the ER-REBOA catherer (Prytime Medical, Boerne, TX). The smaller 7-Fr arterial access required for this device appears to contribute favorably to decreased access site complications and subsequent limb ischemia.[58]

After intra-abdominal hemorrhage has been excluded by focused abdominal sonography for trauma (FAST) or other means, REBOA use for the control of pelvic hemorrhage can be achieved by deployment in the infrarenal aorta between the lowest renal artery and the iliac bifurcation. For the purpose of REBOA technique, this region is referred to as zone 3 (zone 1, left subclavian to celiac artery; zone 2, celiac to lowest renal artery; zone 3, lowest renal artery to iliac bifurcation) (Fig. 2). This more distal position mitigates the potential burden of ischemia associated with more proximal aortic occlusion and decreases the risk for major reperfusion injury following deflation.

## Preperitoneal Pelvic Packing Rationale

Preperitoneal packing constitutes an expedient definitive treatment of pelvic fracture related bleeding that addresses both venous and bony bleeding sources present in 85% of fracture related hemorrhage.[59] Preperitoneal packing is also capable of controlling arterial bleeding, allowing resuscitation and physiologic restoration with delayed AE at a mean of 10 hours later.[60]


**Figure 2.** Resuscitative endovascular balloon occlusion of the aorta catheter inflated in the infrarenal aorta (zone 3) for temporary control of pelvic hemorrhage. A 6-Fr radial sheath tip is visible at the level of the balloon.

Pelvic packing as a technique for pelvic hemorrhage control was initially described by Tscherne et al.[61] in 2000, using laparotomy pads placed into the pelvis via laparotomy incision. Subsequent development of an anterior preperitoneal approach by the group at Denver Health Medical Center[62] was reported in 2005, and this group continues to have the largest reported PPP experience. Most recently, they reported on 128 hypotensive and severely injured PPP patients who sustained a 21% all-cause mortality rate. This compares favorably to the 32% rate reported by the 2015 AAST multicenter study,[2] a 41% mortality rate reported after AE alone,[63] an algorithm-driven management protocol study with a 35% mortality rate,[64] and a study prioritizing hemostatic resuscitation with a 37% mortality rate.[65] A recent analysis of the Trauma Quality Improvement Program database compared hemodynamically unstable pelvic fractures treated with PPP to with treated with zone 3 REBOA and found improved survival with PPP (37.3% vs. 52.0%, $p = 0.048$).[57] Several additional studies have noted significant reduction in mortality following pelvic hemorrhage when PPP was introduced as part of an algorithm of care for these challenging patients.[66–68] Preperitoneal packing has also proven useful in decreasing transfusion requirements in this setting[62] and has been effectively paired with AE as salvage for the minority of patients (15%) who have persistent arterial bleeding documented after packing.[69]

The most commonly reported complication after PPP is infection, ranging from 4% to 21% and most frequently occurring in the setting of open fractures, perineal degloving injuries, patients with associated bowel or bladder injuries, or the need for repeat packing.[60,62,68,70,71] Infection rate does not correlate with the duration of time the laparotomy pads are left in place[70] nor is PPP associated with an increased risk of surgical site infection after internal pelvic ring fixations.[72] Other complications that have been reported include wound dehiscence and deep venous thromboembolism.[71,73]

## Technique

Preperitoneal packing is preceded by pelvic fixation, either with a pelvic binder or optimally with EF,[26,74] facilitating optimal packing tamponade against a stabilized pelvis. The anterior bar of the EF is positioned to allow access for the PPP incision or concurrent laparotomy as necessary. Preperitoneal packing uses a 6- to 8-cm midline incision starting at the pubis and extending toward the umbilicus (Fig. 3). The subcutaneous tissue and fascia are opened in the midline without entering the peritoneal cavity. Blunt finger dissection is performed behind the symphysis and along the pelvic ring laterally to identify the space to be packed, which commonly has already been created by the pelvic hematoma. Laparotomy pads are placed along the pelvic brim on each side, with the sacrum marking the posterior limit of packing. The first laparotomy pad is placed by retracting the lateral margin of the bladder toward the midline with the nondominant hand and pushing the pad down to the sacrum, often using a ringed forceps to effectively push it posteriorly. Two additional pads follow sequentially around the bladder, and the process is repeated on the opposite side (Fig. 4). The result is six laparotomy pads placed in an inverted “U” around the bladder. The fascia is closed with

**Figure 3.** Incision selection for PPP with pelvic binder in place.

a monofilament running suture and the skin with staples. This procedure consistently takes 5 minutes to perform.[75] If a REBOA catheter was inflated in zone 3 before the operating room, deflation of the balloon should be attempted after completion of PPP with concurrent resuscitation. For patients with a positive FAST examination or concern for intra-abdominal injuries, an abdominal exploration can be performed without affecting the PPP. Supraumbilical laparotomy incisions should be separate from the incision for pelvic packing, as connecting these incisions can decompress the pelvic hematoma into the abdomen.[75]

The laparotomy pads are removed after the patient is fully resuscitated and normothermic and has normal coagulation indices. Routine duplex has been used before pack removal to exclude deep vein thrombosis, with subsequent inferior vena cava filter placement when identified in the setting of anticoagulation contraindication. Once all packs have been removed, the preperitoneal pelvic space should be examined for bleeding and hemostasis obtained. This may include direct ligation of small vessels or application of topical hemostatic agents; however, large venous injuries that require ligation or reconstruction can be discovered. Repacking of the pelvis should be avoided, as it has been associated with significant infectious morbidity.[60]

## ANGIOEMBOLIZATION

### Rationale

Angioembolization constitutes an approach to definitive control of pelvic hemorrhage that avoids the need to disturb pelvic retroperitoneal hematoma and facilitates location and control of bleeding sources. Margolies and colleagues[76] were the first to describe AE for pelvic hemorrhage in 1972, injecting the posterior pituitary and the patients' own clotted venous blood via arteriography into identified extravasating vessels in three patients. In a subsequent larger experience, Panetta et al.[77] used AE to successfully control hemorrhage in 87% of patients, resulting in a mortality reduction of 35.5% with most fatalities occurring due to associated injuries. These and other early efforts launched pelvic AE to the forefront of the armamentarium against pelvic hemorrhage[78]

In contemporary practice, 10% of all patients with pelvic fractures undergo angiography, with approximately half exhibiting active extravasation.[2,78] Angioembolization remains among the most common adjuncts used for hemodynamically unstable patients with pelvic fracture hemorrhage in most series,[2] as this endovascular approach avoids entrance into the pelvic hematoma, thereby allowing for the combined effects of both embolization and tamponade.

In attempts to identify optimal indications for AE, several studies have focused on fracture pattern predictors. In one study of 86 patients with ongoing shock, Eastridge et al.[79] found that unstable pelvic fracture patterns were associated with a pelvic source of bleeding requiring embolization in 59% of cases, as opposed to 10% with stable fracture patterns. Unstable fracture

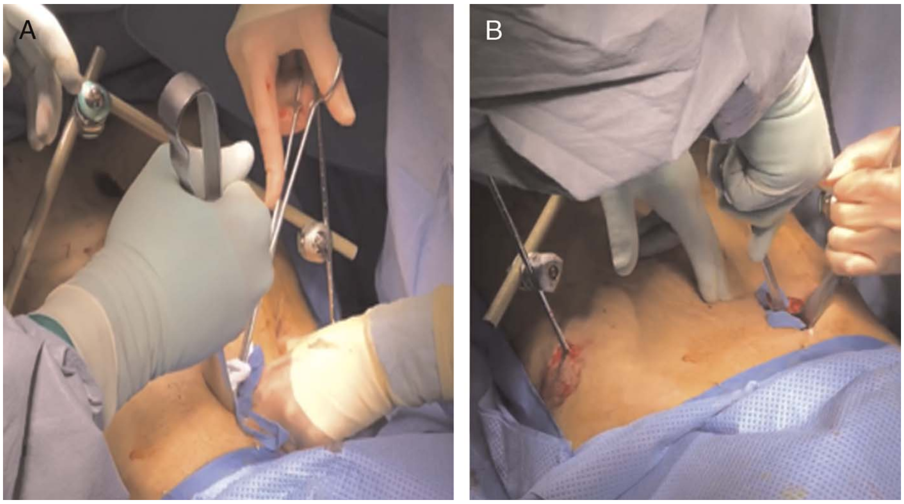


**Figure 4.** Preperitoneal pelvic packing. The first laparotomy pad is placed by retracting the lateral margin of the bladder toward the midline with the nondominant hand and pushing the pad down to the sacrum (*A*), often using a ringed forceps to effectively push it posteriorly. (*B*) Two additional pads follow sequentially around the bladder, and the process is repeated on the opposite side.

patterns were defined as anterior posterior compression (APC) type 2/3, lateral compression 2/3, and vertical shear.[80] In the aforementioned AAST multicenter study, Constantini and colleagues[1] also found that APC 3 and open book pelvic fractures were significantly associated with intervention need.

Contrast extravasation (CE) via modern computed tomography (CT) is frequently used to identify arterial hemorrhage and candidacy for AE.[81] While CE is associated with an increased need for embolization, increased transfusion requirements, and increased mortality, this finding in isolation does not appear to predict the need for intervention.[81,82] In one study, CE predicted the need for intervention in only 23% of patients.[82] Inversely, the absence of CE may be of significant clinical utility, with a negative predictive value approaching 100%.[82]

Angioembolization requires the rapid mobilization of significant resources to improve patient outcomes, with multiple studies demonstrating a direct relationship between delays of AE and higher mortality[83,84] and the value of reduced time to AE via institutional practices.[80] As a result, the American College of Surgeons Committee on Trauma recommends a 30-minute window from time of activation to catheter insertion for level 1 trauma center accreditation. For patients too unstable for CT scan, the presence of ongoing hemodynamic instability combined with an open book or APC 3 pelvic fracture and a negative FAST examination should be considered a potential indication for emergent AE at capable centers.

Potential complications of AE use in the setting of pelvic hemorrhage and hypotension include access-related complications, contrast-related renal dysfunction, and ischemic complications of embolization itself.[13] Ischemic complications may be exacerbated by the use of proximal internal iliac embolization versus more selective distal branch embolization and may include subsequent gluteal compartment syndrome, gluteal necrosis, and pelvic nerve dysfunction.

### Technique

Angioembolization of pelvic hemorrhage is performed using portable, ceiling, or floor mounted fluoroscopic units, preferably in a hybrid operating room to minimize patient movement. Ultrasound-guided access using micropuncture kits and upsizing to 5-Fr sheaths likely reduces iatrogenic injury caused by blind punctures or large sheath insertions. Transfemoral angiography is most commonly used, with the access side based on the location of hemorrhage and need to select the internal iliac artery in either a retrograde or antegrade direction. Musculoskeletal deformity, body habitus, tortuous arterial anatomy, atherosclerotic disease, and the presence of preexisting vascular stents also influence site selection. Longer wires and catheters now allow for transradial access, which may have confer advantages in vessel selection and reduction of transfemoral complications.[85]

Once access is achieved, a distal aortogram with pelvic runoff is obtained. If a bleeding source is identified, selective embolization can be performed by advancement of a catheter into the offending secondary and tertiary branches of the bleeding vessel branch. When performing a more distal "super selection," microcatheters utilization is useful. When precise hemorrhage localization is unsuccessful, a nonselective embolization of the proximal internal iliac can be considered for select hemodynamically unstable patients[86] (Fig. 5).

Among available embolic agents, speed and ease of use guide applicability for trauma. Coils are selected by determining the length and diameter of the target artery, with some having detachable delivery systems that afford a more controlled release into the target vessel. Gel foam slurry is inexpensive and easy to prepare and may eradicate bleeding from the smallest vessels beyond what a coil can typically reach but may carry a higher risk of inadvertent embolism during delivery. Detachable and nondetachable coils, plugs, and hemostatic adjuncts are selected at the discretion of the operator.

## EXTERNAL FIXATION

### Rationale

External fixation remains a significant element of modern management algorithms for hemodynamically unstable pelvic ring injury.[87] Temporizing fixation affords definitive reduction and fixation of the pelvis in a delayed manner as other more emergent injuries are addressed.[88] External fixation benefit is achieved by both minimizing additional trauma via increased stability to the osseous and ligamentous injuries and by reducing pelvic volume in an effort to tamponade hemorrhage. While both of these mechanisms can be achieved with the application of a pelvic binder, EF has the added benefits of promoting improved access to the groin and pelvis while negating the risk of skin necrosis associated with circumferential wrapping via pelvic binder. External fixation can also be left in place for several weeks or serve as definitive treatment of these injuries.

Volume expanded pelvic ring injuries require AE in as much as 15% of instances,[89] and REBOA has emerged as an important adjunct at select centers. Treatment with either strategy requires unobstructed access to groin vasculature typically obstructed by pelvic binders but facilitated by EF. While a binder can be moved to the lower pelvis or even cut to improve groin access and endovascular interventions, both maneuvers potentially compromise the position and mechanical function of a binder.

### Technique

#### EF Types

External fixation of the pelvis can be obtained through the use of a traditional external fixator or pelvic clamp. External fixation is commonly facilitated by the use of a radiolucent operating table and intraoperative fluoroscopic guidance, although certain methods of EF can circumvent these needs (Table 1).

#### EF Frames

Supra-acetabular Schanz pins are placed within a relatively large bony corridor but require fluoroscopy for appropriate positioning. The supra-acetabular frame uses two pins placed from the anterior inferior iliac spine to the posterior ilium in the bone of the sciatic buttress using multiplanar fluoroscopic views. The classic iliac crest frame uses two 5-mm partially threaded Schanz pins placed to each iliac wing starting at the iliac crest and connected by an anterior frame. The pins should be at least 2 cm posterior to the anterior inferior iliac spine to protect the lateral femoral cutaneous nerve and ensure that the largest corridor of iliac bone is accessible (Fig. 6). Schanz pins can be placed in the iliac wing with a percutaneous incision over the lateral ilium

 

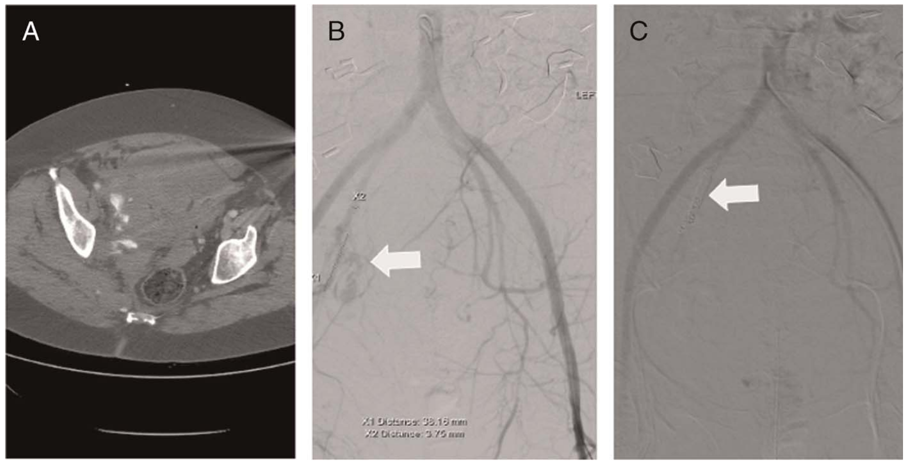


**Figure 5.** Pelvic fracture with CE on CT (*A*). Subsequent diagnostic angiogram confirmed extravasation from proximal right internal iliac artery (*B*), which underwent coil embolization (*C*).

through tactical feedback and without fluoroscopic guidance. However, the smaller osseous corridor in the ilium is less desirable as compared with one placed with use of supra-acetabular pins. While there are less concerns of injury to a major structure (hip joint, neurovascular bundle) with the use of iliac wing pins, the thinner nature of the ilium compromises maintenance of a stable bony corridor. In addition, iliac wing pins have less ability to resist rotational and abduction forces.[90] With stable osseous fixation, standard application of an EF can be left on for multiple days and even as definitive treatment.

Limitations and risks of standard EF application include injury to the hip joint or neurovascular structures of the sciatic notch, pin site infections, pin loosening, the cumbersome nature of the frame, and the inability to directly control posterior ring instability via an anterior based EF. For some fracture patterns, placement of a posterior based sacral screw may be needed to recreate some posterior stability to allow for a reduction of the anterior pelvis.

## Pelvic Clamps

Another option for achieving EF of the pelvis is the use of a large pelvic C-clamp. The C-clamp provides temporary EF that provides pelvic stabilization through pins secured to the anterior ilium, posterior ilium, or trochanter.[91–93] One benefit of the C-clamp is the ability to freely move the device around an axis. This device mobility affords improved imaging or access to the abdomen or pelvis as needed without compromise of device mechanical advantage or pelvic stability. The greater trochanter serves as an easily palpable bony landmark that allows for pin placement without fluoroscopic imaging. In addition, if a pelvic binder is in place, an access hole can be cut in the binder to facilitate pin placement and EF before binder removal.

Several cautions must be used with C-clamp use. The powerful ratcheting nature of the C-clamp creates the potential for overreduction of fracture.[93] Pins placed in the ilium risk comminuted posterior pelvic ring fractures, pin perforation through the ilium, and even dislodgement of pins into the sciatic notch.[94,95] Placing the pins in the posterior ilium can potentially interfere with future surgical sites. The smaller caliber pins used for C-clamp are not durable enough for definitive fixation and may loosen or even break over the course of a few days.[93] In addition, the application of a C-clamp makes it very difficult, if not impossible, to position the patient in subsequent lateral decubitus (Table 1).

# INTERNAL ILIAC ARTERY LIGATION

For select patients with severe hemodynamic instability, those in need of an immediate laparotomy for severe associated intra-abdominal injuries, or those in austere environments with no angiointerventional capabilities, a damage-control procedure may be the only available option for arrest of pelvic hemorrhage. In these instances, the use of bilateral internal iliac artery occlusion (BIIAO) may prove a useful adjunct. This approach includes a formal trauma laparotomy, management of any associated

**TABLE 1.** External Fixation Overview

| | Traditional External Fixator | Pelvic Clamp |
|---|---|---|
| Advantages | Universally available | Freely moving device allowing unimpeded access to abdomen, groin, perineum |
| Disadvantages | Statically positioned and may impede patient positioning | Not available at every trauma center |

| | Supra-acetabular Pins | Iliac Wing Pins | C-clamp | T-clamp |
|---|---|---|---|---|
| Advantages | Large bone corridor | Can be inserted without fluoroscopy | Very powerful | Can be inserted without fluoroscopy |
| Disadvantages | Requires fluoroscopy guidance | Small bone corridor | Requires fluoroscopy guidance | Cannot be used with proximal femur and acetabular fractures |

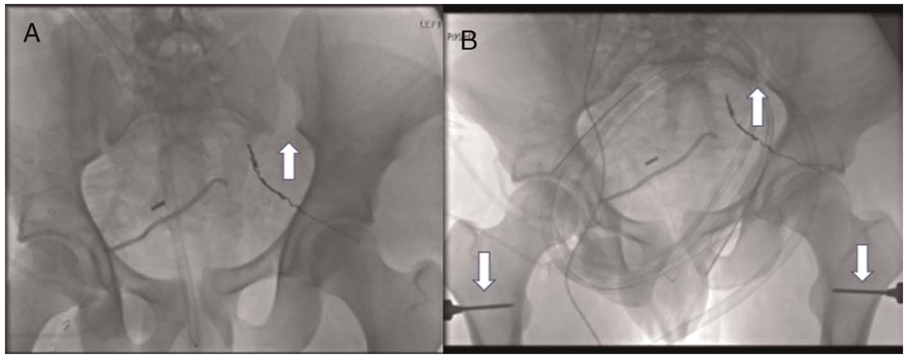


**Figure 6.** Before (*A*) and after (*B*) pelvic fracture reduction using EF under fluoroscopic guidance.

intra-abdominal injuries, exploration of the pelvic hematoma, occlusion of both internal iliac arteries, and direct packing of the fracture. In published experiences, BIIAO has been shown to reduce the internal iliac artery pressure-head flow to the pelvis with outcomes comparable with other damage-control techniques and without additional ischemia or reproductive system sequelae.[11]

## Rationale

There are three main rationales for exploratory laparotomy and BIIAO. First, patients with severe pelvic fractures have a high incidence of associated intra-abdominal injuries. In a single-center series of 1,545 patients with pelvic fractures, associated abdominal organ injuries were found in 30.7% of patients with severe pelvic fracture (Abbreviated Injury Scale [AIS] score, ≥4), including small bowel injury in 8.8%.[96] In another National Trauma Databank (NTDB) study of 3,221 patients with severe pelvic fracture (AIS score of 4 or 5), 34.3% had associated abdominal injury, including 16.7% with bowel injury.[97] Particularly among patients without a reliable examination or antecedent CT scan because of hemodynamic instability, laparotomy as part of emergent intervention mitigates the risk of missed intra-abdominal injuries.

A second reason to consider exploratory laparotomy and exploration of the pelvic hematoma with possible BIIAO is the appreciable incidence of injuries to the major iliac vessels in patients with severe pelvic fractures. In a 2009 NTDB study of 6,377 patients with moderate and severe pelvic fracture, iliac artery injury was identified in 3.5% of patients with severe pelvic fractures.[98] In a more recent NTDB study of 3,221 patients with severe pelvic fracture (AIS score of 4 or 5), 10.7% had common or external iliac vessel injury.[97] Exploratory laparotomy with potential BIIAO facilitates expedient control of this injury when they are identified.

A third reason for exploring the pelvic hematoma is the direct visualization of the bleeding areas and application of local hemostatic agents, which may significantly aid in hemostasis. Pelvic hematoma exploration has the potential to facilitate direct visualization of sources of hemorrhage and permit more precise positioning of these useful adjuncts.

It should be recognized, however, that there are potential complications that can occur related to the use of BIIAO in the setting of trauma. These include the potential for pelvic or gluteal necrosis or sexual dysfunction. Documented experience with this damage-control approach, however, appears to suggest that these complications are rare.[11]

## Technique

Bilateral internal iliac artery occlusion can be achieved using a standard laparotomy incision. The abdominal viscera are retracted cranially, and the iliac arteries may be accessed directly, by opening the pelvic hematoma, through the peritoneum or using a medial rotation of the cecum on the right side and the sigmoid colon on the left side. The hematoma is evacuated, and any obvious major bleeding from the large vessels is controlled with sutures, ligation, or repair. Proximal control of the common iliac artery is obtained, and the bifurcation is

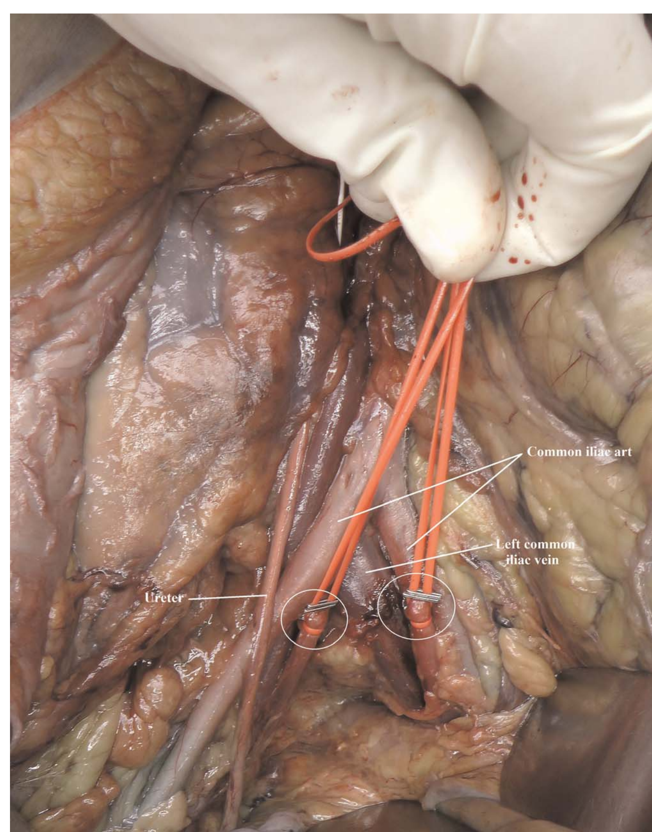


**Figure 7.** Bilateral internal iliac artery temporary occlusion with vessel loops (reproduced with permission from Demetrios D, Inaba K, Velmahos G, eds. *Atlas of Surgical Techniques in Trauma*. New York, NY: Cambridge University Press; 2019).

identified as the artery curves over the sacral promontory. The internal iliac artery is carefully dissected circumferentially. Posterior to the artery lies the iliac vein, and iatrogenic venous injury at this level can be hazardous. Care must also be taken to avoid the ureter, which crosses over the bifurcation of the common iliac artery. The internal iliac artery is encircled twice using a vessel loop. Tension is placed on the vessel loop to interrupt flow, and reversible occlusion is achieved using a large clip on the vessel loop to maintain traction. Alternatively, the internal iliac arteries can be occluded using surgical clips (Fig. 7).

Bilateral internal iliac artery occlusion is followed by application of local hemostatic agents and pelvic packing, with return to the operating room in 24 to 72 hours. Should AE be needed, the vessel loop ligatures or surgical clips may be removed in a hybrid suite to allow for passage of the endovascular wire and catheter into the internal iliac system. Once hemorrhage control is achieved and the patient returns to the operating room for definitive management and closure, the internal iliac arteries' vessel loops or clips are removed to reestablish flow.

## DISCUSSION

Available adjuncts for control of major pelvic hemorrhage constitute an array of potential interventions that can be used along a spectrum of early care environments from the field to the operating room/interventional suite. Each of these tools has valid rationales for use and can be safely and effectively used in support of hemorrhage control for this challenging population. It is important to recognize, however, that each of these adjuncts also requires appropriate expertise and capabilities to use effectively and safely.

Several recent examinations have contrasted the effectiveness of individual interventions against respective alternatives.[6–8,13] While important contributions to the understanding of optimal pelvic hemorrhage control, these investigations may not, however, adequately reflect clinical practice for the most challenging of pelvic hemorrhage cases. In these instances, tailoring of a progressive escalation of response from the emergency room to the operative theater may be required to achieve hemorrhage control. Accordingly, the synergistic employment of available pelvic hemorrhage adjuncts in a thoughtful algorithm of response may be required.

A recent review by Harfouche and colleagues[13] illustrates the potential challenges that might occur with defining the optimal order of a coordinated response to hemorrhage control following pelvic fracture. In this review of patients undergoing REBOA of the distal aorta for emergent hemorrhage control in the emergency department, 31.3% of patients required a second hemostatic adjunct and 30.6% required a third hemorrhage control intervention. Increasing numbers of interventions were associated with both higher transfusion requirements and complications. Among the 52 contributing centers to the used AORTA registry, there was considerable variation in practices across centers, with no specific algorithm of care proving superior to others in terms of complications or survival.

While the aforementioned AORTA registry data suggest that significant variations in actual clinical care exist, algorithms for the management of pelvic fracture with hemodynamic instability have been proposed. Tran et al.[18] from the Western Trauma Association published in 2016 a revised algorithm for care that incorporates all of the contemporarily available adjuncts for the arrest of pelvic hemorrhage. While this decision tool is both well referenced and thoughtfully created, the ability to extrapolate these recommendations to a wide array of trauma centers may be problematic. Key among the challenges is institutional resources and the availability of appropriate expertise for an emergent response.

The utilization of adjuncts for pelvic hemorrhage control has also continued to evolve since the publication of the Western Trauma Association algorithm[18] and the AAST multicenter study conducted by Costantini et al.[2] For example, the AAST study is marked by relative absence of both pelvic PPP and REBOA utilizations from their 2016 effort. More recent reports have documented increased enthusiasm for these interventions among leading trauma centers. In addition, hybrid operating rooms now afford a single location for the conduct of more advanced adjuncts such as EF, PPP, and REBOA without necessitating transition of the patient from the operating room to a traditional interventional radiology suite. These unique environments also afford the ability to combine AE and other procedures with other required operative procedures in a more seemless fashion. These innovations represent potential improvements in the expediency of care that have not yet been adequately studied.

Previous data sets regarding pelvic hemorrhage control are also characterized by the absence of crucial data required to understand the optimal timing, order, and conduct of hemostatic adjuncts. Available data do not adequately characterize the sequence of intervention and are limited by the ability to determine the relative impact of pelvic hemorrhage on subsequent mortality in the multiply injured patient with these fractures. For these reasons, additional multicenter study with appropriate granularity is required.

## SUMMARY

Pelvic fracture–related hemorrhage remains a significant challenge of modern trauma care that is associated with a mortality of more than 30%. While a variety of hemostatic adjuncts are available to modern trauma providers, there has been little change in this lethality over the last decade. Additional study is required to discern the optimal order and conduct of these procedures within an applicable algorithm designed to achieve improved outcomes.

### AUTHORSHIP

All authors contributed to the design, data/literature interpretation, construction, and editing of this review effort.

### DISCLOSURE

The authors declare no conflicts of interest.

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