Review Article

Management of Hemorrhage in Life-threatening Pelvic Fracture

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Abstract

Emergent life-saving treatment is required for high-energy pelvic fracture with associated hemorrhage and hemodynamic instability. Advances in prehospital, interventional, surgical, and critical care have led to increased survival rates. Pelvic binders have largely replaced military antishock trousers. The availability and precision of interventional angiography have expanded considerably. External pelvic fixation can be rapidly applied, often reduces the pelvic volume, and provides temporary fracture stabilization. Pelvic packing, popularized in Europe, is now used in certain centers in North America. The use of standardized treatment algorithms may improve decision making and patient survival rates. Active involvement of an experienced orthopaedic surgeon in the evaluation and care of these critically injured patients is essential.

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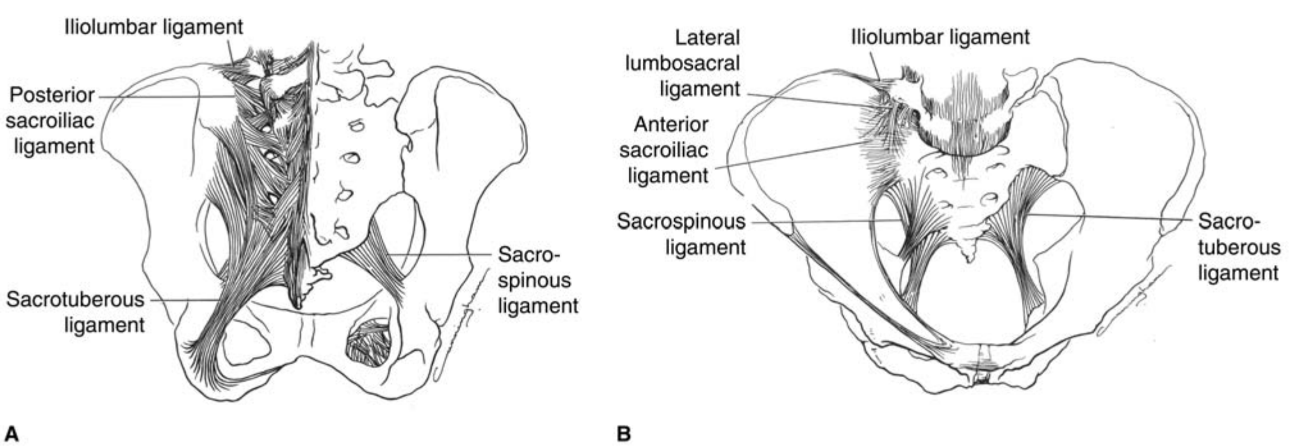
High-energy pelvic fractures are life-threatening injuries. Extensive bleeding associated with pelvic fractures is relatively common but is especially prevalent with high-energy fractures. Approximately 15% to 30% of patients with high-energy pelvic injuries are hemodynamically unstable, which may be directly related to blood loss from the pelvic injury.[1,2] Hemorrhage remains the leading cause of death in patients with pelvic fractures, with an overall mortality rate between 6% and 35% in large series of high-energy pelvic fractures.[1,3-6]

Bleeding associated with pelvic fractures requires efficient evaluation and rapid intervention. Evaluation and treatment of patients with pelvic fractures necessitates a multidisciplinary approach. Although the general surgery trauma specialist ultimately directs the treatment of the multiply injured person, it is important for the patient with pelvic fracture that the orthopaedic surgeon be involved in every phase of treatment, including primary resuscitation.[7] Early assessment by an orthopaedic surgeon familiar with pelvic fracture patterns allows the treatment team to establish diagnostic and treatment priorities, and it expedites the institution of life-saving maneuvers. A thorough understanding of potential sources of bleeding and an awareness of treatment options are essential for all physicians involved.

Anatomy

The pelvis is a ringlike structure made up of three bones: the sacrum and two innominate bones, each comprising the ilium, ischium, and pubis. The innominate bones join the sacrum posteriorly at the two sacroiliac joints; anteriorly, these bones are joined at the pubic symphysis. The symphysis acts as a strut during weight bearing to maintain the structure of the pelvic ring.[8]

Figure 1



Posterior **(A)** and anterior **(B)** view of the pelvic ligaments. (Reproduced with permission from Tile M, Helfet DL, Kellam JF, eds: *Fractures of the Pelvis and Acetabulum*, ed 3. Philadelphia, PA, Lippincott Williams & Wilkins, 2003, pp 13, 15.)

The three bones and three joints constituting the pelvic ring are stabilized by ligamentous structures, the strongest and most important of which are the posterior sacroiliac ligaments. These ligaments are made up of short oblique fibers that run from the posterior ridge of the sacrum to the posterosuperior and posteroinferior iliac spines as well as longer longitudinal fibers that run from the lateral sacrum to the posterosuperior iliac spine and merge with the sacrotuberous ligament. The anterior sacroiliac ligament is far less robust than the posterior sacroiliac ligament. The sacrotuberous ligament is a strong band that runs from the posterolateral sacrum and dorsal aspect of the posterior iliac spine to the ischial tuberosity. This ligament, along with the posterior sacroiliac ligaments, provides vertical stability to the pelvis. The sacrospinous ligament runs from the lateral edge of the sacrum and coccyx to the sacrotuberous ligament and inserts onto the ischial spine. The iliolumbar ligaments run from the fourth and fifth lumbar transverse processes to the posterior iliac crest; the lumbosacral ligaments run from the fifth lumbar transverse process to the sacral ala (Figure 1).

Major blood vessels lie on the inner wall of the pelvis. The common iliac artery divides, giving off the external iliac artery, which exits the pelvis anteriorly over the pelvic brim. The internal iliac artery lies over the pelvic brim. It courses anterior and in close proximity to the sacroiliac joint. The posterior branches of the internal iliac artery include the iliolumbar, superior gluteal, and lateral sacral arteries. The superior gluteal artery sweeps around to exit the greater sciatic notch, where it lies directly on bone. Anterior branches of the internal iliac artery include the obturator, umbilical, vesical, pudendal, inferior gluteal, rectal, and hemorrhoidal arteries. The pudendal and obturator arteries are anatomically related to the pubic rami and can be injured with fractures or injuries to these structures. These arteries and their associated veins can all be injured during pelvic disruption (Figure 2). An understanding of pelvic anatomy will help the orthopaedic surgeon recognize which fracture patterns are more likely to cause direct damage to major vessels and result in significant retroperitoneal bleeding.

Patient Evaluation

Complete evaluation of the patient with a high-energy pelvic fracture is

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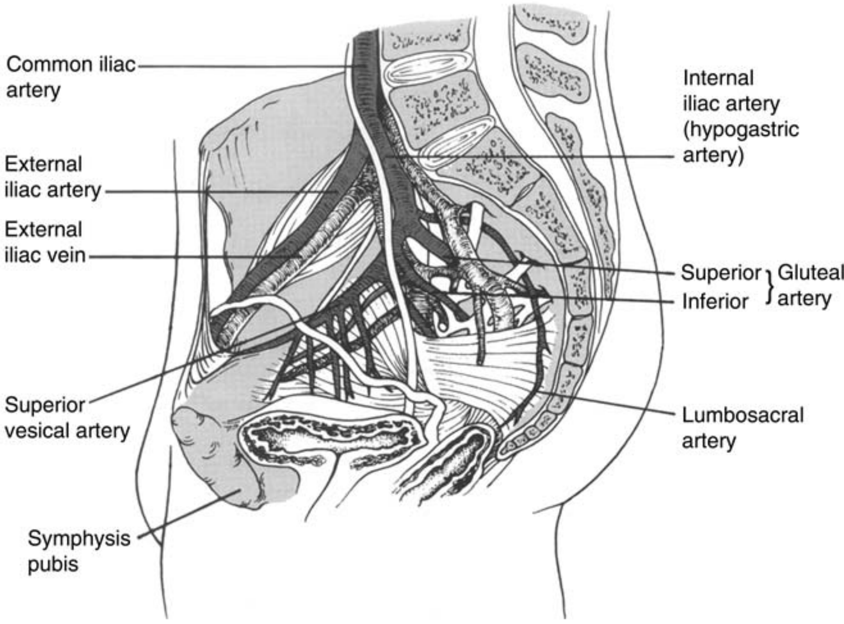
essential because this is rarely an isolated injury.[9,10] The same forces that lead to disruption of the pelvic ring are frequently associated with abdominal, head, and thoracic injury.[1,11] In addition to these injuries, 60% to 80% of patients with a high-energy pelvic fracture have other associated musculoskeletal injuries, 12% have urogenital injuries, and 8% have lumbosacral plexus injuries.[3,12]

A plan for simultaneous assessment and treatment of a patient with a high-energy pelvic fracture is required. An interdisciplinary team, including a general surgeon, an orthopaedic surgeon, a representative from the blood bank, and an interventional radiologist, is equipped to promptly assess and manage the spectrum of injuries associated with pelvic fractures. Priority should be given to the evaluation and treatment of airway, breathing, and circulatory problems. Evaluation and management of hypovolemic shock is mandatory as the airway and breathing are being stabilized.

Figure 2



Internal aspect of the pelvis showing the major blood vessels that lie on the inner wall of the pelvis. (Copyright © Jesse B. Jupiter, MD, and Bruce D. Browner, MD.)

Hypotension is associated with an increased risk of mortality, adult respiratory distress syndrome, and multiple organ failure.[1] Hypotension associated with blunt trauma may result from a variety of insults, including hypovolemic, septic, cardiac, or neurologic compromise. A rapid and systematic search for the source of the hypotension must be undertaken. Hemorrhagic shock is the most common cause of hypotension in blunt trauma patients. A patient can be hypotensive from blood loss associated with one bleeding site or a combination of many bleeding sites. Physical examination, chest radiographs, and tube thoracostomy will detect the presence and severity of intrathoracic blood loss. Physical examination of the abdomen may be unremarkable in the unresponsive patient. However, the intra-abdominal space must be excluded as a possible bleeding source in the patient who is hemodynamically unstable. Emergent evaluation is most commonly made by a focused abdominal sonography for trauma examination.

Bleeding from the pelvic fracture site is seldom the only cause of blood loss in the patient with multiple injuries, and massive bleeding from a pelvic fracture alone is uncommon. In one large series of patients with pelvic fractures, the major bleeding occurred at nonpelvic sites.[10] Nevertheless, pelvic fracture must be considered among the most prominent sites of significant bleeding in a hemodynamically unstable patient, particularly when initial attempts to control bleeding from other sources fail to stabilize the patient.[13] In cases of suspected pelvic fracture bleeding, provisional pelvic stabilization should occur immediately during initial evaluation and resuscitation. Provisional stabilization may consist of a pelvic binder or a simple sheet wrapped securely around the pelvis and secured with a sturdy clamp.

The severity of blood loss can be determined on initial evaluation by assessing pulse, blood pressure, and capillary refill. The Advanced Trauma Life Support classification system of the American College of Surgeons is useful for understanding the manifestations associated with hemorrhagic shock in adults[14] (Table 1). Blood volume is estimated at 7% of ideal body weight, or approximately 4,900 mL in a patient weighing 70 kg (155 lb).

Class I hemorrhage, defined as blood loss of <15% of total blood volume, leads to no measurable changes in heart or respiratory rates, blood pressure, or pulse pressure and requires little or no treatment. Class II hemorrhage is defined as blood loss of 15% to 30% of blood volume (750 to 1,500 mL), with clinical

Table 1

Advanced Trauma Life Support Classification of Hemorrhage[14]

Class	Average Blood Loss (mL)	Blood Volume (%)	Common Signs and Symptoms	Resuscitation Requirements
I	<750	<15	No changes in heart rate, respiratory rate, or blood pressure	None
II	750-1,500	15-30	Tachycardia and tachypnea; systolic blood pressure may be only slightly decreased; slightly reduced urine output (20-30 mL/hr)	Usually crystalloid solution alone, but some patients may require blood transfusion
III	1,500-2,000	30-40	Marked tachycardia and tachypnea, cool extremities with significantly delayed capillary refill, decreased systolic blood pressure, decreased mental status, decreased urine output (5-15 mL/hr)	Frequently requires blood transfusion
IV	>2,000	>40%	Marked tachycardia, significantly decreased systolic blood pressure, cold and pale skin, severely decreased mental status, negligible urine output	Life-threatening hemorrhage requiring immediate transfusion

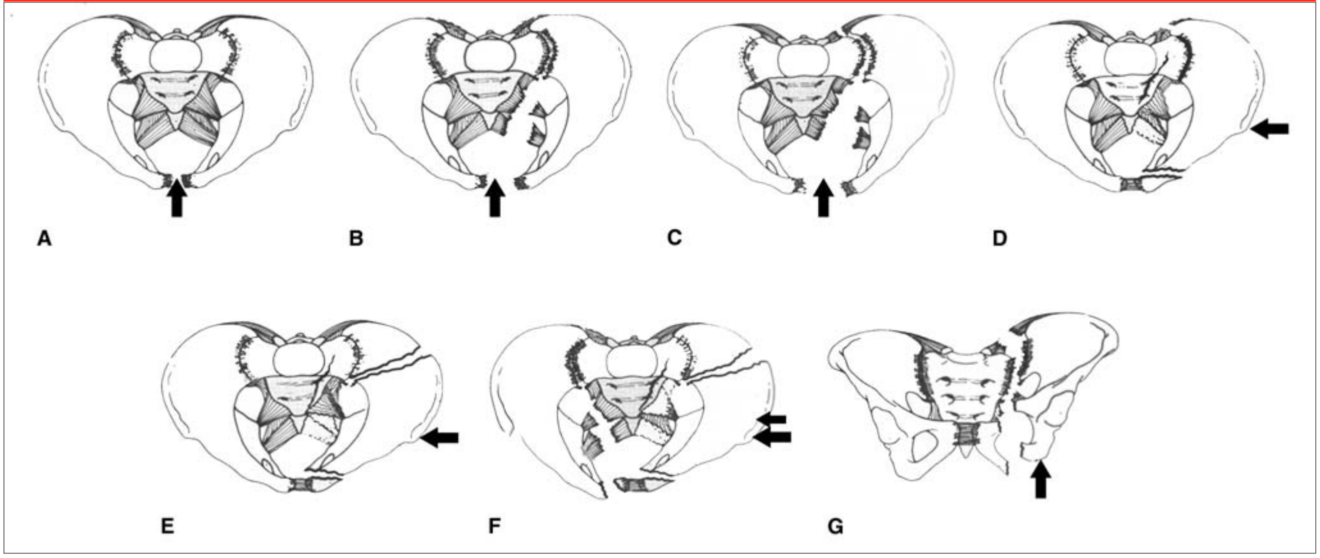
signs including tachycardia and tachypnea. Systolic blood pressure may be only slightly decreased, especially when the patient is in the supine position, but the pulse pressure is narrowed. Urine output is only slightly reduced (ie, to 20 to 30 mL/hr). The patient with a class II hemorrhage can usually be resuscitated with a crystalloid solution alone, but some patients may require blood transfusion.

Class III hemorrhage is defined as loss of 30% to 40% (1,500-2,000 mL) of blood volume. Inadequate perfusion in patients with class III hemorrhage results in marked tachycardia and tachypnea, cool extremities with significantly delayed capillary refill, hypotension, and significant negative changes in mental status. Class III hemorrhage represents the smallest volume of blood loss that consistently produces a decrease in systemic blood pressure. The resuscitation of these patients frequently requires blood transfusion in addition to administration of crystalloid solutions. Finally, class IV hemorrhage is defined as blood loss >40% of blood volume (>2,000 mL), representing life-threatening hemorrhage. Signs include marked tachycardia, significantly depressed systolic blood pressure, and narrowed pulse pressure or unobtainable diastolic blood pressure. The skin is cold and pale, and the mental status is severely depressed. Urine output is negligible. These patients require immediate transfusion for resuscitation and frequently need immediate surgical intervention.

The practice of grasping the iliac crests in search of palpable instability lacks sensitivity and specificity and rarely provides information that cannot be obtained on a single anteroposterior pelvic radiograph. Gross posterior disruption of the pelvis is usually evident on this view when the pelvis is fractured. Inlet and outlet views of the pelvis, which can provide more information about the presence and location of posterior ring injuries, should be obtained only after the patient has achieved hemodynamic stability. CT is extremely valuable for defining posterior ring instability. A rapid CT protocol for abdominal trauma evaluation can include cut scans through the sacrum and sacroiliac joints. The information from this study often helps direct early management because it may aid in defining the magnitude of the posterior ring injury. However, prolonged CT scanning in the acutely hypotensive patient should be avoided. Additional thin-cut CT scans may be indicated to further evaluate pelvic or acetabular fractures, but only after the patient is stabilized.

Contrast-enhanced CT imaging of the pelvis, which is often done in the hemodynamically stable trauma patient, is a noninvasive technique that has proved to be reasonably accurate in determining the presence or absence of ongoing pelvic hemorrhage. In a study comparing this methodology with findings on pelvic angiography, CT detected bleeding in 16 of 19 patients who had extravasation or vascular injury demonstrated by angiography, for a sensitivity of 84%.[15] Results of pelvic angiography were negative in 11 patients, and no patient had evidence of bleeding on

Figure 3



The Young-Burgess classification of pelvic fracture. **A,** Anteroposterior compression type I. **B,** Anteroposterior compression type II. **C,** Anteroposterior compression type III. **D,** Lateral compression type I. **E,** Lateral compression type II. **F,** Lateral compression type III. **G,** Vertical shear. The arrow in each panel indicates the direction of force producing the fracture pattern. (Copyright © Jesse B. Jupiter, MD, and Bruce D. Browner, MD.)

preangiographic CT scans. Two sites of contrast-agent extravasation identified by CT imaging in two patients did not show bleeding at angiography, for a specificity of 85% for the detection of bleeding. The overall accuracy of CT for determining the presence or absence of bleeding in this study was 90%.[15]

Classification Systems and Prognostic Value

Several classification systems have been devised to describe pelvic injuries based on the nature and stability of the pelvic disruption or on the magnitude and direction of forces delivered to the pelvis.[8,16-18] Each classification has been developed to provide guidance to general and orthopaedic surgeons about the type and likelihood of difficult management problems that might be encountered with each fracture type. Of these pelvic fracture classification systems, the one described by Young and Burgess[16] is most closely correlated with resuscitation needs and patterns of associated injuries. This system is based on a standard series of pelvic views, including an anteroposterior pelvis view and an inlet and outlet view, as described by Pennal et al.[17]

The Young-Burgess classification divides pelvic disruptions into anterior-posterior compression (APC), lateral compression (LC), vertical shear (VS), and combined mechanism (CM) injuries (Figure 3). The APC and LC categories are further subdivided from type I to III based on the increasing severity of the injury produced by increasing force magnitude. APC injuries are caused by an anterior impact to the pelvis, often leading to pubic symphysis diastasis. They are "open book" injuries that disrupt the anterior sacroiliac ligaments as well as the ipsilateral sacrospinous and sacrotuberous ligaments. APC injuries are considered to be good radiographic markers for the branches of the internal iliac vessels, which are in close juxtaposition with the anterior sacroiliac joint.

LC injury results from a lateral impact to the pelvis that rotates the pelvis on the side of the impact toward the midline. The sacrotuberous and sacrospinous ligaments, as well as the internal iliac vessels, are shortened and are not subjected to tensile forces. Disruption of large named vessels (eg, internal iliac artery, superior gluteal artery) is relatively uncommon with LC injuries; when this does occur, it is thought to result from laceration from fracture fragments.

VS injuries are distinguished by vertical translation of the hemipelvis. Displacement of the hemipelvis may be accompanied by severe local vascular injury. The CM injury pattern includes high-energy pelvic fractures produced by a combination of two separate force vectors.

The Young-Burgess classification of pelvic fractures and presumed force vectors has also been shown to correlate well with the pattern of organ injury, resuscitation requirements, and mortality.[1] In particular, a

Figure 4

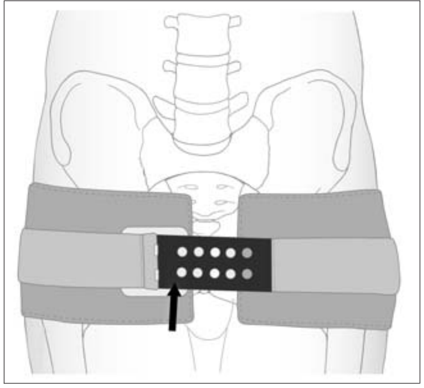


Illustration demonstrating proper application of a pelvic circumferential compression device (pelvic binder), with an adjustable buckle (arrow) to control tension. (Adapted with permission from Krieg JC, Mohr M, Ellis TJ, Simpson TS, Madey SM, Bottlang M: Emergent stabilization of pelvic ring injuries by controlled cicumferential compression: A clinical trial. *J Trauma* 2005;59:659-664.)

rise in mortality has been shown as the APC grade increases. The pattern of injuries seen in the APC type III fracture has been correlated with the greatest 24-hour fluid requirements.[1] In a series of 210 consecutive patients with pelvic fractures, Burgess et al[2] found that transfusion requirements for patients with LC injuries averaged 3.6 units of packed red blood cells (PRBCs), compared with a mean of 14.8 units for patients with APC injuries. In the same series, patients with VS injuries averaged 9.2 units, and patients with CM injuries had an average transfusion requirement of 8.5 units. The overall mortality rate in this series was 8.6%. A higher mortality rate was seen in the APC (20%) and CM (18%) patterns than in the LC (7%) and VS (0%) patterns. Burgess et al[2] noted that exsanguination from pelvic injuries resulting from lateral compression was rare, and the authors attributed death in patients with LC injuries to other causes. The most common identifiable cause of death in patients in this series with LC fractures was closed head injury. In contrast, the identifiable cause of death in patients with APC injuries was combined pelvic and visceral injury. These findings indicate that the ability to recognize the pelvic fracture pattern and the direction of the corresponding injury force can help the resuscitation team anticipate requirements for fluids and blood transfusion as well as help to direct early assessment and treatment. The patient with complete posterior instability can be anticipated to present with a severe hemorrhage.

Treatment Methods

Military Antishock Trousers

Military antishock trousers (MAST) can provide temporary compression and immobilization of the pelvic ring and lower extremity via pneumatic pressure. In the 1970s and 1980s, the use of MAST was advocated to induce pelvic tamponade and increase venous return to aid resuscitation.[19] However, MAST use limits abdominal examination and may cause lower extremity compartment syndrome or aggravate an existing one. Although still useful for stabilization of patients with pelvic fractures, MAST has largely been replaced by the use of commercially available pelvic binders.

Pelvic Binders and Sheets

Circumferential compression can be readily achieved in the prehospital setting and provides early, beneficial stabilization during transport and resuscitation. A folded sheet wrapped circumferentially around the pelvis is cost effective, noninvasive, and easy to apply.[20] Various commercial pelvic binders have been devised. A tension of about 180 N has been shown to provide maximum effectiveness.[21] One study reported that pelvic binders reduced transfusion requirements, length of hospital stay, and mortality in patients with APC injuries[22] (Figure 4).

External rotation of the lower extremities is commonly seen in persons with displaced pelvic fractures, and forces acting through the hip joint may contribute to pelvic deformity. Correction of lower extremity external rotation can be achieved by taping the knees or feet together, and this may improve the pelvic reduction that can be achieved with circumferential compression.

External Fixation

Standard Anterior External Fixation

Multiple studies have reported a benefit of emergent pelvic external fixation in the resuscitation of the hemodynamically unstable patient with an unstable pelvic fracture.[2,5,23] The beneficial effects of external fixation in pelvic fractures may arise from several factors. Immobilization may limit pelvic displacement during patient movements and transfers, decreasing the possibility of clot disruption. In certain patterns (eg, APC II), reduction of pelvic volume may be achieved by application of the external fixator. Experimental studies have shown that reduction of open book pelvic injury leads to increases in retroperitoneal pressures, which may aid in tamponade of venous bleeding.[24] Apposition of the displaced fracture can facilitate the hemostatic pathway to control bleeding from any raw bony surfaces.

C-Clamp

Standard external pelvic fixation does not provide adequate posterior pelvic stabilization. This limits its effectiveness in fracture patterns that involve significant posterior disruption or in cases in which the iliac wing is fractured. A posteriorly applied C-clamp has been developed to address these inadequacies. The clamp allows prompt application of a compressive force posterior across the sacroiliac joints. Extreme care must be exercised to avoid iatrogenic injury during its application; the procedure generally should be performed under fluoroscopic guidance.[25] Applying the C-clamp to the trochanteric region of the femur offers an alternative to standard anterior external fixation for provisional fixation of APC injuries.[26]

Angiography

Angiographic exploration should be considered in patients with continued unexplained blood loss despite pelvic fracture stabilization and aggressive fluid infusion. The overall prevalence of patients with pelvic fractures who require embolization is reported to be <10%.[2,27-31] In one recent series, angiography was performed in 10% of patients who sustained a pelvic fracture.[32] Patients who were older and who had a higher Revised Trauma Score were most likely to undergo angiography. In another study, 8% of the 162 patients reviewed by the authors required angiography.[2] Embolization was needed in 20% of APC injuries, VS injuries, and complex pelvic fracture patterns, but in only 1.7% of LC injuries. Eastridge et al[31] reported that 27 of 46 patients with persistent hypotension and a severely unstable pelvic fracture, including APC II, APC III, LC II, LC III, and VS injuries, had active arterial bleeding (58.7%). Miller et al[30] found that 19 of 28 patients with persistent hemodynamic instability attributable to pelvic fracture showed arterial bleeding (67.9%). In other studies, when angiography was performed, it was successful in stopping pelvic arterial bleeding in 86% to 100% of the cases.[5,29,31] Ben-Menachem et al[33] advocate "preemptive embolization," stressing that if an artery is found at angiography to be transected, it should be embolized to avoid the risk of delayed hemorrhage that can occur with clot lysis. Other authors describe nonselective embolization of bilateral internal iliac arteries to control multiple bleeding sites and concealed arterial injuries caused by vasospasm.[13]

Early angiography and subsequent embolization have been demonstrated to improve patient outcomes. Agolini et al[29] showed that embolization within 3 hours of arrival resulted in a significantly greater survival rate. Another study found that pelvic angiography performed within 90 minutes of admission improved survival rates.[34] However, aggressive use of angiography may cause ischemic complications.[35] Angiography and embolization are not effective in controlling bleeding from venous injuries and bony sites, and venous bleeding represents the preponderance of hemorrhage source in high-energy pelvic fractures. Time spent in the angiography suite for hypotensive patients without arterial injury may not contribute to survival.

Pelvic Packing

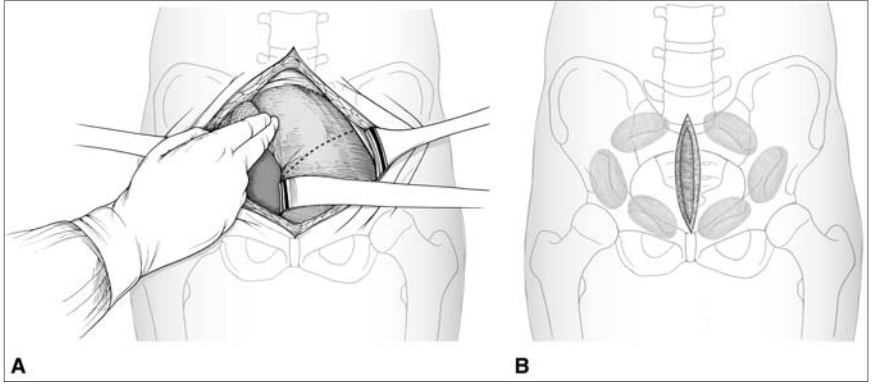
Pelvic packing was developed as a method to achieve direct hemostasis and to control venous bleeding resulting from pelvic fracture. For more than a decade, trauma surgeons in Europe have been advocating exploratory laparotomy followed by pelvic packing.[36] This technique is believed to be especially useful in patients in extremis. Ertel et al[37] showed that multiply injured patients with pelvic fractures can be safely treated using a C-clamp and pelvic packing without arterial embolization. Local packing was also effective in controlling arterial bleeding.

More recently, a modified method of pelvic packing—retroperitoneal packing—has been introduced in North America.[38] This technique facilitates control of retroperitoneal bleeding through a small incision (Figure 5). The intraperitoneal space is not entered, leaving the peritoneum intact to help develop a tamponade effect. The procedure is quick and easy to perform, with minimal blood loss. Retroperitoneal packing is appropriate for patients with a variety of severity of hemodynamic instability, and it can reduce unnecessary angiography. Cothren et al[39] reported no deaths as a result of acute blood loss in persistent hemodynamically unstable patients when direct packing was used. Only 4 of 24 nonresponders in this study required subsequent embolization (16.7%), and the authors concluded that packing can quickly control hemorrhage and reduce the need for emergent angiography.[39]

Fluid Resuscitation

Fluid resuscitation assumes critical importance as efforts are undertaken to determine and control the site of hemorrhage. Two large-bore (≥16-gauge) intravenous cannulas should be established centrally or in the upper extremities during the initial assessment. Crystalloid solution ≥2 L should be given over 20 minutes, or more rapidly in patients who are in shock. If an adequate blood pressure response is obtained, crystalloid infusion can be continued until type-specific or fully matched blood is available. Type-specific blood, which is crossmatched for ABO and Rh type, can usually be provided within 10 minutes; however, such blood may contain incompatabilities with other minor antibodies. Blood that has been fully typed and cross-matched carries the least risk of transfusion reactions, but

Figure 5



Illustrations demonstrating the retroperitoneal packing technique. **A,** An 8-cm midline vertical incision is made. The bladder is retracted to one side, and three unfolded lap sponges are packed into the true pelvis (below the pelvic brim) with a forceps. The first is placed posteriorly, adjacent to the sacroiliac joint. The second is placed anterior to the first sponge at a point corresponding to the middle of the pelvic brim. The third sponge is placed in the retropubic space just deep and lateral to the bladder. The bladder is then retracted to the other side, and the process is repeated. **B,** Illustration demonstrating the general location of the six lap sponges following pelvic packing. (Adapted with permission from Smith WR, Moore EE, Osborn P, et al: Retroperitoneal packing as a resuscitation technique for hemodynamically unstable patients with pelvic fractures: Report of two representative cases and a description of technique. *J Trauma* 2005;59:1510-1514.)

it also takes the most time to obtain (approximately 60 minutes).[14] When the response to crystalloid infusion is transient or blood pressure fails to respond, 2 additional liters of crystalloid solution are given, and type-specific or non–cross-matched universal-donor (ie, group O negative) blood is administered immediately. A lack of response indicates that ongoing blood loss is likely, and angiographic and/or surgical control of the bleeding may be needed.[14]

Blood Products and Recombinant Factor VIIa

Hypotensive patients who do not respond to initial fluid resuscitation require massive amounts of fluid subsequently, leading to deficiency of the hemostatic pathway. Therefore, all such patients should be assumed to require platelets and fresh-frozen plasma (FFP). In general, 2 or 3 units of FFP and 7 to 8 units of platelets are required for every 5 L of volume replacement.[14]

Massive blood transfusion has potential risks of immunosuppression, inflammatory effects, and dilutional coagulopathy. Thus, the optimal volume and relative requirements of blood products for resuscitation remain controversial. In addition, the amount of PRBC transfusion is an independent risk factor for postinjury multiple organ failure.[6,40] Some authors have proposed that coagulopathic trauma patients should be primarily resuscitated with more aggressive use of FFP, with a transfusion composed of PRBCs, FFP, and platelets in a 1:1:1 ratio to prevent early coagulopathy promotion.[7,41]

Recombinant factor VIIa (rFVIIa) may be considered as a final intervention when coagulopathy and life-threatening bleeding persist despite other treatment. This is an off-label use of rFVIIa. Boffard et al[42] performed a multicenter study in which severely traumatized patients who received 6 units of PRBCs within 4 hours of admission were randomized to either rFVIIa treatment or placebo. In the rFVIIa group, the number of red cell transfusions was significantly reduced (approximately 2.6 red blood cell units; $P = 0.02$), and there was a trend toward a reduction in mortality and complications.

Evaluation of Resuscitation Status

End points of resuscitation are determined based on the combination of laboratory data and physiologic signs. A hemoglobin level reading is known to be inaccurate during the acute phase of resuscitation. The commonly considered end points of resuscitation include normal blood pressure, decreased heart rate, adequate urine output (≥30 mL/hr), and normal central venous pressure.[14] However, even after normalization of these parameters, inadequate tissue oxygenation may persist. Additional laboratory measures that can be used to evaluate tissue oxygenation include base deficit, bicarbonate, and lactate. All of these assess anaerobic glycolysis. The terms base deficit and base excess are used interchangeably, the only difference being that base deficit is expressed as a positive number and base excess is expressed as a negative number. A normal base deficit is 0 to 3 mmol/L; this is routinely measured with an arterial blood gas analysis. A persistent base deficit suggests insufficient resuscitation.

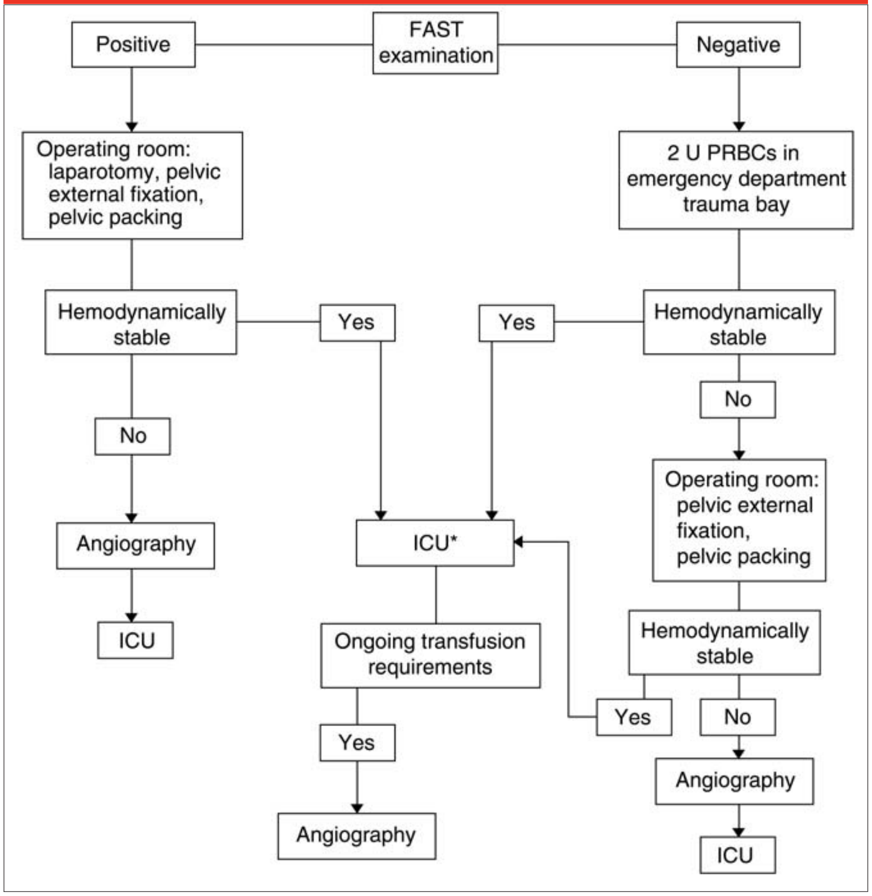
Treatment Algorithms and Survival Rates

Retrospective analysis of outcomes before the institution of treatment algorithms dramatically illustrates the pitfalls that these protocols seek to avoid. In one series, the deaths of 43 patients, representing 60% of the deaths in the series, were attributed entirely or in part to pelvic fractures.[9] Of the 26 patients in whom pelvic fracture was considered to be the primary cause of death, 24 were in shock or had clinical evidence of hypovolemia at the time of admission, and 18 exsanguinated from their pelvic fractures shortly after hospital admission.

The establishment of standardized clinical treatment algorithms for patients with pelvic fracture greatly increased the probability of rapid stabilization and survival.[22,29,30] Bosch et al[4] reported that implementation of a standard protocol at a trauma center led to a decrease in mortality associated with high-energy pelvic fractures from 66.7% to 18.7%. Biffl et al[7] reported that their clinical pathway, which included the immediate presence of orthopaedic attending surgeons in the emergency department, pelvic wrapping, and subsequent aggressive use of C-clamps, led to significantly decreased mortality, from 31% to 15% ($P < 0.05$). Balogh et al[34] established evidence-based institutional guidelines consisting of pelvic binding and abdominal clearance within 15 minutes, pelvic angiography within 90 minutes, and minimally invasive orthopaedic fixation within 24 hours. Use of this guideline reduced 24-hour PRBC transfusion volume from 16 ± 2 U to 11 ± 1 U ($P < 0.05$) and reduced mortality from 35% to 7% ($P < 0.05$).

Some algorithms are so complex that they may seem impossible to follow. One reason for this complexity is the myriad of variations in causes of shock and in sources of bleeding in patients with pelvic fractures. Also, treatment tends to be highly case-dependent. The other reason is that many treatment algorithms are established according to the capabilities of the institution for which they are developed. Although the fundamental principle of the protocols is useful, it may be necessary to modify the algorithms to fit the resources and staff expertise at each institution.

Figure 6



Algorithm for the treatment of patients with pelvic fracture who present with hemodynamic instability. *Patients in whom a laparotomy was not done usually have an abdominal CT scan en route to the intensive care unit (ICU). In the ICU, the patient receives further fluid resuscitation and is warmed; attempts are made to normalize the coagulation status. Recombinant factor VIIa should be considered if the patient is recalcitrant to all other interventions. FAST = focused abdominal sonography for trauma, PRBCs = packed red blood cells

The patient with a high-energy pelvic fracture who presents to our institution with hemodynamic instability is initially given 2 L of crystalloid solution (Figure 6). A portable chest radiograph, along with radiographic views of the pelvic and lateral cervical spine, are examined to rule out a thoracic source of blood loss. A central venous pressure line is placed, and base deficit is measured. A focused abdominal sonography for trauma (FAST) examination is performed. If the result is positive, the patient is taken directly to the operating room for an exploratory laparotomy. A pelvic external fixator is placed, and pelvic packing is performed. The patient who remains hemodynamically unstable undergoes pelvic angiography prior to transfer to the intensive care unit (ICU). If hemodynamic stability is restored, the patient is transferred directly to the ICU. In the ICU, the patient receives further fluid resuscitation and is warmed; attempts are made to normalize the coagulation status. If the patient requires ongoing transfusion while in the ICU, angiographic assessment, if not previously done, should be performed. Recombinant factor VIIa should be considered if the patient is recalcitrant to all other interventions.

If the FAST result is negative, transfusion of PRBCs is begun in the emergency department. If the patient remains hemodynamically unstable following the second unit of PRBCs, she or he is taken to the operating room for pelvic external fixation and pelvic packing. The patient who remains hemodynamically unstable undergoes pelvic angiography prior to transfer to the ICU. If hemodynamic stability is restored, the patient is transferred directly to the ICU. An abdominal CT scan can be performed at this time. If the patient requires ongoing transfusion while in the ICU, angiographic assessment, if not previously done, should be performed.

Summary

High-energy pelvic fracture combined with hemodynamic instability is among the most severe of traumatic injuries. Efficient, coordinated assessment and treatment are necessary to ensure the best chance for survival. Hemodynamic evaluation and recognition of the fracture patterns are the first steps in management. In many centers, the treatment paradigm consists of angiographic embolization along with early mechanical stabilization of the pelvis. Emergent pelvic packing may also be an effective treatment. Aggressive resuscitation, including the use of FFP and platelets, should be considered, as should the use of rFVIIa in patients whose bleeding is refractory to all other methods.

Successful management of pelvic fracture hemorrhage is best accomplished by a team approach involving professionals from a variety of specialties. The experienced orthopaedic surgeon can provide precise recognition of fracture patterns, achieve immediate pelvic stabilization, and assist with proper decision making to maximize patient survival.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. Most of the references cited in this article are level IV case series. Reference 42 is a level I study. References 7, 11, 13, 15, 16, 25, and 33 are review articles, textbooks, or expert opinion. References 24 and 26 are biomechanical/anatomic studies.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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