Chapter 55
Pelvic Trauma
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Perspective

Background

Patients with traumatic pelvic ring injury may represent an immense challenge for the emergency physician. First, patients with pelvic ring fractures are at risk for exsanguinating pelvic hemorrhage. Furthermore, the profound magnitude of force required to disrupt the pelvic ring frequently causes severe injuries to other organ systems. The resuscitation from hemorrhagic shock, rapid identification of other major injuries and sites of blood loss, and the coordination of definitive angiographic and surgical treatments are paramount to achieving good clinical outcomes.

Epidemiology

Based on data from trauma registries, the majority of high-energy pelvic ring injuries are caused by motor vehicle collisions (MVCs), motorcycle crashes, and pedestrians being struck by motor vehicles, together accounting for 80 to 84% of pelvic fractures; and falls from height, which account for 5 to 12% of pelvic fractures. The mortality rates reported in the literature associated with pelvic fracture range from 9 to 22%1-5; in studies of large cohorts of trauma patients, the presence of pelvic fracture has been consistently shown to be an independent risk factor for death compared with trauma patients without pelvic fracture.6-8 Patients with pelvic fractures and with shock on arrival to the hospital have mortality rates of 33 to 57%.3,4 Increased age, shock on arrival at the hospital, high injury severity and revised trauma scores (which generally reflect the presence of multisystem injuries), and the need for transfusion have all been shown to increase the risk of death.3-5,9,10 The mortality rate among pedestrians struck by motor vehicles who sustain pelvic injury has been shown to be 23%.11

Despite advances in motor vehicle safety design, MVCs continue to be a major cause of pelvic fracture. Rates of pelvic fracture secondary to MVC range from 10 to 28%.9,12,13 Lateral impact remains the most prevalent mechanism for pelvic trauma in collisions, for which the widespread advent of front airbags has little effect. Some have speculated that the increased popularity of sport-utility vehicles in past decades is contributing to the severity of side-impact injuries, specifically as a result of the higher bumper in these vehicles striking the side of lower cars.9,12,14

Principles of Disease

Anatomy

Detailed descriptions of pelvic anatomy may be found in standard anatomy texts. This section focuses on the relevant anatomy essential to understanding pelvic injuries.

Bony and Ligamentous Anatomy

The pelvic ring is made up of right and left innominate bones and the sacrum. The innominate bones consist of the pubis, ischium, and ilium (Fig. 55-1). The bony pelvis provides protection for its visceral contents, serves as attachment points for muscles, and transmits weight from the trunk to the lower limbs. The main weight-bearing forces are transmitted through the posterior wall of the pelvis, called the posterior arch, which is composed of thick bone and ligaments. The rich network of major arteries, veins, and nerves that course in front of the posterior arch may be injured concomitantly with forces causing bony injuries of this arch.

Knowledge of the ligamentous attachments of the pelvic ring is crucial to understanding how stability is maintained or disrupted in pelvic injury. The stability of the pelvis is maintained by ligaments, as well as the muscles and fascia that make up the pelvic floor. Anteriorly, the symphysis pubis provides the major mechanical stability. Posteriorly, a complex of strong ligaments—the sacrospinous, sacrotuberous, iliolumbar, and anterior and posterior sacroiliac (SI) ligaments—maintains the integrity of the posterior arch (Fig. 55-2). It is important to appreciate that mechanically unstable pelvic fractures are unstable primarily because of the disruption of these posterior ligaments.

Vascular Anatomy

Most of the blood supply to the pelvis comes from the left and right internal iliac arteries. The internal iliac arteries course at the level of the SI joints. The various arteries that derive from the internal iliac arteries initially run in close proximity to the posterior pelvic arch and eventually anastomose extensively with one another, forming a rich collateral network (Fig. 55-3). The superior gluteal artery is the largest branch and is commonly injured in fractures of the posterior pelvic arch. The obturator and internal pudendal branches are often injured in fractures involving the pubic rami.
The venous system also has many collateral branches and is without valves, allowing bidirectional flow. The veins are arranged in a plexus that adheres closely to the pelvic walls. Because these veins are thin-walled, they do not have the ability to constrict in response to damage. This anatomic arrangement of the arteries and veins accounts for the hemorrhage often seen with pelvic fractures.

**Neurologic Anatomy**

The cauda equina courses through the sacral spinal canal and exits through the sacral neural foramina to form the lumbar and sacral plexus. Injury to the posterior bony pelvis and sacrum may result in neurologic deficits in the lower extremities and autonomic dys-function involving the bowel, bladder, and genitalia.

**Pathophysiology and Key Patterns of Pelvic Fracture**

Numerous classification schemes exist for pelvic fractures. Two widely used schemes for pelvic injury are presented here. The classification by Tile stresses the biomechanical stability of the pelvic ring\(^\text{15}\) (Box 55-1). The Young-Burgess classification emphasizes the mechanisms of injury\(^\text{16}\) (Box 55-2). From a practical viewpoint, it is highly useful to consider both of these elements in the assessment of a pelvic ring fracture. Within both classification systems exist numerous subtypes of injuries, the interobserver
Box 55-1  Tile's Classification of Pelvic Fractures

**Type A**—Stable, posterior arch intact
- Includes avulsion fractures, isolated iliac wing fracture, pubic ramus fractures, minimally displaced ring fracture, transverse fractures of the sacrum or coccyx.

**Type B**—Partially stable, incomplete disruption of the posterior arch
- Includes anteroposterior injuries (open book) and lateral compression injuries. May be unilateral or bilateral. These injuries are rotationally unstable but vertically stable.

**Type C**—Unstable, complete disruption of the posterior arch
- Includes iliac, sacroiliac, and vertical sacral injuries that result from vertical shearing forces. May be unilateral or bilateral. These injuries are both rotationally and vertically unstable.


Box 55-2  Young-Burgess Classification of Pelvic Fractures

**Anteroposterior Compression**
1. Symphysis diastasis <2.5 cm
2. Symphysis diastasis >2.5 cm, sacrospinous and anterior SI ligament disruption, results in rotational instability
3. Symphysis diastasis >2.5 cm, with complete disruption of the anterior and posterior SI ligament, results in complete rotational and vertical instability

**Lateral Compression**
1. Sacral crush injury on ipsilateral side
2. Sacral crush injury with disruption of posterior SI ligaments; iliac wing fracture may be present (crescent fracture); rotationally unstable
3. Severe internal rotation of ipsilateral hemipelvis with external rotation of contralateral side (“windswep” pelvis), rotationally unstable

**Vertical Shear**
Vertical displacement of symphysis and sacroiliac joints resulting in complete rotational and vertical instability

**Combined Mechanisms**
Any combination of the above mechanisms


SI, sacroiliac.

reliability of which has been questioned.17,18 For the emergency physician, a good understanding of both the underlying principles of pelvic stability and mechanisms of injury is far more important than a detailed knowledge of the numerous subtypes of injury that exist within the classification schemes. The broad distinction of mechanically stable from unstable fractures of the pelvic ring is clinically useful to bear in mind in assessing patients, as it has been demonstrated consistently over time that those with unstable injuries have higher mortality and greater transfusion requirements.16,19,20

Stable Injuries (Tile Type A)

Fractures of individual bones without involvement of the pelvic ring represent one third of all pelvic fractures. In general, most stable pelvic fractures heal well with rest and analgesic drugs for pain control (Fig. 55-4).13

Undisplaced or Minimally Displaced Fractures of the Pelvic Ring. The normal pelvis is not totally rigid because of the slight mobility at the SI joints and symphysis pubis and the inherent elasticity of bone. A single break in the ring is possible. Nevertheless, the pelvis is not totally forgiving, and identification of a single break in the ring should prompt a search for a second disruption.

An isolated fracture of the superior or inferior pubic ramus is the most common pelvic fracture. These fractures are stable. They are common fractures in elderly people after a fall and should be considered in the evaluation of an acutely painful hip. Fracture of the body of the ischium is a rare injury that may result from a fall in the sitting position. These fractures around the obturator foramen are treated conservatively with bed rest, analgesia, and early mobilization.

Fracture of the superior and inferior pubic rami on the same side is a commonly encountered injury after a fall or MVC. These are generally stable fractures and are treated conservatively. However, the presence of significant displacement at the fracture site indicates a second disruption elsewhere in the pelvic ring that should be diagnosed. Alternatively, fractures of both rami on the same side may be associated with an unrecognized impaction fracture of the posterior pelvis.

If the patient with a ramus fracture reports posterior pelvic pain and plain radiographs do not reveal posterior injury, further investigations may reveal occult posterior fractures. A study performed more than 35 years ago found that patients who sustained apparently isolated pubic ramus fractures showed increased uptake of radionuclides on bone scans in the acetabulum and SI joint, suggesting that occult bony or ligamentous injury accounted for the pain.21 More recently, a study that prospectively evaluated elderly patients who were diagnosed with isolated ramus fractures on plain films found that 95% had sacral fracture detected by magnetic resonance imaging (MRI).22 This study does not imply a need to perform MRI on all elderly patients with ramus fractures in the ED; rather, it enhances our understanding of the pathophysiology of ramus fractures and underscores the importance of adequate analgesia in these patients. The lateral compression type I fracture described by Young and Burgess (Fig. 55-3)—characterized by pubic ramus fracture with ipsilateral sacral compression—bears special consideration among the mechanically stable pelvic fractures, as it has been shown to be associated with a mortality rate of 8% with a high incidence of associated injuries.23,24

Also termed a straddle fracture, four-pillar injuries involve fractures of both pubic rami on both sides of the symphysis pubis,
causing the so-called “butterfly segment” (Fig. 55-6). The injury is produced by a direct blow with a straddle mechanism. Although these fractures may occur without posterior arch disruption, four-pillar injuries are also commonly associated with lateral compression or vertical shear forces that may cause concomitant injuries to the posterior pelvic arch. CT of the pelvis is required in cases of four-pillar injuries to detect and classify precisely the posterior arch injury and plan orthopedic treatment. The genitourinary tract frequently is injured concomitantly with this type of pelvic fracture and should be evaluated carefully (see Fig. 55-6).

Isolated fracture of the iliac wing was described by Duverney in 1751 and now bears his name. It is caused by direct trauma to the iliac crest, usually by lateral compression forces. Although displacement is usually minimal because of the arrangement of the muscle attachments of the abdominal wall, orthopedic consultation is recommended. The fracture may extend into the acetabulum, altering the treatment and prognosis. Severely displaced fractures of the iliac wing require open reduction and internal fixation. It is worth noting that a high incidence of major associated nonpelvic injuries among patients with isolated iliac wing fracture has been reported.

Transverse Fractures of the Sacrum. Transverse fractures of the sacrum do not compromise the pelvic ring. Transverse fractures at or below S4 are unlikely to be accompanied by neurologic injury. An upper sacral transverse fracture is the result of a flexion injury, such as being struck on the lower back by a heavy load while bending over, or by direct forces to the sacrum, as in a fall from a great height. The patient reports pain in the buttocks, perirectal area, and posterior thighs. There may be local pain, swelling, and bruising overlying the sacrum, and on gentle bimanual rectal examination, severe pain, abnormal motion, and palpable hematoma may be elicited. Radiographically, the fracture may be difficult to visualize on anteroposterior (AP) and lateral projections, in which case a pelvic outlet view may be helpful. Simple transverse fractures at or below S4 are treated conservatively. Above S4, neurologic injuries are common, necessitating careful clinical evaluation and surgery when neurologic compromise is present.

Avulsion Fractures. These usually occur during athletic activities and are the result of a sudden, forceful muscular contraction or excessive muscle stretch. They are seen more commonly in older children and teenagers before closure of the corresponding physis occurs; adults may have the same symptoms from ligamentous injury at these sites without radiographic abnormality.

The ischial tuberosity may be avulsed during strenuous contraction of the hamstrings. There is pain on palpation of the involved tuberosity, and this pain is increased by flexion of the hip with the knee in extension (hamstrings stretched), but not with the knee flexed (hamstrings relaxed). Ischial tuberosity avulsion also may cause chronic discomfort with no history of acute injury. A portion of the iliac crest epiphysis may be avulsed by contraction of the abdominal muscles. Similarly, the anterior superior

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**Figure 55-5.** Young-Burgess classification. A, Lateral compression. Type I: A posteriorly directed force causing a sacral crushing injury and horizontal pubic ramus fractures ipsilaterally. Type II: A more anteriorly directed force causing horizontal pubic ramus fractures with an anterior sacral crushing injury and either disruption of the posterior sacroiliac joints or fractures through the iliac wing. Type III: An anteriorly directed force that is continued, causing external rotation of the contralateral side; the sacroiliac joint is opened posteriorly, and the sacrotuberous and spinous ligaments are disrupted. B, Anteroposterior (AP) compression. Type I: Symphysis disrupted but with intact posterior ligamentous structures. Type II: Continuation of a type I fracture with disruption of the sacrospinous and potentially the sacrotuberous ligaments and an anterior sacroiliac joint opening. Type III: Continuation force disrupts the sacroiliac ligaments. C, Vertical shear. Vertical fractures in the rami and disruption of all posterior ligaments. This injury is equivalent to an AP type III or a completely unstable and rotationally unstable fracture. Arrow indicates the direction of force. (Redrawn from Young JWR, Burgess AR: Radiologic Management of Pelvic Ring Fractures, Baltimore, Munich, Urban & Schwarzenberg, 1987. Browner BD: Skeletal Trauma: Basic Science, Management, and Reconstruction, 3rd ed. Copyright © 2003 Saunders, an imprint of Elsevier.)
iliac spine may be avulsed by forcible contraction of the sartorius muscle. Forceful contraction of the rectus femoris (as in kicking a ball) can result in the less common injury of anterior inferior iliac spine avulsion; however, this radiographic finding should be distinguished from a normal variant, the os acetabuli, which is a secondary center of ossification at the superolateral margin of the acetabulum.26 Clinical examination is similar in these injuries and reveals local pain, swelling, and limitation of motion.

Conservative treatment, including analgesia and bed rest in a position that avoids tension on the affected muscles, is generally all that is required for avulsion injuries; surgical treatment is rarely necessary. Orthopedic consultation is advised for follow-up care.

**Stress Fractures.** Stress fractures occur with vigorous athletic or military training and in the last trimester of pregnancy.27 The diagnosis of stress fractures is based on the clinical evaluation and can be confirmed, if required, by radionuclide bone scan, although MRI has been shown to be a superior method for detecting these injuries.28

**Pathologic and Insufficiency Fractures.** Pathologic fracture related to neoplasm, Paget’s disease, or dietary osteomalacia is included in the differential diagnosis. Radiation therapy has also been shown to increase the risk of pelvic fracture.

**Partially Stable and Unstable Injuries**

*Tile Types B and C*

Partially stable and unstable injuries are caused by high-energy impacts. The forces applied to the pelvis determine the types of injuries that occur. Broadly, forces may be applied to the pelvic ring in AP, lateral, or vertical directions that result in characteristic injury patterns; combinations of forces result in

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**Figure 55-6.** Four-pillar (straddle) fracture. A and B, Partial inlet view of pelvis shows straddle fracture. (1) and (2) Marked comminution of left pubic bone and comminuted right superior and inferior rami. This partial inlet projection shows displacement of fragments into the pelvis, which is not evident on the anteroposterior view of the same patient in C and D. A true inlet projection and computed tomography scan (not available) would provide further information about the posterior arch, which is injured frequently in straddle fractures and should be imaged (see text). C and D, Postvoid cystogram of the same patient with anteroposterior pelvis. (1) Fractures of pubic rami are seen again but do not appear to be as displaced compared with A and B because this projection is an anteroposterior view. Even minor degrees of angulation of the x-ray beam can change the appearance of pelvic fracture displacement. (2) Extravascular contrast indicates bladder rupture; (3) left acetabular fracture is seen in this projection but not in B because of the difference in projection. The acetabular fracture disrupts the ilioischial line (see also Fig. 55-13) and is a posterior column fracture.
more complex injuries. The terms unstable fracture (referring to mechanical stability) and unstable patient (referring to hemodynamic status) should not be confused, although a cause-and-effect relationship often exists.

Anteroposterior Compression. Severe AP compression forces result in disruption at or near the symphysis pubis. Symphysis widening of less than 2.5 cm is considered a stable injury (the symphysis should normally be ≤0.5 cm in an adult but can increase 2–3 mm during or after pregnancy); however, with continued force in the AP direction, the hemipelvis externally rotates, tearing the sacrospinous, sacrotuberous, and anterior SI ligaments. The SI joint opens and hinges on the intact posterior SI ligaments. The resulting injury is aptly described as an “open-book” fracture. The pelvis is rotationally unstable in the horizontal plane, but the intact posterior SI ligaments maintain vertical stability.\(^\text{15,16}\)

When diastasis of the pubic symphysis is greater than 2.5 cm on the AP radiograph, the posterior injury is usually seen as widening of the SI joint and occasionally as a sacral or iliac fracture (see Fig. 55-5).\(^\text{15}\) If the injurious forces continue, they may separate the hemipelvis, and the SI joint is seen as widely separated on the plain AP radiograph (Fig. 55-7) and the CT scan.\(^\text{15}\) The AP radiograph may be misleading in suggesting a pure open-book fracture in cases with symphysis disruptions greater than 2.5 cm. These cases commonly are associated with vertical shear fractures, and careful clinical and computed tomography (CT) assessment for vertical instability is essential to classify the fracture properly and plan treatment.\(^\text{15}\)

These same forces also may injure the neurologic and vascular structures at the posterior arch; the overall volume of the pelvis is increased in the open-book injury, facilitating the expansion of a retroperitoneal hematoma. Several studies have demonstrated that patients with severe grades of AP compression injuries have the highest crystalloid and blood requirements.\(^\text{16,19}\)

Lateral Compression. Lateral compression of the pelvic ring results in varying degrees of internal rotation of the affected hemipelvis. Initially, this causes buckling of the sacrum and horizontal pubic rami fractures. Rami fractures may occur on the ipsilateral or contralateral side, the latter being referred to as the “bucket-handle” fracture (Fig. 55-8).

As the magnitude of force increases, the symphysis may disrupt, causing overlapping of the pubic bones. Note that on plain radiographs, evidence of injury to the sacrum may be subtle; overlapping pubic bones with any significant displacement should prompt a search for a posterior injury.

Similar to the AP injury, with increasing disruption of the posterior ligaments comes increasing rotational instability. In the most severe lateral compression trauma, the ipsilateral pelvis internally rotates to such a degree that the contralateral pelvis may externally rotate. This is referred to as the “windswept” pelvis. Lateral compressive injuries result in varying degrees of horizontal rotational instability; however, the vertical stability of the pelvis is maintained (see Fig. 55-8).

As internal rotation causes the pelvic volume to decrease, lateral compressive injuries are generally associated with lesser degrees of blood loss than are AP injuries.

Vertical Shear. Vertical shear injuries represent the most unstable injuries to the pelvic ring and are associated with violent axial loading of the hemipelvis (e.g., fall from height, “submarining” underneath a dashboard). Fractures occur in vertical planes. Anteriorly, the symphysis and rami may be disrupted. Posteriorly, gross displacement and instability in the rotational and vertical planes may be present through the sacrum, the SI joint, or the ilium such that the hemipelvis may displace posteriorly and cephalad\(^\text{15,16}\) (see Fig. 55-9).

Avulsion of the ischial spine, the lower lateral lip of the sacrum, and the transverse process of the fifth lumbar vertebra (sites of insertion of ligaments) (Fig. 55-9 and Box 55-3) are important clues to the presence of vertical shear fractures.\(^\text{15}\) The vertical shearing forces transmitted through the bony pelvis are also transmitted through the rich vascular network and nerve plexus that are directly adjacent to the bone. This activity accounts for the major hemorrhage and neurologic injuries associated with vertical shear fractures.

Vertical Sacral Fractures. A crucial distinction in considering sacral fractures is that transverse fractures do not involve the pelvic ring, but vertical fractures do. Vertical sacral fractures are caused by high-energy injuries and were classified by Denis into three groups according to whether the fracture line extends (1) laterally to the sacral foramina, (2) through the foramina, or (3) medially to the foramina, involving the central spinal canal\(^\text{26}\) (Fig. 55-10). The radiographic diagnosis of this fracture hinges on careful examination of the symmetrical cortical lines that are normally present at the superior margins of the sacral foramina on the AP view. Disruption, distortion, or asymmetry of these lines is an important marker of sacral fractures.\(^\text{26}\)

There is a high risk of neurologic complications associated with these injuries: 6% when lateral to the foramina, 28% when through the foramina, and 58% when medial to the foramina.\(^\text{29}\) Neurologic dysfunction correlates to the nerve roots involved but may include any bowel, bladder, or sexual dysfunction. Surgery is commonly

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**Figure 55-7.** Interpretive drawing (A) and radiograph (B). Severe unilateral open-book fracture from anteroposterior compression forces that is also open (compound). (1) Separated pubic symphysis with asymmetry of hemipelvis, (2) normal sacroiliac joint, (3) separated sacroiliac joint, (4) cystogram with displacement and abnormally elongated shape of bladder caused by retroperitoneal hematoma associated with separated left sacroiliac joint, which has pushed the bladder to the right, (5) extravasated contrast into perineum from urethral rupture, (6) soft tissue air indicating an open fracture.
Pelvic fractures treated by direct manual pressure or pressure dressing. Pelvic fractures communicating with the rectum have traditionally mandated a diverting colostomy; however, a systematic review of the literature on this topic found no difference in infection rates between patients treated with colostomy and those treated without.32

Penetrating Pelvic Trauma
Because of the complex anatomy of the viscera, blood vessels, and nerves within the pelvis, penetrating trauma to this area presents a major challenge. Overall mortality in this group of patients has been reported to be 6 to 12%, but the mortality rate of patients in shock is 50%. 33,34 Vascular injuries singly and in combination may involve the aorta; common iliac artery; and external, internal, and common iliac veins. Injuries to genitourinary structures and hollow viscera may occur, with fecal contamination from colorectal injury being a major concern. When present, the finding of blood on DRE is an important clue that rectal injury has occurred. Emergent surgical consultation is required in all cases of penetrating pelvic trauma.

Open Pelvic Fractures
An open pelvic fracture is present when there is direct communication between the fracture site and a skin, rectal, or vaginal wound. These are potentially lethal injuries, especially if the open nature is not recognized: hemorrhage accounts for early mortality, but infection, sepsis, acute respiratory distress syndrome, and multisystem organ failure are all causes of delayed death.24,30 The majority of case series before 1991 reported mortality rates greater than 50%; rates reported from 1991 to 1999 ranged from 5 to 30%,30 although a recent series reported a 45% mortality rate.31

The skin over the posterior pelvis and gluteal area and perineum is inspected carefully for wounds. Some fractures are open only by virtue of a bone spicule penetrating the vagina or rectum and are identified by careful digital rectal examination (DRE) and vaginal examination. Hemorrhage from a large open laceration should be treated by direct manual pressure or pressure dressing. Pelvic fractures communicating with the rectum have traditionally mandated a diverting colostomy; however, a systematic review of the literature on this topic found no difference in infection rates between patients treated with colostomy and those treated without.32

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Figure 55-9. A and B, Vertical shear fractures bilaterally. At first glance the pelvis appears normal because of the smooth, uninterrupted arcuate line, but careful interpretation reveals the extremely critical nature of the injuries. (1) Fractures through the sacrum—note loss of definition and symmetry of sacral foramina, indicating vertical fractures through both sides of the sacrum (see computed tomography scan in D). (2) Transverse process fragment from right L5 (iliolumbar ligament attachment) is pathognomonic for a vertical shear fracture through the right sacrum. (3) Transverse process fragment from left L5, pathognomonic for a vertical shear fracture through the left sacrum. (4) Both hemipelvises are dislocated cephalad because of the double-ring fractures through each side of the sacrum. This dislocation explains why the L5 transverse processes appear so close to the iliac crests (the body of L5 is obscured because of rotational dislocation of the central free sacral fragment posteriorly and because of technique). (5) Normal sacroiliac joints. C and D, Computed tomography scan of same pelvis. (1) Bilateral comminuted fractures of sacrum with lateral displacement of both hemipelvises, (2) normal sacroiliac joints.

**Box 55-3** Radiographic Clues to Posterior Arch Fractures

- Avulsion of L5 transverse process*
- Avulsion of ischial spine*
- Avulsion of lower lateral lip of the sacrum (sacrospinalis ligament)*
- Asymmetry or lack of definition of bone cortex at superior aspect of the sacral foramina

*Indicates mechanical instability.

**CLINICAL FEATURES**

**History**

Understanding the mechanism of injury is an important means of determining a patient’s risk of having a pelvic fracture and, if present, the pattern and severity of the fracture. Low-energy injuries (e.g., fall on level ground) typically cause stable injuries to the pelvis; patients who have sustained high-energy injuries (e.g., MVCs, falls from heights) are at risk for unstable fracture patterns of the pelvis as well as associated injuries to other organ systems.

Determining the direction of forces applied to the pelvis can also give important clues to the types of injury sustained. AP forces (e.g., head-on MVCs) may cause open-book injuries to the pelvis. Lateral forces to the pelvis (e.g., side-impact collisions) may disrupt the posterior ligaments; however, the pelvic floor generally remains intact. Vertical shear injuries (e.g., falls from height) may disrupt the posterior ligaments and pelvic floor, causing gross instability of the pelvis.

Age is an important consideration in patients with pelvic fracture. Osteopenic bone may be disrupted by lesser forces. Furthermore, studies consistently demonstrate higher morbidity and mortality among elderly patients with pelvic fracture. Although pelvic hemorrhage remains an important consideration among elderly patients with pelvic fracture, higher mortality rates are further influenced by a greater prevalence of preexisting medical conditions in this population that increase the risk of death from multisystem organ failure. Decreased physiologic reserves in older patients may limit success in the acute resuscitation and definitive treatment of injuries.

Injuries to other organ systems are extremely common in patients with pelvic fracture. It is important to identify all major injuries to other organ systems to prioritize definitive surgical treatment for the multiply traumatized patient. In women, it is important to consider the possibility of pregnancy and to test for pregnancy whenever appropriate.
Physical Examination

On inspection, rotation of the iliac crests indicates a serious pelvic fracture. Leg-length discrepancy may suggest a hip injury or cephalad migration of an unstable hemipelvis. Careful inspection of the skin and skin folds is necessary to identify open fractures. Perineal or genital ecchymosis or hematoma may be observed, and in cases in which many hours have elapsed since the injury, ecchymosis in the periumbilical area (Cullen’s sign) or flanks (Grey Turner’s sign) from retroperitoneal hemorrhage may be present. Careful palpation of the pelvic ring to seek the presence of point tenderness is imperative; palpation starts at the symphysis anteriorly and proceeds to both pubic rami, the iliac spines and crests, and finally to the sacrum and SI joints posteriorly. The presence of tenderness in any of these locations is an important indicator of pelvic ring injury in alert patients without distracting injury.37

Manipulation of the pelvis during physical examination should be gentle and kept to a minimum. “Springboarding” of the pelvis (i.e., vigorous downward pressure on the anterior superior iliac spines) to assess the rotational stability of the pelvic ring should be strictly avoided, as this maneuver has the potential to disrupt any tenuous blood clotting that may have occurred around a fracture site and may therefore worsen hemorrhage.

The penis should be milked to examine for blood at the meatus. Although the value of the DRE has been questioned in the literature with claims that it has extremely low sensitivity as a diagnostic test, it remains useful as a screening tool.38 The DRE should evaluate sensation, sphincter tone, position and consistency of the prostate, presence of a presacral hematoma, bony contour of the sacrum and coccyx, mucosal penetration of bony spicules, and presence of frank or occult blood. In the setting of a pelvic fracture, female patients should undergo a vaginal examination to diagnose an open fracture. Because it is possible to create an open fracture iatrogenically through the vaginal or rectal wall, DRE and vaginal examination should be performed carefully, especially in an unconscious patient who cannot localize pain. The examiner should be mindful when performing these examinations that bony spicules can lacerate the examining finger. Extravasated urine may be detected in the scrotum or the subcutaneous tissues of the penis, vulva, or abdominal wall. The presence and quality of pulses in the lower limb should be assessed, as should sensation, strength, and deep tendon reflexes.

Associated Pelvic Injuries

Urologic Injury

The overall incidence of bladder or urethral disruption associated with any pelvic fracture is approximately 4 to 6%, with increased risk among those with severe pelvic injuries.2 Because the urethra is far less exposed in women than in men, injury to the urethra in women with pelvic fracture is rare.39,40

A review of 721 patients with pelvic fracture revealed an incidence of bladder rupture in 5% of patients. Those with fractures of the anterior arch of the pelvis are at greatest risk for bladder injury: diastasis of the symphysis more than 1 cm and fracture around the obturator ring with displacement greater than 1 cm were associated with a tenfold and threefold increased risk of bladder rupture, respectively.41

The presence of gross hematuria indicates injury of the lower urinary tract. Blood at the urethral meatus necessitates a retrograde urethrogram followed by a cystogram. Gross hematuria is investigated with a combination of urethrography, intravenous pyelography, cystography, and CT. The sequence and types of examinations are individualized for each patient. Fracture to the inferomedial pubic ramus and increasing symphyseal diastasis have both been shown to be predictive of urethral injury.42 Of note, it has been reported that retrograde urethrocystography done before CT of the pelvis may impair the ability of CT to detect extravasation of contrast that would indicate active pelvic bleeding.43 Therefore if CT is to be performed, it should be done before retrograde urethrocystography.

Sexual dysfunction in both men and women is a recognized complication of pelvic trauma. The incidence of impotence associated with urethral rupture is significant. In the absence of urethral injury, sexual dysfunction in men still may occur secondary to neurovascular disruption associated with the pelvic fracture.44

Neurologic Injury

The risk of neurologic injury has been shown to correlate with instability of the pelvic injury, with a reported incidence of neurologic dysfunction of 1.5, 3.8, and 14% in Tile type A, B, and C fractures, respectively; acetabular fractures were associated with a 10% incidence of neurologic dysfunction.45 Neurologic injury occurs commonly in patients with vertical sacral fractures or transverse fractures above the S4 level. Among patients with vertical fractures that involve the foramina, 28% have associated neurologic deficits. In patients with fractures medial to the foramina involving the spinal canal, 57% have neurologic deficits.29

Cauda equina syndrome and various plexopathies and radiculopathies may occur as follows. Injury to the L5 root may cause weakness of muscles in the anterior tibial compartment and sensory deficits in the dorsum of the foot and lateral calf. Injury to S1 and S2 roots may cause weakness of hip extension, knee flexion, and plantar flexion and sensory deficits on the posterior

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Figure 55-10. The Denis classification of vertical sacral fracture. Zone I is lateral to the sacral foramina (known as the sacral ala). Zone II is transforaminal. Zone III is the central sacrum medial to the foramina.
aspect of the leg, sole and lateral foot, and genitalia. Injury to S2-5 roots and distal afferent, efferent, and autonomic fibers causes sensory deficits in the perineum, sexual dysfunction, and bowel and bladder dysfunction. Cauda equina syndrome may be fully or partially present with sacral fractures. Hyperesthesia and later anesthesia occur in a saddle-shaped distribution in the groin; in addition, weakness of ankle plantar flexion, hamstrings, and gluteus muscles and decreased or absent ankle jerk are present. With involvement of the lower sacral roots, a neurogenic bladder with overflow incontinence, motor and sensory deficits in the lower extremities, anal sphincter dysfunction, and sexual dysfunction may occur. All patients with neurologic deficits from sacral fractures require orthopedic or neurosurgical consultation.

Gynecologic Injury

Blood at the introitus may indicate a urethral injury, open pelvic fracture, or local laceration without communication with the bony pelvis. Delayed urologic and sexual dysfunction and complications with pregnancy are common after pelvic injury. Gynecology consultation is indicated when there is injury to the female reproductive tract in association with a pelvic fracture and for all pregnant women who sustain pelvic fracture of any kind.

Associated Nonpelvic Injuries

The magnitude of force required to disrupt the pelvis commonly results in severe injuries to other organ systems. Among those patients who die with pelvic fracture, it is rare that the pelvic fracture is an isolated injury. Furthermore, associated injuries among trauma patients with pelvic fracture may contribute more to mortality than the pelvic injury itself.

Some authors have described patterns of associated nonpelvic injuries with certain patterns of pelvic fracture; however, these findings have not been consistently reproduced in the literature. Severe injuries to head, spine, thorax, and abdomen may occur with both stable and unstable pelvic fractures; they may all occur with all major mechanisms of pelvic injury. One associated injury that reflects the dispersion of enormous forces throughout the body is the rupture of the thoracic aorta; albeit uncommon in blunt trauma, it is five to eight times more likely to occur. All patients with neurologic deficits from sacral fracture should prompt a careful evaluation for other system injuries.

DIAGNOSTIC STRATEGY

Radiology

Plain Radiography

Routine radiographs of the pelvis are not necessary in cases of blunt trauma if the patient is asymptomatic, awake, and alert and has normal findings on physical examination of the pelvis. However, routine AP plain radiography of the pelvis (PXR) is advised by the Advanced Trauma Life Support (ATLS) guidelines for patients with severe mechanisms of injury who are symptomatic or whose examination is compromised by either decreased level of consciousness or distracting injuries.

On the AP radiograph, the symphysis pubis is normally no more than 5 mm wide, and a small (1- or 2-mm) vertical offset of the left and right pubic rami is normal. Overlapping at the symphysis pubis is abnormal and is the result of a severe crushing injury. Normally the SI joint is approximately 2 to 4 mm wide.

On the AP view, the physician may judge the degree of pelvic rotation caused by technique and positioning by the presence of asymmetry in the size and shape of the left and right obturator foramina and iliac wings. Diastasis of the SI joint also causes an asymmetrical appearance of the obturator foramina and the iliac wings: If there is displacement into external rotation, the affected iliac wing appears broader, and the anterior iliac spine appears more prominent. Avulsion fracture of the fifth lumbar transverse process by the iliolumbar ligament often accompanies an SI joint disruption or a vertical sacral fracture and is a valuable clue to posterior arch injuries (see Fig. 55-9 and Box 55-3).

Computed Tomography

CT is the imaging test of choice for evaluating the injured pelvis. CT provides detailed information about the posterior arch and rotational deformities that indicate the relative stability of the pelvic ring; furthermore, the acetabulum, which may be difficult to assess with plain radiographs, can be well visualized with CT. CT has demonstrated a much higher sensitivity and specificity than plain radiography in detecting pelvic fracture. Furthermore, abdominopelvic CT provides detailed information about concomitant injury to abdominal organs that aids in the planning of laparotomy, external fixation of the pelvis, angiography, and definitive orthopedic management of the pelvic injury. Finally, it has been demonstrated that selective CT scanning of the chest, abdomen, and pelvis in patients who sustain high-energy trauma results in a high miss rate of important diagnoses that alter treatments plans versus “pan” CT scanning (i.e., including all of the head, neck, chest, abdomen, and pelvis). It should be noted that the decision to “pan” CT scan should be based on a combination of factors, such as abnormal vital signs, neurologic status, the detection of injuries on clinical examination, and the patient’s mechanism of injury. Clinical judgment should guide the decision, to avoid wasting resources and unnecessarily exposing patients to radiation.

Given the speed with which current CT scanners are able to obtain images, unless patients require immediate lifesaving surgical treatment in the operating room, it is recommended that all patients with high-energy mechanisms of injury with suspected pelvic fracture or pelvic fracture confirmed by PXR undergo CT investigation.

The reliability of the single AP PXR to detect pelvic fractures has been questioned in the literature. Two case series have reported sensitivities of only 64 and 68% with specificities of 90 and 98%, respectively, thus prompting the question of whether PXR is necessary at all when patients are to undergo immediate abdomino-pelvic CT evaluation. In particular, sacral fractures and SI joint disruptions are not well visualized on the AP view. However, the addition of inlet and outlet views of the pelvis has been shown to increase the sensitivity and specificity of plain radiographs in detecting significant pelvic fracture (Fig. 55-11) and SI joint disruption and should be considered in all patients with presumed stable anterior pelvic ring injuries with any complaints of posterior pelvic pain.

When patients are too unstable to undergo CT investigation, the AP PXR is useful in screening for pelvic injuries that are most associated with major blood loss and potentially require urgent intervention. That is, although PXR may miss many fractures, a very abnormal PXR is predictive. Findings that predict the need for transfusion include open-book fracture or displacement of 0.5 cm or more at any fracture site in the pelvic ring and displaced symphysis pubis, displaced obturator ring fracture, or obvious vertical displacement in the posterior pelvis. It is important to note that all of these signs may be associated with posterior pelvic injury. Therefore the PXR remains a vital test when CT cannot be immediately performed and should be used to alert both surgeons and angiographers of the potential need for definitive management of pelvic hemorrhage.
Evaluation of Hemorrhage

Hemorrhage is the most devastating direct complication of pelvic fracture. In the original series of high-energy pelvic injuries used to formulate their classification system, Burgess and colleagues analyzed blood transfusions and found that an average of 14.8 units were required in the AP compression group, 9.2 units in the vertical shear group, and 3.6 units in the lateral compression group. The correlation between transfusion requirements and type of pelvic fracture has been confirmed in more recent studies that demonstrate that unstable fracture patterns increase the need for transfusion and risk of mortality, with one series reporting a median of 10 units of blood required (range 1-70 units).

Major pelvic hemorrhage results from lacerations of the rich vascular network supplying the pelvis in the retroperitoneal space. Pelvic hemorrhage is commonly venous in origin and may be contained and tamponaded retroperitoneally by an intact peritoneum. However, it is possible for bleeding to extend beyond the retroperitoneum and dissect into the anterior abdominal wall (to the chagrin of the unwary clinician who introduces a scalpel or peritoneal dialysis catheter) or through the peritoneum into the abdomen.
abdominal cavity (see later). Bleeding also may occur from the
marrow at the fracture sites.66 Finally, coagulopathy is another
cause of persistent retroperitoneal bleeding and should be consid-
ered when the patient does not respond to fluid and blood
replacement.

The combination of both pelvic and intra-abdominal bleeding is
associated with devastating outcomes.63 In one large series,
major pelvic injury was associated with intra-abdominal injuries in
31% of cases; the liver and spleen were injured in 10 and 6% of
these cases, respectively.7 In the patient with pelvic fracture who is in shock, it is important to establish early whether there
is hemorrhage within the abdominal cavity necessitating laparo-
otomy. Diagnostic strategies for evaluation of pelvic fracture–
associated hemorrhage include diagnostic peritoneal lavage (DPL), ultrasound, and CT. Regardless of the modality of evalu-
ation, it is crucial to avoid unnecessary laparotomy because of
the higher mortality rate for hemodynamically unstable
patients with pelvic fractures who undergo a negative abdominal
exploration.

Diagnostic Peritoneal Lavage

DPL is a widely accepted, rapid, and accurate means of establish-
ing the presence of intra-abdominal hemorrhage. Although it has
been largely supplanted in many centers by ultrasound and CT,
DPL nevertheless remains an effective tool to assist with difficult
triage decisions in the trauma patient. A pelvic fracture presents a
special situation for DPL because of the possibility that a retro-
peritoneal hematoma may dissect into the anterior abdominal
wall. However, when a fully open technique is used (i.e., the peri-
toneum is entered under direct visual control), the false-positive
and false-negative rates are each 0.7%.87

DPL may be performed in the infraumbilical location in most
patients; however, the supraumbilical location should be used if
any of the following conditions are present: prior abdominal scars,
time delay since the injury of more than 1 hour, or a hematoma
encountered during the procedure.82

A negative peritoneal aspirate indicates that the peritoneal
cavity is not a major source of bleeding or a significant contribu-
tor to hemorrhagic shock. If external and thoracic sources of blood
loss and spinal cord injury have been eliminated as causes of
hemodynamic instability, a negative peritoneal aspirate in a patient
with a major pelvic fracture indicates pelvic hemorrhage. A com-
bination of angiography with rapid therapeutic embolization,
surgical packing of the pelvis, and mechanical fracture stabiliza-
tion should be pursued.

Gross aspiration of blood indicates possible major intra-
abdominal hemorrhage, and laparotomy is recommended at the
earliest opportunity for hemodynamically unstable patients.47 The
lavage that is positive by cell count criteria alone is a special situ-
ation. If these patients are hemodynamically unstable, it is advis-
able to perform angiography with therapeutic embolization and
external pelvic fixation before laparotomy.66,87

Ultrasound

Focused assessment with sonography in trauma (FAST) is widely
used to identify free intraperitoneal fluid in the trauma patient.
An important caveat to note is that FAST is not helpful for evaluat-
ing the retroperitoneal space where pelvic hemorrhage occurs.
Although a positive FAST study that shows free fluid is widely used
as a triage point to decide on laparotomy in a hemodynamically
unstable patient, its reliability in patients with major pelvic injury
has been questioned. Sensitivities ranging from 24 to 81% and
specificities ranging from 87 to 96% for the detection of hemo-
peritoneum have been reported49,65 in patients with pelvic fracture;
the presence of pelvic fracture has been reported to be a predictor
of a false-negative FAST examination, with an odds ratio of 3.5
(95% confidence interval 1.3-9.2).79

Although these reports come from retrospective case series—
and therefore do not necessarily represent the highest levels of
evidence—the high incidence of false-negative FAST examina-
tions reported in the literature in patients with pelvic injury is
nonetheless cause for concern. This is because pelvic and intra-
abdominal hemorrhages are highly associated and in combination
result in major blood loss.63

Computed Tomography

CT is unquestionably the diagnostic test of choice for detecting
pelvic and intra-abdominal injuries. It reveals bleeding in both
the peritoneal and retroperitoneal spaces. CT with intravenous
contrast often can distinguish a stable hematoma from ongoing
bleeding from pelvic arteries. The presence or absence of extra-
vasated intravenous contrast material on CT scan of the pelvis is
useful in predicting which patients will require therapeutic angiography51; however, its absence does not rule out ongoing pelvic bleeding: One series found the sensitivity for the detection of
arterial bleeding by CT to be only 66% in patients who also underwent angiography.72 It is worth noting that with improving CT technology, its use will continue to evolve for
patients with pelvic hemorrhage. Specifically, pelvic CT angiog-
raphy (CTA) has been reported to not only localize active pelvic
bleeding but also distinguish bleeding from an arterial versus a
venous source.73,74 This is a distinction that could have great
impact on the decision to perform therapeutic angiography for
active arterial bleeding. Advancing CT technology will require
further study to define its role in patients with pelvic hemor-
rhage, but it is likely that it will also be concurrently incorporated
into clinical practice.

MANAGEMENT

Resuscitation

The mortality rate in patients with blunt trauma who have the
combination of pelvic ring fractures and hemorrhagic shock is
approximately 50%.47 ATLS guidelines advocate the initial use of
crystalloid solutions to stabilize vital signs in the trauma patient.
However, when severe hypotension is present in patients with
severe pelvic fracture, transfusion of blood products (including
packed red blood cells, plasma, platelets, and occasionally cryopre-
cipitate) is crucial early in the resuscitation. Some patients appear
to achieve hemodynamic stability after minimal volume infusion
only to decompensate precipitously. It is important to note that
case series commonly report patients with severe pelvic injury
who require transfusion of packed red blood cells on the order of
10 to 20 units within the first 24 to 48 hours.

The endpoint for fluid resuscitation should be evidence of
end-organ perfusion. A large body of evidence from animal
studies suggests that standard volumes of crystalloid fluids typi-
cally used in traumatic hemorrhagic shock to restore normal
heart rate and blood pressure lead to greater volumes of blood
loss compared with low-volume resuscitation strategies that
accept lower systemic blood pressures.75,76 Furthermore, in a
landmark human study of hypotensive patients with penetrating
chest injury, it was shown that delaying fluid resuscitation
(despite systolic blood pressure below 90 mm Hg) resulted in a
higher rate of discharge from the hospital than did immediate
fluid resuscitation.76a

For patients with pelvic fracture, attempts to achieve a normal
pulse and blood pressure with fluid resuscitation in the ED are
unrealistic and should not delay more definitive treatments to halt
the hemorrhagic process.
Lower limb intravenous sites should be avoided in patients with severe pelvic fractures because the infused products may be delivered to the retroperitoneal space.

Box 55-4 details the methods for controlling hemorrhage in the ED phase of the care of patients with pelvic fractures.

**Control of Hemorrhage**

In addition to blood transfusion, two important therapeutic modalities for control of hemorrhage are mechanical stabilization of the pelvis and angiographic embolization. There has been some debate as to which of these modalities should take precedence, and this has been predicated on institutional availability. As a general rule, angiography with therapeutic embolization of bleeding arteries is more effective than and takes precedence over invasive external fixation.\(^{77,78}\)

**Box 55-4** Pelvic Fracture–Related Hemorrhage: Goals in the Emergency Department

1. **Resuscitation**: Recognize the patient who is in hemorrhagic shock, and initiate blood transfusion early in the resuscitation.
2. **Recognition**: Realize that patients with posterior arch injuries are at higher risk for pelvic hemorrhage.
3. **Evaluation**: Identify associated nonpelvic injuries (especially head, chest, and intra-abdominal) that contribute immensely to increase in mortality in patients with pelvic fracture.
4. **Stabilization**: Wrapping the pelvis in a sheet and towel clamps is the easiest way to immobilize the pelvis in the emergency department. Stabilization by external fixation or pelvic C-clamp should be performed by orthopedic surgeons.
5. **Control of pelvic bleeding**: Angiography is highly effective in treating pelvic arterial hemorrhage. Pelvic packing during laparotomy is another way of controlling bleeding. Institutional practices determine if one or both techniques are used.

**Stabilizing the Pelvis**

**Noninvasive Techniques.** The most readily available means to quickly stabilize the pelvis in the ED may be realized with a simple sheet and towel clamps. Wrapping the pelvis tightly with a sheet and securing this with towel clamps has been shown to be effective in reducing an open-book pelvic injury (Fig. 55-12),\(^{79,80}\) thereby reducing the potential volume in the pelvis for blood loss. A technique of taping the lower extremities in internal rotation has also been described as a means of achieving a closed pelvic reduction in the presence of symphyseal diastasis.\(^{81}\)

Other commercial circumferential compression devices have been developed to facilitate noninvasive stabilization of the pelvis. Generally speaking, in cadaveric studies, it appears these devices are effective at reducing the open-book pelvis.\(^{82,83}\) One retrospective comparison of patients with exsanguinating pelvic hemorrhage found that patients treated with a noninvasive splinting device had substantially lower transfusion requirements than those who had formal external fixation of the pelvis performed emergently (4.9 units vs. 17.1 units in the first 24 hours, \(P = .008\)). However, there was no statistically significant change in mortality between the two groups (26% vs. 37%, \(P = .11\)).\(^{84}\)

Patients who have sustained AP open-book injuries are likely to derive the most benefit from tight wrapping of the pelvis. This maneuver may not be desirable when lateral compression forces have already internally rotated the hemipelvis because indiscriminately forceful wrapping may, in fact, worsen the degree of displacement. Here, some judgment is required to discern whether one is wrapping the pelvis to reduce the volume of an externally rotated pelvis versus splinting a pelvis to minimize pelvic movement that may occur, especially when the patient is transferred.

**Invasive Fixation.** External fixation of the pelvis is performed by orthopedic surgeons. The goal of fixation is to prevent movement at pelvic fracture sites and attendant bleeding.\(^{15}\) Although the acute application of an external fixator has not been proved to

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**Figure 55-12.** A, Circumferential pelvic antishock sheeting is applied in this example patient. The patient’s clothing should be removed before application. The sheet is positioned beneath the patient’s pelvis smoothly. The ends of the sheet are crossed in an overlapping manner anteriorly (B) and are pulled taut (C). Clamps secure the smooth and snug sheet (D).
decrease morbidity or mortality in a prospective study, there is evidence that this technique improves clinical outcome by limiting hemorrhage and restoring mechanical integrity. Application of the fixator is time-consuming; therefore it should not delay more definitive treatment of pelvic bleeding by angiography or the treatment of other sources of severe blood loss. The timing of the application of the external fixator requires coordination among the trauma surgeon, orthopedic surgeon, and interventional radiologist. Early surgical consultation is vital to efficient planning and prioritization of surgical management.

Many stable AP and lateral compression fractures can be treated definitively by the external fixator. When the pelvis is vertically displaced, traction combined with external fixation is necessary to reduce the pelvis pending definitive open surgical repair. Most fixators can be constructed to allow convenient surgical access to the abdomen and groin.

The pelvic C-clamp is one type of external fixation device that can theoretically be applied rapidly by the orthopedic surgeon in the ED to externally stabilize the posterior pelvic arch on an emergency basis. It is likely more effective in reducing AP than vertical injuries. Institutional practices may influence the use of C-clamp over standard external fixation. Although the C-clamp may aid in stabilizing blood loss, its application does not obviate the need for angiography. It is unclear whether the C-clamp offers any additional advantage over wrapping the pelvis with a sheet during initial resuscitation efforts.

The specific mode of invasive fixation will be institution specific and will rely heavily on the experience of the treating orthopedic surgeons.

Angiography and Embolization

Arteriography and venography have been investigated for managing hemorrhage associated with pelvic fractures. Although pelvic bleeding is commonly venous in origin, venography is not useful in managing these cases; the extensive anastomoses and valveless collateral flow make embolization ineffective. In contrast, arteriography is excellent at both diagnosing and managing arterial bleeding.

Arteriography is performed with the contrast material injected through the femoral artery on the less-injured side or via the upper extremity. The examination starts above the level of the aortic bifurcation and proceeds to selective branches of the internal iliac (hypogastric) artery. Transcatheter embolization with thrombogenic coils, foam, or spherules is used to stop the hemorrhage from the branches of the internal iliac artery.

Embolization is highly effective for controlling arterial bleeding. One case series of 556 patients undergoing pelvic angiography reported that repeat angiography was necessary in only 7.5% of patients as a result of ongoing bleeding. These authors found that hypotension, a need for more than 2 units of packed red cells, syncope widening, and more than two arteries embolized at the first angiogram predicted the need for repeat angiography.

Angiography is indicated when hypovolemia persists in a patient with a major pelvic fracture despite control of hemorrhage from other sources. Although it is impossible to determine whether bleeding is venous or arterial in origin until angiography is performed, one study found that inadequate response to initial resuscitation (defined as failure to maintain a systolic blood pressure above 90 mm Hg after the administration of 2 or more units of packed red cells or less) and the presence of contrast extravasation on admission CT were both indicative of active arterial bleeding. Although the presence of contrast extravasation on CT is an indication for angiography, the absence of contrast blush on CT is not sufficient to rule out serious pelvic bleeding. SI joint disruption, persistent systolic blood pressure below 100 mm Hg, and female gender were shown to be predictors of need for embolization at the time of angiography.

The timing of angiography is individualized for each patient depending on priorities for treatment of concomitant injuries. Posterior arch disruptions are associated with the most severe hemorrhage; angiography should be considered at an early stage for these patients. Whether patients undergo angiography immediately from the ED or angiography immediately precedes laparotomy, it is important to be mindful of the logistical delay that often occurs in mobilizing the angiography team, so this intervention should be anticipated as early as possible. The transfer of the patient to the angiography suite also requires orchestrating the necessary personnel and equipment to care for the critically injured patient there. The feasibility of use of mobile angiography equipment in the ED for acutely controlling pelvic hemorrhage has been reported; this removes the usual logistic delays while ensuring a greater degree of safety in monitoring patients during the procedure.

Hemodynamically Unstable Patients with Pelvic and Intra-abdominal Hemorrhage

Patients who hemorrhage from both the pelvis and the abdomen have mortality rates above 40% and deserve special consideration. These patients may be too unstable to undergo CT imaging. Prioritizing the need for laparotomy versus angiography in these patients may be challenging when the need for laparotomy is based on the detection of intra-abdominal fluid by FAST or DPL. Unnecessary laparotomy performed in patients who are hemodynamically unstable with pelvic fracture has been shown to contribute to high mortality rates. Therefore in these cases, it is crucial that the efforts of the general surgeon, orthopedic surgeon, and interventional radiologist be coordinated to optimize the timing of necessary procedures.

Gross aspirates of blood on DPL are strong indicators for prompt laparotomy. Given the high rates of false-negative FAST examinations in pelvic trauma, caution should be used in making difficult triage decisions regarding laparotomy versus angiography on the basis of FAST findings in this setting. However, when the FAST examination does reveal hemoperitoneum, it is generally accepted that laparotomy be pursued first. When concurrent pelvic bleeding is highly suggested (e.g., severe open-book pelvis), it is advisable that angiography promptly follow laparotomy.

At the time of laparotomy, it may be appropriate for the orthopedic surgeon to place either an external fixator or a pelvic C-clamp. Packing of the pelvis at the time of angiography has been reported as a means to obtain hemostasis in pelvic hemorrhage. Although there is limited evidence from clinical studies to support packing, it has become a mainstay of treating pelvic hemorrhage at some centers, especially in Europe. Part of the rationale for use of packing rather than angiography is the fact that pelvic bleeding is commonly venous in origin, for which arteriography is useless. In contrast, packing may aid in tamponading bleeding from the posterior venous plexus. It is recommended that the pelvis be stabilized before packing to provide solid structural support against which packing may be performed. Intraperitoneal, retroperitoneal, and extraperitoneal techniques of packing have been described, with authors reporting retroperitoneal and extraperitoneal approaches being rapidly done even in the ED setting. A systematic review of pelvic packing concluded that for patients with hemodynamic instability caused by pelvic hemorrhage, packing could be used as a temporizing measure for control of bleeding until more selective treatments could be performed.

When FAST or DPL does not reveal hemoperitoneum in the presence of severe pelvic fracture, emergent angiography should
be arranged. If pelvic bleeding continues despite angiography (i.e., secondary to venous bleeding), open stabilization and packing should be considered as the next step.

For any trauma center, planning for challenging clinical situations by emergency physicians, trauma surgeons, and angiographers and the creation of protocols for care may be useful in optimizing a timely and coordinated response.\(^\text{78,97,98}\)

**Acetabular Fractures**

Many pelvic fractures in adults involve the acetabulum. Pain and inability to bear weight are the hallmark complaints associated with acetabular fractures. On clinical examination, tenderness with percussion of the heel of the foot or medial pressure on the greater trochanter is an important clue to the presence of an acetabular fracture. It is important to note the presence of neurologic deficit, as the sciatic nerve is commonly injured. A common mechanism of acetabular injury is the so-called “dashboard” injury whereby the knee of a person seated in the front seat of a car strikes the dashboard in sudden deceleration, driving the head of the femur into the acetabulum; as a result, concurrent fracture or dislocation of the patella (or both) are common.

Acetabular fractures are broadly classified into three types\(^\text{15}\) (Fig. 55-13 and Box 55-5).

Type A fractures may be subdivided into anterior and posterior column injuries. Posterior wall fractures are the most common acetabular injuries and are generally caused by a forceful impact to a flexed knee (e.g., dashboard injury)—the force is transmitted up through the femur through the posterior acetabulum. An associated posterior dislocation of the hip is frequently associated with posterior rim fracture of the acetabulum and may result in an unstable hip joint and recurrent dislocation. Posterior hip dislocation is commonly associated with secondary sciatic nerve injury. The anterior column of the acetabulum is commonly injured when a superior ramus fracture extends into the low anterior column.

Type B fractures involve both anterior and posterior columns, but a portion of the acetabulum remains attached to the ilium. When the columns are split, this is referred to as a T fracture. The T fracture is associated with the worst prognosis, owing to the difficulty in obtaining open anatomic reduction.

Type C fractures are readily apparent on plain radiographs as a result of disruption of the ilium.

Assessment of the AP pelvic radiograph should focus on the ilioischial and iliopsoas lines as well as the anterior and posterior lips of the acetabulum (Fig. 55-14). Ramus fractures should be evaluated for possible extension into the acetabulum. Oblique views of the acetabulum (Judet views) can aid in visualizing the anterior and posterior columns. CT is, without question, the imaging test of choice for visualizing acetabular fractures and planning for possible surgical repair. It is important to note that because fracture of the acetabulum often occurs with a high-energy mechanism, even patients with isolated acetabular fractures may have significant hemorrhage necessitating blood.

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**Box 55-5** Classification of Acetabular Fractures

- **Type A**: Fractures of one column of the acetabulum (anterior or posterior column).
- **Type B**: Transverse (T-type) fractures involving both anterior and posterior columns; portion of acetabulum remains attached to proximal ilium.
- **Type C**: Transverse (T-type) fractures through both anterior and posterior columns; no portion of acetabulum remains attached to axial skeleton.


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**Figure 55-13.** Universal classification of acetabular fractures. A, Type A: Fractures of one column or one wall, for example, posterior column (left) and anterior (right) column. B, Transverse or T-type fractures involving both columns but by definition leaving a fragment of articular cartilage attached to the proximal ilium and, thus, to the axial skeleton. C, Type C: Two-column fracture of the acetabulum. By definition, no portion of the articular surface remains attached to the axial skeleton because fracture of both columns of the ilium is proximal to the joint. (From Tile M: Fractures of the Pelvis and Acetabulum, 3rd ed. Philadelphia, Lippincott, Williams & Wilkins, 2003.)

**Figure 55-14.** Schematic drawing of radiographic anatomy of acetabulum in anteroposterior pelvis projection. (a) Arcuate (iliopectineal) line. (b) Iliioischial line. (c) Radiographic U, or teardrop, caused by superimposition of parasagittal surface of ilium onto anteroinferior portion of acetabulum. (d) Acetabular roof. (e) Anterior lip of acetabulum. (f) Posterior lip of acetabulum. (Redrawn from Rogers LF, Novy SB, Harris NF: Occult central fractures of the acetabulum. AJR Am J Roentgenol 124:98, 1975.)
transfusion. All patients with acetabular fracture require orthopedic referral in the emergency department.

**Coccyx Fractures**

Fractures of the coccyx occur frequently after a fall in the sitting position or a kick. Fracture and injury also may occur during parturition. Physical examination reveals local tenderness to palpation in the gluteal crease, with pain and sometimes abnormal motion of the coccyx during palpation on DRE. Normally, the tip of the coccyx moves 30 degrees anteriorly and 1 cm laterally. Displacement also is diagnosed on rectal examination, but attempts at reduction are not recommended.

Radiographic confirmation of a coccygeal fracture is not always necessary. Displaced fractures often are seen on the lateral view, but the diagnosis is evident on rectal examination. Undisplaced fractures may be difficult to show radiographically. The physician must decide whether the knowledge gleaned from radiographic studies would alter the therapy to a degree that warrants radiation exposure to the pelvis, especially considering that most of these fractures occur in women.

Treatment of coccygeal fracture consists of bed rest, stool softeners, analgesia, and sitz baths to relieve muscle spasm. As activity is increased, maneuvers that may minimize discomfort include use of an inflatable rubber donut cushion, alternate sitting on the side of each buttock, slouching to displace body weight more proximally, and sitting on a hard chair rather than a soft one (sinking into a soft chair may distribute weight onto the coccyx). Because of muscle action on the fragment, healing is slow and patients should be cautioned that discomfort may be prolonged. In the case of persistent severe disability, an orthopedic consultation is indicated for considerations of local steroid injection or possible coccyctomy. Other causes of coccydynia (besides fracture) include trauma during parturition; faulty posture; midline disk herniations (caused by nonsegmental referral of pain from irritation of the dura); lumbar facet arthropathy; compression of the first, fourth, and fifth sacral roots; neuralgia from sacral plexopathy or sacrococcygeal neuropathy; infections; and local tumors.

**KEY CONCEPTS**

- The most serious pelvic ring injuries caused by high-energy impact include (1) AP compression fractures (open book), (2) vertical shear fractures, and (3) any fractures that involve significant displacement. These are associated with major blood loss and transfusion requirements.
- Pelvic injury is a marker for serious injury of other organ systems. The vast majority of patients who die with pelvic fracture are those who have sustained multiple trauma.
- Careful examination of the skin in the perineum and buttocks and digital rectal and vaginal examinations are necessary to diagnose open fractures because these are associated with the highest mortality rates.
- CT is the imaging test of choice to diagnose pelvic fracture and concurrent intra-abdominal injuries for patients stable enough to undergo CT. CT aids in establishing surgical priorities and planning of definitive orthopedic care. The presence of contrast extravasation with modern CT imaging is a subject of ongoing research with respect to localizing pelvic bleeding and distinguishing between arterial and venous sources.
- In the hemodynamically unstable patient who cannot undergo CT imaging, the AP radiograph usually reveals serious pelvic fractures that result in major pelvic bleeding. Inlet and outlet radiographs improve the sensitivity and specificity of pelvic plain radiography.
- The combination of posterior arch fracture plus hypotension is associated with a mortality rate of approximately 50%. Early fluid resuscitation with blood products is recommended for patients suspected to have active pelvic bleeding.
- Trauma hospitals should have institutional guidelines and mechanisms to facilitate early decisions regarding the treatment for pelvic hemorrhage that may include angiography and embolization, pelvic packing, invasive fixation, or any combination of these.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.
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