Diagnosis and Management of Pelvic Fractures

Richard McCormack, M.D., Eric J. Strauss, M.D., Basil J. Alwattar, M.D., and Nirmal C. Tejwani, M.D.

Abstract

The diagnostic and therapeutic modalities utilized in the management of pelvic ring fractures depend on patient characteristics, mechanism of injury, and hemodynamic status at the time of presentation. Knowledge of the complex anatomy and biomechanics of pelvic stability may guide appropriate initial management strategies. Even with the development of specific treatment algorithms and advances in both diagnostic and operative techniques, fractures of the pelvis continue to cause significant morbidity and mortality. The current paper reviews the diagnosis and management of pelvic ring fractures, focusing on current concepts with respect to initial assessment and treatment protocols, including the identification of associated injuries and emergency methods of provisional pelvic stabilization.

Since the initial description of a "double vertical" fracture as a combination of pubic rami fractures and a fracture of the iliac wing by French surgeon Joseph Malgaigne in his 1859 atlas of traumatology, pelvic fractures have received a considerable amount of attention in the orthopaedic literature, having to do with their complexity and associated morbidity and mortality.[1]

Classic anatomic and biomechanical studies in pelvic disruption, performed during the mid-20th century by George F. Pennal,[2] a Canadian surgeon, helped define the three main types of pelvic fractures "by direction of force": lateral compression (LC), anteroposterior compression (APC), and vertical shear (VS). That these categories are still used in pelvic fracture classification systems is testimony to Pennal's work. During this time-period and up until the mid-1970s, pelvic injuries generally were managed nonoperatively, using compression devices, plaster casts, and bed rest. Over time, outcome studies demonstrated that posttraumatic anatomic deformities and pelvic instability correlated with persistent pain and functional limitation.

The poor outcomes associated with conservative management of pelvic fractures spurred the development of various operative treatment strategies for these injuries. Expanding indications for pelvic fracture surgery coupled with improved techniques and instrumentation helped reduce the morbidity and mortality associated with pelvic trauma in the 1970s and 1980s. During the last two decades, advances in radiographic imaging, critical care management of the polytrauma patient, and minimally invasive surgical approaches, as well as the development of specific treatment algorithms, have continued to improve the outcomes seen in pelvic fracture patients.

Epidemiology

Incidence

Fractures of the pelvic ring have been reported to comprise 2% to 8% of all skeletal injuries[3-6] and are often associated with high-energy trauma, most commonly, motor vehicle accidents and falls from a height. The incidence of pelvic fracture appears to be increasing, secondary to increases in the number of high-speed motor vehicle accidents and the number of patients surviving these accidents, due to airbags and safer car designs. Among multiply injured patients with blunt trauma, almost 20% have pelvic injuries.

A classic epidemiologic assessment of pelvic fractures presenting to the Mayo Clinic was reported by Melton and

Richard McCormack, M.D., is a Resident; Eric J. Strauss, M.D., is Assistant Professor, Division of Sports Medicine; Basil J. Alwattar, M.D., at time of submission, was a Chief Resident; and Nirmal C. Tejwani, M.D., is Associate Professor, Division of Orthopaedic Trauma in the Department of Orthopaedic Surgery at the NYU Hospital for Joint Diseases, NYU Langone Medical Center, New York, New York.

Correspondence: Nirmal C. Tejwani, M.D., Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, 301 East 17th Street, New York, New York 10003; nirmal.tejwani@nyumc.org.

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colleagues.[7] The overall reported incidence in this patient cohort was 37 per 100,000 person-years. Among patients 15 to 25 years of age, the incidence was significantly greater in males compared to females, with the majority associated with severe trauma. After age 55, there was an exponential increase in the incidence of pelvic fracture in both genders, with elderly females having a reported incidence of 446 fractures per 100,000 person-years. A similar incidence of 24 fractures per 100,000 person-years was reported by Ragnarsson and Jacobsson[8] in their review of cases presenting to a Swedish center over a 10-year period. Once again, high-energy, unstable pelvic fractures were more common among younger male patients, while lower energy, stable fracture types were seen with increased incidence among elderly females. Gansslen and coworkers[9] in a multicenter study out of Germany, reported on 3260 pelvic fractures treated over a 3-year period. These investigators also identified a bimodal distribution of injuries, with peaks in frequency occurring in patients aged 15 to 30 years and those 50 to 70 years old. Higher-energy, unstable Tile type C fractures were more commonly seen in the younger patient population.

Open pelvic fractures in which direct communication exists between a skin, vaginal, or rectal wound and the fracture site have been reported to comprise 2% to 4% of all pelvic injuries.[4,10,11] They are most commonly seen in young males involved in traffic accidents and range from small puncture wounds to complete traumatic hemi-pelvectomy. Secondary to the transmission of the high-energy impact associated with open pelvic fracture, there is often disruption of the pelvic floor musculature, leading to the loss of the tamponade effect and persistent bleeding.[5] Even with standardized treatment protocols, aggressive fracture care, and advances in critical care, the mortality rates associated with open pelvic fractures remain as high as 25% to 50% in some reported series.[12-15]

Associated Injury

Secondary to the high-energy mechanisms of injury required to cause a pelvic fracture, these injuries are commonly associated with injuries to other body systems. Epidemiologic studies have reported that 12% to 62% of patients with pelvic fractures had additional injuries to the thorax, brain, long bones, and abdominal organs, to include the genitourinary system, spine, and the peripheral nervous system.[9,16,17] In Gänsslen's multicenter review, of the 312 pelvic fracture patients with associated injuries, 63% had injury to the bladder or urethra, 35% had associated head injuries, 24% had nerve injuries, and 20% had intestinal injuries.[9] Basta and associates[18] found the location and displacement of anterior pelvic fractures were predictive of the presence of urethral injury in a case control study of pelvic fracture patients with and without associated urethral injury. They observed that each millimeter of pubic diastasis or inferomedial pubic bone fracture fragment displacement was associated with a 10% increased risk of urethral injury.

Mortality

Mortality rates associated with pelvic fractures range from as low as 5% to 10% to as high as 50% to 60% in the orthopaedic surgery and trauma literature.[9,11,14,16,19,20] This variability in reported mortality rates is likely related to significant differences in patient cohorts and fracture types reported in these studies. Hemodynamic instability and multiple organ failure (MOF) as direct consequences of pelvic hemorrhage have been identified as the primary causes of death following pelvic fracture. Smith and colleagues[19] reported an overall mortality rate of 21% in their review of 187 hemodynamically unstable patients with pelvic fractures. Among patients who did not survive their injuries, autopsy findings demonstrated that the principal cause of death in 74% was exsanguination, while MOF was the primary cause in 18%. The investigators found that, while fracture pattern and treatment with angiography-embolization did not correlate with mortality, Injury Severity Score (ISS), Revised Trauma Score (RTS), age (greater than 60 years), and transfusion requirement (more than 6 units in the first 24 hours) were directly correlated. Demetriades and coworkers[16] reported a 16.5% mortality rate among their 1545 pelvic fracture patients. In their study, an ISS greater than 25 was identified as the only risk factor associated with increased mortality. O'Sullivan and associates[21] examined 174 consecutive patients with unstable pelvic fractures in an effort to identify specific risk factors for mortality. The investigators reported an overall mortality rate of 20% and found that an ISS of more than 25, an RTS score less than 8, an age greater than 65, systolic blood pressure under 100 mmHg, a Glasgow Coma Scale under 8, transfusion requirements of more than 10 units in the first 24 hours, and a colloid infusion of more than 6 liters in the first 24 hours were all associated with an increased risk of death from injury. The RTS was most predictive in this study, with a score less than 8 correlating with a 65% mortality rate.

Kido and colleagues[22] performed a retrospective review of 102 consecutive patients with bleeding pelvic fractures and severe associated injury (ISS greater than or equal to 3) at their level I trauma center, to identify patient characteristics associated with increased early mortality (within 24 hours). At their institution, all patients with a pelvic fracture and signs of intraperitoneal bleeding (hypotension) receive a computed tomography (CT) scan with IV contrast after initial fluid resuscitation to evaluate for bleeding. In the study, patients diagnosed with pelvic arterial bleeding (by extravasation of contrast) underwent transarterial embolization. Patients with intraperitoneal fluid collection on CT were taken to the operating room for exploratory laparotomy. Of the 102 patients, 47 died within 24 hours: 47% from hemorrhagic shock and 21% from central nervous system injuries. Head and neck injuries and shock symptoms (hypotension) were associated with increased risk of death, whereas the mechanism of injury and pelvic fracture type did not show an appreciable impact on mortality.[22]

Relevant Anatomy and Biomechanics

Pelvic Ring

The adult pelvic ring is composed of three bones: two innominate bones and the sacrum. Each innominate bone is formed by the fusion of the embryonic ilium, ischium, and pubis, which occurs at the tri-radiate cartilage.[17,23,24] The osseous structures of the pelvis meet anteriorly in the midline at the pubic symphysis and posteriorly at the sacroiliac joints.

Pelvic stability is primarily conferred by its ligamentous connections, with the majority of support provided by the posterior supporting ligaments. The sacroiliac (SI) joint is not a true synovial joint. The sacral portion is covered in cartilage, whereas the iliac portion is covered with fibrocartilage. There is minimal motion occurring at these joints with weightbearing and activity. Superior to the articular surfaces are the sacral and iliac tuberosities. The interosseous SI ligaments, which attach to these tuberosities, are among the strongest ligamentous connections in the body. Additional posterior support is provided by the anterior and posterior sacroiliac ligaments, along with the iliolumbar ligaments, which connect the transverse processes of the L5 vertebral body to the iliac crest. Altogether, these posterior structures function as a tension band resisting rotational and VS displacement forces. The sacrospinous and sacrotuberous ligaments of the pelvic floor also play a role in resisting external rotation and VS forces. The sacrospinous ligament is a strong transverse band running from the lateral aspect of the sacrum to the ischial spine, where the sacrotuberous ligament travels to connect the dorsal portion of the sacrum to the ischial tuberosity. Anterior pelvic stability is provided by the symphysis pubis, the midline articulation of the pubic bones. At the symphysis, the opposing bony surfaces are covered by cartilage and united by layers of fibrocartilage and fibrous tissue.

The arcuate line and the sacral promontory create the pelvic brim, which separates the pelvis into a true and false pelvis. The floor of the true pelvis is created by the pelvic diaphragm (levator ani and coccygeal musculature), through which the anal canal, vagina, and urethra traverse. In addition to providing structural support during weightbearing and activity, the bony and ligamentous components of the pelvis create a stable, protective compartment for the contained visceral, neural, and vascular structures. Those structures that are at risk of injury with pelvic fractures include the nerves of the lumbosacral-coccygeal plexus (terminates in the sciatic, pudendal, obturator, superior, and inferior gluteal nerves); the median sacral, superior rectal, internal iliac, and external arteries; and their associated venous plexi, the urethra, vagina, and anal canal.

The osseous and ligamentous components of the pelvis creates a situation where it functions biomechanically as a ring. As described in other areas of the body, disruption of one portion of the pelvic ring should raise suspicion of disruption in a second location. In an often cited study by Gertbein and Cheno,[25] six patients with presumed single, isolated injuries to the pelvic ring underwent follow-up radiographs and bone scans. The investigators found evidence on bone scan of a second injury site (posteriorly at the SI joint or acetabulum) in each case, confirming the ring theory of pelvic injuries. With weightbearing, the anterior structures of the pelvis act as a strut to prevent anterior collapse.

Biomechanics and Pelvic Stability

Biomechanical studies have demonstrated that the anterior structures of the pelvis contribute up to 40% of pelvic stiffness and stability, especially in scenarios such as a two-legged stance, where the symphysis is under tensile loads. However, in situations where there is absence of anterior support (congenital absence, after tumor resection, or with isolated symphyseal injuries) the pelvis remains stable. Sectioning studies by Pennal and coworkers[26] found that cutting the pubic symphyseal ligaments resulted in a diastasis of up to 2.5 cm. Further pelvic opening appeared to be resisted by the anterior sacroiliac ligaments, along with the sacrospinous ligaments. Sectioning of the anterior SI ligaments and the sacrospinous ligaments allowed the pelvis to completely open, until the point of bony abutment by the posterior superior iliac spines (PSISs). However, even in this situation of complete rotational instability, the pelvis remained stable to vertical loads, due to the integrity of the posterior SI ligamentous complex. Subsequent to sectioning of the posterior structures, the entire hemipelvis was noted to be unstable. An understanding of the anatomic and biomechanical contributions of the bony and ligamentous pelvic structures becomes important once the mechanisms of pelvic injury and their influence on the diagnosis and management of pelvic fractures are considered.

Mechanisms of Injury

The inherent stability of the pelvic ring afforded by its osseous and ligamentous anatomy typically requires high-energy traumatic events to cause fracture. Various clinical and biomechanical studies have demonstrated that the force vector applied to the pelvis dictates the resultant fracture pattern. LC forces, as those commonly seen in side-impact motor vehicle accidents and falls, apply an internal rotation moment on the pelvis. This results in fracture of the pubic rami anteriorly. If the posterior elements of the sacroiliac joint remain intact, the internal rotation of the pelvis causes anterior compression of the anterior sacrum. If the anterior injury occurs directly though the symphysis, overlap may be seen of one pubic body over the other.

Anterior to posterior directed forces on the pelvis, which may be seen with head-on motor vehicle accidents, falls, and crush injuries, typically impart an external rotation moment on the hemipelvis, leading to an “open-book” type injury. With this mechanism of injury, anteriorly, the pubic symphysis is disrupted or, less commonly, fracture of the pubic rami occurs. Continued external rotation of the ilium may tear the anterior SI ligamentous structures until the PSISs abut. Vertical stability is maintained via the intact posterior SI ligaments.

Shearing forces applied to the pelvis during falls from a height, typically, result in pelvic instability. Posteriorly, the SI ligamentous structures are disrupted, as the applied force is directed perpendicular to these soft tissue attachments. Anteriorly, there is either disruption of the pubic symphysis or fracture of the pubic rami. Loss of both the anterior and posterior ligamentous structures leads to vertical displacement of the hemipelvis.

The term combined mechanical injury (CMI) has been used to describe the mechanisms of pelvic fractures that contain different aspects of the various applied forces causing pelvic injury. Fractures resulting from combined mechanisms are unstable by definition, as the posterior SI ligamentous structures are typically completely disrupted.

Classification Systems

The classification of pelvic fractures requires adequate plain films (anteroposterior, inlet, and outlet views[2]), along with thin-cut (3 mm) CT scans. Presently, three main classification systems are used in the evaluation of pelvic fractures, all of which are adaptations of the original work of Pennal and Tile.[2,17,24,26] Their utilization helps the treating surgeon develop a management strategy and predict potential associated injuries and prognosis.[17]

Tile

In Tile's classification, the pelvis is divided into the posterior arch (posterior to the acetabulum) and the anterior arch (anterior to the acetabulum). Fracture type is dictated by the stability of the posterior arch (sacroiliac complex), with a spectrum ranging from stable type A injuries to unstable type C fractures (Table 1).[24] Tile type A fractures are those where the pelvic ring is stable. They are subdivided into A1 injuries, which are avulsion fractures that do not involve the pelvic ring; A2 injuries, which are iliac wing fractures or stable minimally displaced anterior arch fractures; and A3 injuries, which are stable, transverse fractures of the sacrum or coccyx. Tile type B injuries are defined as being partially stable. Rotational instability is present, but the pelvis is stable vertically, secondary to an incomplete disruption of the posterior arch structures and the presence of an intact pelvic floor. Type B1 injury is an external rotation open-book type fracture, where there is disruption of the anterior pelvic arch through the symphysis pubis or through the rami, and the rotation hinges on an intact posterior SI complex. Type B2 fractures are internal rotation LC injuries in which there is a combination of anterior and posterior arch fractures. These injuries are subdivided into type B2-1 fractures, where the anterior arch disruption is ipsilateral to the compression fracture present posteriorly, and type B2-2 fractures ("bucket-handle" injuries), where the lesions are contralateral to each other. Type B3 pelvic fractures are bilateral, partially stable injuries. They include bilateral open-book fractures (B3-1), bilateral lateral-compression injuries (B3-2), and combinations of the two. In Tile type C fractures, the pelvis is rendered unstable both rotationally and vertically, due to complete disruption of the anterior arch, posterior arch, and pelvic floor. Type C1 fractures are unilaterally unstable, type C2 fractures are comprised of an unstable pattern on one side of the pelvis and a partially stable (type B injury) contralaterally, and type C3 fractures are bilaterally unstable.

The Young-Burgess classification is based primarily on the mechanism of injury and is currently the most widely used system reported in the orthopaedic literature. This system was based initially on a retrospective analysis of the clinical and radiographic appearance of 142 pelvic fracture cases.[27] The investigators identified three main force vectors causing pelvic fracture (Table 2). In fractures caused by anteroposterior compression (APC) forces, there is injury to the anterior structures in the form of pubic symphysis separation or vertically oriented pubic rami fractures, along with varying degrees of posterior injury. APC I injuries demonstrate no posterior instability, with diastasis of the pubic symphysis limited to less than 2.5 cm. APC II fractures are associated with some degree of posterior instability, due to injury to the anterior sacroiliac complex allowing greater than 2.5 cm of symphyseal diastasis and anterior SI widening; however, the posterior SI ligaments are intact. In APC III injuries, there is complete disruption of the SI joint, leading to widening and instability. Fractures caused by LC forces are associated with horizontally oriented pubic rami fractures anteriorly and variable injuries posteriorly. In LC I injury, the internal rotation of the pelvis causes a compression fracture of the sacrum on the side of impact. LC II fractures have a crescent fracture present on the side of impact, and LC III fractures have an LC I or LC II fracture on the side of impact, with an associated open-book type injury present contralaterally. VS pelvic fractures are the most unstable injury patterns, with vertical displacement of the hemipelvis due to symphyseal diastasis or rami fractures, anteriorly, and iliac wing fractures, sacral fractures, or sacroiliac joint dislocations present posteriorly.

Orthopaedic Trauma Association

The pelvic fracture classification developed by the Orthopaedic Trauma Association (OTA) is a more comprehensive system designed to standardize and more accurately report various fracture patterns (Table 3). OTA type 61A fractures are defined as stable pelvic injuries, including type 61A1 fractures, which are avulsion fractures of the innominate bone; type 61A2 fractures, which are fractures of the innominate bone; and type 61A3 fractures, which are transverse fractures of the sacrum and coccyx. OTA type 61B fractures are defined as being partially stable, with type 61B1 characterizing a unilateral disruption of the posterior arch (external rotation, APC, open-book type injury), type 61B2 fractures being a unilateral disruption of the posterior arch (internal rotation, LC injury), and type 61B3 fractures

Table 1 Tile Classification

Type	Description
Type A	Stable
A1	Fractures of the pelvis not involving the ring; avulsion injuries
A2	Stable, minimal displacement of the ring
Type B	Rotationally unstable; vertically stable
B1	External rotation instability; open-book injury
B2	LC injury; internal instability; ipsilateral only
B3	LC injury; bilateral rotational instability (bucket handle)
Type C	Rotationally and vertically unstable
C1	Unilateral injury
C2	Bilateral injury, one side rotationally unstable, with the contralateral side
C3	Bilateral injury, both sides rotationally and vertically unstable, with an associated acetabular fracture

LC, lateral compression.

Table 2 Young-Burgess System Classification

Category	Distinguishing Characteristics
LC	Transverse fracture of pubic rami, ipsilateral or contralateral to posterior injury
I	Sacral compression on side of impact
II	Crescent (iliac wing) fracture on side of impact
III	LC I or LC II injury on side of impact; contralateral open-book (APC) injury
APC	Symphyseal diastasis or longitudinal rami fractures
I	Slight widening of pubic symphasis (less than 2.5 cm) or anterior SI joint; stretched but intact SI, sacrotuberous, and sacrospinous ligaments; intact posterior SI ligaments
II	Symphyseal diastasis greater than 2.5; widened anterior SI joint; disrupted anterior SI, sacrotuberous, and sacropsinous ligaments; intact posterior SI ligaments
III	Complete SI joint disruption with lateral displacement, disrupted anterior SI, sacrotuberous, and sacrospinous ligaments; disrupted posterior SI ligaments
VS	Symphyseal diastasis or vertical displacement anteriorly and posteriorly, usually through the SI joint, occasionally through the iliac wing or sacrum
CMI	Combination of the injury patterns, LC/VS is most common

APC, anteroposterior compression; CMI, combined mechanical injury; LC, lateral compression; SI, sacroiliac; VS, vertical shear.

Table 3 OTA Classification of Pelvic (Six) Ring (One) Fractures

Type	Description
A	Lesion sparing (no displacement of posterior arch)
1	Fracture of innominate bone, avulsion
2	Fracture of innominate bone, direct blow
3	Transverse fracture of sacrum and coccyx
B	Incomplete disruption of posterior arch, partially stable
1	Unilateral, partial disruption of posterior arch, external rotation (open-book
2	Unilateral, partial disruption of posterior arch, internal rotation (LC injury)
3	Bilateal, partial lesion of posterior arch
C	Complete disruption of posterior arch, unstable
1	Unilateral, complete disruption of posterior arch
2	Bilateral, ipsilateral complete, contralateral incomplete
3	Bilateral, complete disruption

LC, lateral compression.

demonstrating bilateral partial lesions of the posterior arch. OTA type 61C fractures are unstable injuries, secondary to complete disruption of the posterior arch. Type 61C1 injuries are unilateral, type 61C2 injuries are complete ipsilaterally and incomplete contralaterally, and type 61C3 injuries have bilateral complete disruptions. Within this classification system, there are many subgroups and divisions that accurately describe increasingly specific fracture patterns; these subdivisions are useful for research purposes, but relatively cumbersome for routine use.

Evaluation and Initial Management

Information obtained from emergency medical personnel regarding details of the mechanism of injury and initial patient presentation may be useful in raising suspicion for a pelvic fracture and the presence of associated injuries. Pre-hospital protocols, including cervical spine immobilization, protection of the airway and maintenance of adequate ventilation, intravenous access, and circulatory support, in addition to rapid transport to a trauma center, have been instituted in an effort to optimize initial patient management.[17]

ATLS Assessment and Management

Initial hospital evaluation and management in the emergency room proceeds according to the guidelines of the Advanced Trauma Life Support (ATLS) protocol.[5] The primary survey includes an assessment of the patient's airway and breathing, while intravenous access is obtained with two large bore IVs, allowing for resuscitation to occur simultaneously with the diagnostic evaluation.

Hemodynamic stabilization is of paramount importance in the initial management phases of suspected pelvic fractures. Once the airway has been adequately secured, a search for potential sources of bleeding is started. Inspection during the primary survey may identify signs of injury-associated hemorrhage, such as flank ecchymosis or scrotal edema. Trauma radiographs, including anteroposterior views of the chest and pelvis, may also help localize a bleeding source. The focused assessment sonogram for trauma (FAST) may be utilized in the emergency setting to identify intraperitoneal fluid.[5,17] In many centers, a positive FAST exam in a hemodynamically unstable patient is an indication for immediate abdominal exploration.[28] In a recent retrospective review of the utility of FAST exams in pelvic fracture patients, Tayal and associates[29] reported an overall sensitivity of 81% and a specificity of 87%. In cases where the FAST is equivocal and ongoing hemorrhage is suspected, a diagnostic peritoneal lavage (DPL) is a useful additional assessment tool.[17,30,31] Using a supra-umbilical insertion site, a DPL yielding more than 8 cc of blood is considered positive for intraperitoneal bleeding, prompting emergent abdominal exploration.[17] The supra-umbilical site is preferred in pelvic fracture patients to avoid the possibility of false positive results occurring, secondary to aspiration of the pelvic fracture hematoma.

Physical Examination of the Pelvis

Once active hemorrhage and life-threatening associated injuries have been ruled out during the primary survey, the physical examination can then be focused on the pelvis. Recent studies have demonstrated that clinical examination can be sensitive in the identification of pelvic fracture in the conscious and interactive patient. Gonzalez and colleagues,[32] in their review of 2176 blunt trauma patients, reported that a focused physical examination had a 93% sensitivity for the diagnosis of pelvic fracture.

Significant shortening or external rotation of one of the patient's lower extremities on inspection may help identify a VS or an open-book APC type pelvic injury. Palpation of the anterior pelvis may demonstrate a symphyseal gap indicative of diastasis. Compression testing in the anteroposterior direction through applied downward pressure on the anterior superior iliac spines (ASISs) and in the lateral direction via compression of the iliac crests is performed in an effort to identify pelvic rotational instability. Pelvic compression should be limited to a single attempt, in an effort to limit repeated disruption of fracture site clots.

Rectal and pelvic examinations are of utmost importance during the initial evaluation to rule out the presence of an open fracture. Blood in the vaginal vault or in the rectum should raise the level of suspicion for an open injury. Palpable bony spicules within the rectum or vagina may be present indicating an open injury. A high-riding prostate may also be detected on rectal examination, indicating the presence of a periurethral or periprosthetic hematoma occurring secondary to genitourinary injury.[17,23]

When possible, a complete neurologic examination should be performed, focusing on sciatic nerve and sacral plexus function, as these nerves are at risk for injury. Evaluation of rectal tone and the presence of the bulbocavernosus reflex are included in the initial neurologic evaluation.

Diagnosis of Associated Injuries

Genitourinary

Large case series have reported that genitourinary injury occurs in as many as 15% to 20% of pelvic fracture cases.[17,18,33-36] Identification of blood at the urethral meatus, gross hematuria, or significant penile or scrotal swelling or ecchymosis should raise suspicion for injury to the bladder or urethra and warrant a urology consult and further work-up, including a urethrogram or possible operative exploration. Additionally, the pelvic fracture pattern, as seen on the initial anteroposterior trauma pelvic radiograph, may predict the risk of genitourinary injury. Basta and coworkers,[18] in a case-control review of 119 pelvic fracture patients, correlated anterior pelvic fractures (in particular, inferomedial pubic bone fracture or pubic symphysis diastatis with 1 cm or more of displacement) with associated urethral injury. The investigators found that each millimeter of pubic symphysis diastasis or inferomedial pubic bone fracture displacement was associated with a 10% increased risk of urethral injury. Andrich and associates[37] reviewed 108 males and females with pelvic ring fractures at their institution and found that 27 (25%) had lower urinary tract injuries (LUTI). Although the study failed to show a correlation between pelvic fracture mechanism (Tile A, B, or C) and the presence of a LUTI, the study did find that more severe urethral injuries (complete urethral disruption and complex LUTI) occurred only in males with Tile C injuries. In a retrospective review of 721 patients with blunt trauma pelvic fractures, Avey and colleagues[38] found 37 bladder ruptures (5%), all of which had hematuria greater than 30 RBC/HPF (red blood cells per high-power field). Pelvic injuries associated with bladder injury included diastasis of the pubic symphysis greater than 1 cm and fracture of the obturator ring, with a displacement greater than 1 cm.[38]

Gastrointestinal

Intra-abdominal injuries can occur with pelvic fractures. Bowel can become entrapped within a pelvic fracture and present as an acute intestinal obstruction or intermittent ileus. Stubbart and Merkley[39] reported a case of descending and sigmoid colon herniation resulting from an ilium fracture. Although a review of the literature shows that bowel entrapment is a relatively rare complication, it can be fatal and must be differentiated from adynamic ileus, a more benign condition that occurs in up to 5% to 18% of pelvic fractures, which lasts an average of 3 days. Patients with pelvic fractures and a persistent ileus should undergo a CT with enteric contrast to rule out occult bowel injury, such as entrapment at the pelvic fracture site.[39]

Hemorrhage

All pelvic fractures are associated with some form of bleeding. Sources of blood loss include cancellous bone at the fracture site, laceration of retroperitoneal veins in the pelvis, and laceration of branches of the internal iliac artery, which accounts for approximately 25% of hemodynamically unstable pelvic fractures.[40,41] It is difficult to determine whether a patient is hemorrhaging from a venous or an arterial bleed. Arteriography can identify arterial bleeding, venography shows venous bleeding (although it is difficult to distinguish between major or minor bleeds), and pelvic CT can show the presence of a hematoma (which is suggestive of a bleed, but not specific). Huittinen and Slätis[42] performed a cadaveric study of 27 patients with pelvic fractures who died from hemorrhage. Postmortem anatomic dissection and arteriography of the hypogastric artery was performed. Extravasation from the hypogastric artery through the cancellous bone and torn tissues was seen in 23 cadavers. Based upon their findings, Huittinen and Slätis concluded that "accurate reposition of the dislocated pelvic fracture is preferable to ligation of the hypogastric arteries for control of severe hemorrhage from pelvic fractures."

Early identification of patients with hemorrhage is critical in management. Although evaluation of patients with blunt abdominal injury, typically, involves a focused assessment with sonography for trauma (FAST) exam, in patients with pelvic fractures, a negative exam does not rule out intraperitoneal hemorrhage. Friese and coworkers[43] performed a retrospective review of 96 patients with pelvic fracture and risk factors for hemorrhage (systolic blood pressure less than 100 mmHg or an unstable fracture pattern) who underwent a FAST and either operative exploration or CT scan for confirmation. In the study, there were 11 true positives, 52 true negatives, two false positives, and 31 false negatives (sensitivity of 26% and negative predictive value of 63%).[43]

Clinical factors can be used to help predict which patients with pelvic fractures are more at risk of bleeding. Blackmore and associates[40] performed a retrospective cohort study of 627 patients with pelvic fractures (20% of whom had major pelvic hemorrhage) and identified four predictors of hemorrhage, including an emergency room hematocrit of less than 30, a pulse greater than 130 BPM, displaced obturator ring fracture, and pubic symphyseal wide diastasis (greater than 1 cm used for displacement). Patients with zero predictors had a 2% change of major hemorrhage, whereas patients with three or more predictors had a greater than 60% chance of having hemorrhage. In a retrospective review of 382 patients with isolated pelvic or acetabular fractures, Magneussen and colleagues[44] found that isolated pelvic fractures with major ligament disruption (APC I or II, LC III, VS, or CMI) were more likely to require transfusions (44%) than other pelvic fractures (8.5%). Patients with APC 3 and VS fractures required the most amount of blood (12.6 units and 4.6 units, respectively).

Emergency Methods of Provisional Pelvic Stabilization

In the emergent setting, the orthopedic surgeon has a number of options for provisional pelvic stabilization to help tamponade bleeding in patients with pelvic fractures who are hemodynamically unstable, including using a pneumatic anti-shock garment (PASG), wrapping a sheet around the pelvis, or placing a pelvic binder on arrival, as well as more definitive fixation with an anti-shock pelvic clamp (C-clamp) or traditional anterior external fixation.

Pneumatic Anti-Shock Garment

PASG, also known as a military anti-shock trouser, is sometimes used in the pre-hospital and emergency room setting to increase blood pressure, reduce pelvic fractures, and tamponade hemorrhage. A number of problems have occurred with the PASG, however, including lower extremity ischemia and compartment syndrome. The PASG is bulky, and when in place, it is difficult to access the abdomen, genitourinary system, and lower extremities.[45-47] While there may be theoretical benefits to the PASG, Chang and colleagues[48] showed in a prospective randomized study of 248 patients with traumatic shock that PASG provided no mortality benefit or difference in hospital stay as compared to no PASG.

Wrapping Sheet

Circumferential compression with a sheet around the pelvis or a pelvic binder can be used as an emergent method of stabilizing the pelvis and reducing pelvic volume in open-book pelvis fractures. The sheet should be placed at the level of the greater trochanter and wrapped tightly around the patient and secured with a clamp or cable ties. A bolster should be placed under the knees and the lower thighs, and ankles should be bandaged together to help stabilize the pelvis. Nunn and coworkers[49] presented a series of seven hemodynamically unstable patients with pelvic fractures (APC II, APC III, LC III, and CMI), showing that circumferential compression with a sheet helped stabilize the patient by increasing blood pressure and reducing tachycardia; patients still required significant fluid resuscitation and blood transfusions over the subsequent 12 hours.

Pelvic Clamping

Ganz and associates[50] introduced the C-clamp as a tool to rapidly stabilize posterior pelvic ring fractures in hypotensive patients. Using their instructions to place the C-clamp, the PSIS is first palpated. The entry point of the Steinmann pins is noted to be three to four fingerbreadths anterolateral to the PSIS, along a line drawn between the ASIS and the PSIS. A stab incision is made over the entry point, the pins are advanced to bone and driven in 1 cm with a hammer. The hemipelvis is compressed with the sidearms using a wrench.[50]

In a retrospective review of 14 patients in hemorrhagic shock with unstable B or C pelvic ring fractures and who were treated with a pelvic C-clamp, Sadri and colleagues[51] found that five patients remained hemodynamically unstable and required arterial angioembolization. Although exact times were not reported, they stated patients who required pelvic C-clamps were taken to the operating room within 2 hours of arrival to the hospital, and a C-clamp was placed within 20 minutes; thus, extrapolating these results to practice requires an efficient triage set-up and readily available orthopaedic and support staff.[51]

External fixation via anterior stabilization can be performed for partially stable (type B) pelvic fractures. There are two sites for anterior pin placement, either in the superior iliac crest above the ASIS or lower between the iliac spines (which allows easier access to the abdomen). The pullout strength at these two sites is comparable. Pins can be placed percutaneously or through an open technique. Two or three pelvic pins are placed in each crest and connected via a rectangular or trapezoidal frame. Reduction of the pelvic fracture occurs by correction of the displacement (typically, with internal rotation for open-book fractures or external rotation for LC fractures). Unstable pelvic fractures (type C) can be mechanically fixed with either a pelvic C-clamp or traditional external fixation and distal femur skeletal traction.[52]

Bassam and coworkers[53] prospectively evaluated external fixation, as compared to angiography, in 15 patients with pelvic fractures who were hemodynamically unstable. Based upon a previous study, which showed that posterior arterial bleeding from the internal iliac artery or its posterior branches was more common in unstable posterior pelvic fractures, this group divided these patients into either anterior pelvic ring fractures (APC I and LC I) or posterior pelvic ring fractures (APC II, APC II, LC II and LC III). Patients with anterior fractures were treated initially with emergent external fixation, whereas patients with posterior fractures were treated initially with arterial angiography and embolization. Of note, patients with anterior and posterior pelvic ring fractures were treated with an external fixator if the fracture was vertically stable and with angiography if the fracture was vertically unstable. Eight patients were treated initially with external fixation, whereas seven patients underwent angiography. Four of the eight patients who were treated with external fixation required angiography for continued hemodynamic instability, whereas none of the patients who were treated initially with angiography required external fixation. Three patients in the external fixator group suffered large buttock and thigh hematomas (as compared to no hematoma complications in the angiography group). From these results, Bassam and associates[53] concluded that all patients with pelvic fractures who were hemodynamically unstable should be treated with arterial angioembolization, regardless of fracture type.

Biffl and colleagues[28] performed a retrospective review of 216 patients with pelvic fractures requiring blood transfusions pre-introduction (143 patients) and post-introduction (73 patients) of a newly instituted clinical pathway that involved having an orthopaedic trauma attending available on presentation to the emergency department, closing the pelvis on arrival by wrapping the pelvis with a sheet, and taping the knees and ankles together, using a pelvic C-clamp for mechanical stabilization as an alternative to traditional external fixator devices. Although it is difficult to isolate how each change affected outcomes, overall mortality decreased from 31% to 15% (16% to 5% within the first 24 hours) and death from exsanguinations decreased from 9% to 1%.

Imaging Evaluation

The standard trauma radiographs are an anteroposterior (AP) view of the chest, a lateral view of the cervical spine, and an AP view of the pelvis. The AP of the pelvis can be used to look for anterior injuries (pubic rami fractures and symphysis displacement), sacroiliac joint and sacral fractures, iliac fractures, and L5 transverse process fractures. Inlet and outlet views should be performed. The inlet view is taken with the patient supine and the X-ray beam directed 60° caudally (i.e., perpendicular to the pelvic brim). The inlet view is used to look for anterior or posterior displacement of the sacroiliac joint, sacrum, or iliac wing. Internal rotation deformities in ilium or sacral impaction fractures are also apparent on the inlet view. The outlet view is taken with the patient supine and the X-ray beam directed 45° cephalad; the view is used to look for vertical displacement of the hemipelvis. The Judet views (iliac and obturator oblique) are pelvic radiographs taken at 45° external and internal rotation, showing the posterior column-anterior wall of the acetabulum and anterior column-posterior wall, respectively. A stress view can be performed to assess vertical stability. A push-pull force is applied through the limb; the hemipelvis is unstable if it moves greater than 0.5 to 1 cm. A CT scan is helpful in evaluating the sacroiliac complex.

In classifying pelvic fractures, it is important to determine if a fracture is stable or unstable (rotationally and vertically). Radiographic signs of instability include: sacroiliac displacement of greater than 0.5 mm in any plane; a posterior fracture gap; or avulsion of the fifth lumbar transverse process, the lateral border of the sacrum (implying a tear in the sacrotuberous ligament), or the ischial spine (implying a tear in the sacrospinous ligament).[54]

A patient with a pelvic fracture, who is hemodynamically unstable despite aggressive fluid resuscitation and mechanical stabilization, may be a candidate for pelvic angiography. Fangio and coworkers[55] evaluated the use of pelvic angioembolization as first-line treatment for hemodynamic instability. They performed a retrospective study of 311 patients with pelvic fractures, of whom 32 were hemodynamically unstable and underwent pelvic angiography; 25 patients required angiographic embolization, 24 of whom had a "successful" outcome, as determined by cessation of contrast extravasation, and 21 patients showed hemodynamic improvement.

Some institutions advocate taking hemodynamically unstable patients for angioembolization regardless of CT findings. Brown and associates[56] showed that pelvic CT findings of no hematoma or blush still may have bleeding requiring angioembolization. In a retrospective review of 37 patients with pelvic fractures, who underwent pelvic CT on admission and pelvic angiography, they found that in the six patients who did not have evidence of hematoma, five had bleeding requiring angioembolization, and of the 31 patients who did not have blush on CT, 22 had bleeding requiring angioembolization.

There are some concerns regarding angioembolization for control of bleeding in patients with pelvic fractures. First, arterial angioembolization stops pelvic arterial bleeding; however, it does not control venous bleeding or bony hemorrhage, two major sources of bleeding associated with pelvic fractures. Second, taking a patient to the angiography suite can be time consuming and may delay taking a patient to the operating room. In a patient with a pelvic fracture, who may require emergent abdominal or thoracic exploration, this delay may be fatal. In a prospective study, Cothren and colleagues[57] treated 28 consecutive patients with hemodynamic instability (defined as persistent systolic blood pressure less than 90 mmHg, despite 2u PRBC) and pelvic fracture with preperitoneal packing (PPP) and skeletal fixation (either anterior external fixator or a pelvic C-clamp placement) as initial treatment of instability. With PPP, the pelvis was directly packed through a preperitoneal approach. Packing was removed 24 to 48 hours after the initial procedure. PPP resulted in lower transfusion requirements (preoperative transfusion requirement of 12 units on average as compared to 6 units postoperatively). The mortality rate in this study was 25%, which is lower than what had previously been reported in similar patients (typically, greater than 40%).[56]

Summary

A pelvic ring fracture is a high-energy injury and should be suspected in any patient whose presenting history includes a suspicious mechanism (motor vehicle accident, crush injury, or fall from a height). The diagnosis of patients with a pelvic ring fracture should focus on determining the stability of the pelvic ring, which can be assessed clinically and radiographically. As with any high-energy fracture, a careful physical examination should be performed to rule out an open fracture. The stability of the pelvic ring is determined by the integrity of the posterior weightbearing sacroiliac complex, which includes the sacroiliac (posterior and anterior), sacrospinous, and sacrotuberous ligaments. Direct lateral pressure on the iliac crests indicates if rotational instability exists. Movement of the hemipelvis as manual traction is applied to the lower extremity indicates vertical instability. At minimum, an AP of the pelvis should be performed to help classify the fracture and evaluate the sacroiliac joint as a marker for instability. A CT scan is helpful in evaluating the sacroiliac complex to determine if vertical instability is present. If possible, the pelvic fracture should be classified according to the Tile and Young and Burgess systems.

Management of patients with pelvic ring fractures begins in the pre-hospital setting. In patients with hemodynamic instability, a pelvic binder should be placed to help decrease the pelvic volume and stabilize the pelvis. On arrival to the emergency department, the trauma surgeon should direct assessment and management. A major risk factor for mortality in patients with pelvic ring fractures is hypotension not responsive to fluid resuscitation. After a chest plain film (to rule out hemothorax) and a FAST (to rule out hemoperitoneum and need for exploratory laparotomy) have ruled out other sources of hemorrhage, the most likely source of bleeding is from the pelvic venous and arterial system or from the cancellous bone at the fracture site. The pelvis should be stabilized with a pelvic binder. If the patient continues to be unstable, the patient should be taken for arterial angiography and embolization. After a patient is hemodynamically stabilized, full imaging (including inlet, outlet, Judet, and CT scan) can be performed. If the pelvic fracture type is unstable (Tile B or C; Young and Burgess APC II, APC III, LC II, LC III, VS), the patient will require operative fixation and can be treated with more definitive stabilization, such as an external fixator or a pelvic C-clamp (if posterior instability exists) in the interim.

Conclusion

There are a number of areas of uncertainty in the initial triage and management of patients with pelvic ring fractures. While it is clear that hemodynamically unstable patients have a higher mortality, the source of bleeding (venous, arterial, or bony) is typically not clear. A better understanding of the source would help determine if patients would be more likely to benefit from emergent arterial angiography or pelvic stabilization. With regard to pelvic stabilization, more head-to-head studies need to be performed to determine what the best method of emergent stabilization would be. Pelvic ring fractures present a diagnostic and management challenge to orthopaedic surgeons and require the coordination of emergency room physicians and trauma surgeons to rapidly diagnose unstable fractures and stabilize hemodynamically unstable patients prior to definitive operative fixation as needed.

Disclosure Statement

None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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