Acute Pelvic Fractures: I. Causation and Classification

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Abstract

Acute pelvic fractures are potentially lethal, even with modern techniques of polytrauma care. The appropriate treatment of such fractures is dependent on a thorough understanding of the anatomic features of the pelvic region and the biomechanical basis of the various types of lesions. Although the anterior structures, the symphysis pubis and the pubic rami, contribute approximately 40% to the stiffness of the pelvis, clinical and biomechanical studies have shown that the posterior sacroiliac complex is more important to pelvic-ring stability. Therefore, the classification of pelvic fractures is based on the stability of the posterior lesion. In type A fractures, the pelvic ring is stable. The partially stable type B lesions, such as "open-book" and "bucket-handle" fractures, are caused by external- and internal-rotation forces, respectively. In type C injuries, there is complete disruption of the posterior sacroiliac complex. These unstable fractures are almost always caused by high-energy severe trauma associated with motor vehicle accidents, falls from a height, or crushing injuries. Type A and type B fractures make up 70% to 80% of all pelvic injuries. Because of the complexity of injuries that most often result in acute pelvic fractures, they should be considered in the context of polytrauma management, rather than in isolation. Any classification system must therefore be seen only as a general guide to treatment. The management of each patient requires careful, individualized decision making.

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The past two decades have seen major advances in our knowledge of pelvic-ring disruptions occurring due to high-energy injury. The forces necessary to disrupt the pelvis of a young person with normal bone are massive; hence, the injury cannot be considered in isolation, but must be viewed as part of the spectrum of polytrauma. Such injuries are potentially lethal, with mortality rates of 10% to 20% for unstable pelvic fractures.[1-5] In the case of open fractures, the mortality can be as high as 50%,[6-8] even with modern techniques of polytrauma care. The key to logical decision making in such cases is understanding the injury, since saving the patient's life, the first priority in polytrauma management, is closely related to accurate diagnosis of the type of fracture and stabilization of the pelvic ring.

General Concepts

Anatomy

The pelvis is a ring-like structure made up of the two innominate bones and the sacrum. Because these bones have no inherent stability, the stability of the pelvic ring is due mainly to its surrounding soft-tissue envelope.

The stabilizing structures of the pelvic ring are the symphysis pubis, the posterior sacroiliac complex, and the pelvic floor (Fig. 1). The anterior structures, the symphysis pubis and the pubic rami, contribute approximately 40% to the stiffness of the pelvis; the posterior structures, approximately 60%. The posterior part of the pelvic ring can remain stable even if portions of the anterior pelvis are removed or absent, such as may occur after tumor surgery or in cases of exstrophy of the bladder. Clinical and biomechanical studies have shown that the posterior sacroiliac complex, also known as the posterior tension band of the pelvis, is more important to pelvic-ring stability than the anterior structures.[9,10]

Sacroiliac Complex

Pelvic stability is dependent on an intact posterior sacroiliac complex (Fig. 1, A). The posterior liga-

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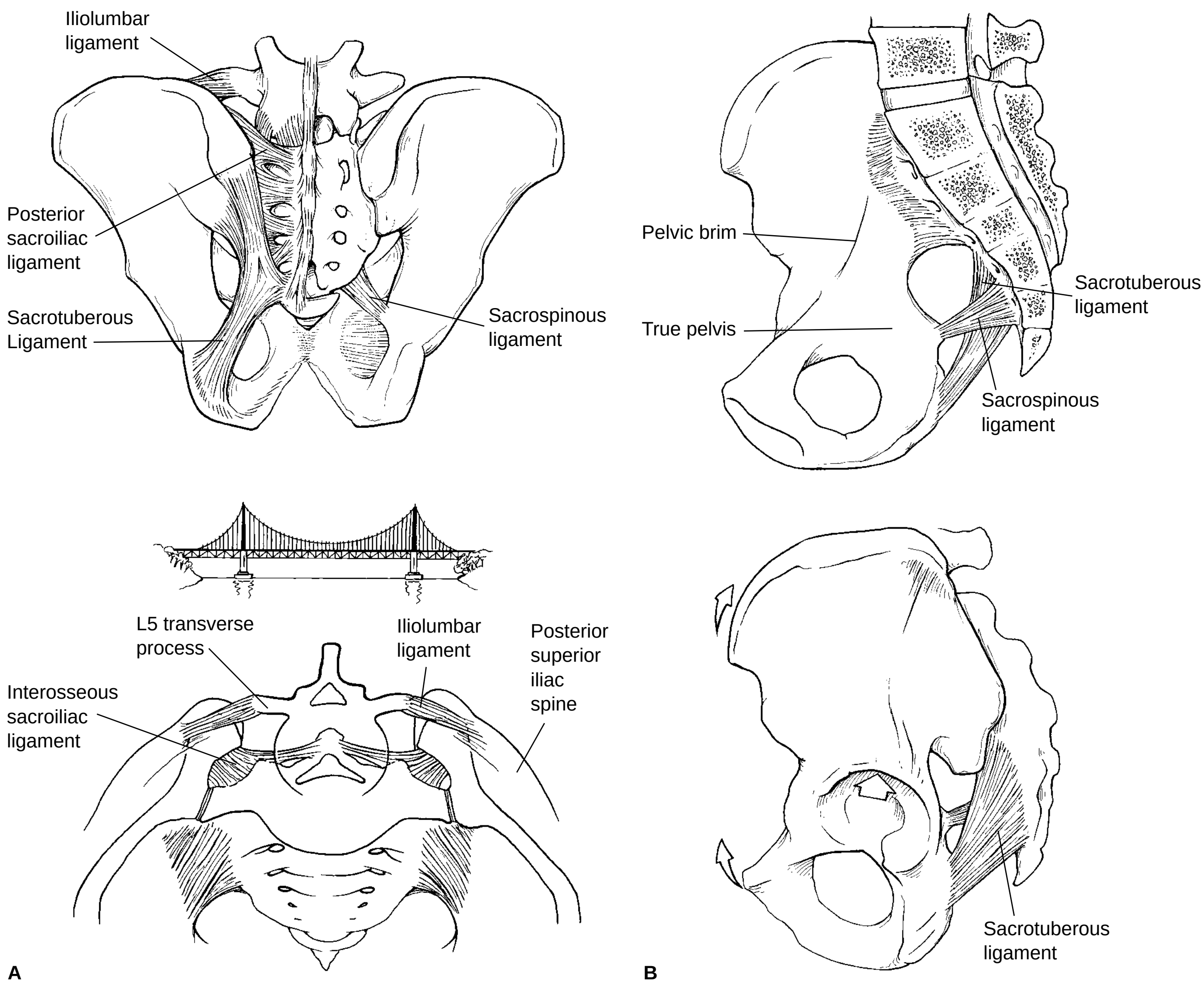


Fig. 1 **A,** Major posterior stabilizing structures of the pelvic ring. **Top,** Posterior view. **Bottom,** Transverse view illustrates the suspension bridge–like arrangement of ligaments binding the posterior sacroiliac complex. Note vertical direction of the interosseous posterior sacroiliac ligaments, which are the strongest in the body. Transverse process acts as the suspension joining the pillars, represented by the posterior superior iliac spines, to the sacrum. **B,** Major ligamentous structures of the pelvic floor. **Top,** Sagittal view shows attachments of sacrotuberous and sacrospinous ligaments. **Bottom,** Sacrotuberous ligament, which joins the sacrum to the ischial tuberosity, resists a shearing rotatory force (arrows).

mentous structures that create the major tension-band effect of the pelvic ring may be likened to a suspension bridge, with the posterior superior iliac spines being the pillars, the interosseous sacroiliac ligaments acting like suspension bars, and the sacrum being the bridge. The iliolumbar ligaments join the transverse processes of L5 to the iliac crest, further enhancing the suspensory mechanism, as do the transverse fibers of the sacroiliac ligaments, both anteriorly and posteriorly. The strongest ligaments in this complex—indeed, in the human body—are the interosseous sacroiliac ligaments, which prevent the sacrum from displacing anteriorly. The articular portion of the joint is relatively small and is shaped like an ear. The anterior sacroiliac ligaments afford some stability by limiting external rotation.

Pelvic Floor

The two major ligamentous structures on each side of the pelvic floor are the sacrospinous ligament and the sacrotuberous ligament (Fig. 1, B). The sacrospinous ligament, an extremely strong band that runs transversely from the lateral edge of the sacrum to the ischial spine, resists external rotation. The sacrotuberous ligament arises from the posterior aspect of the sacroiliac complex and extends to the ischial tuberosity. In the sagittal plane this ligament resists vertical-shearing and rotational forces applied to the hemipelvis. The entire pelvic floor is covered by muscle and investing fascia.

Types of Anatomic Lesions

If a ring structure is fractured in one area, it must be broken in another, the only exception being a greenstick injury in a child. Therefore, if an anterior fracture is noted, there must be a concomitant posterior injury. The literature, especially the general surgical literature, has failed to recognize this fact, classifying pelvic fractures as either anterior or posterior, when in fact both types of lesions must occur in all cases of major pelvic trauma.

Anterior Lesions

The anterior pelvic lesions (Fig. 2) include disruptions of the symphysis pubis, overlapping and / or locking of the symphysis pubis, unilateral fractures of both rami (superior and inferior), bilateral fractures of all four pubic rami, and combinations of ramus fractures with disruption of the symphysis.

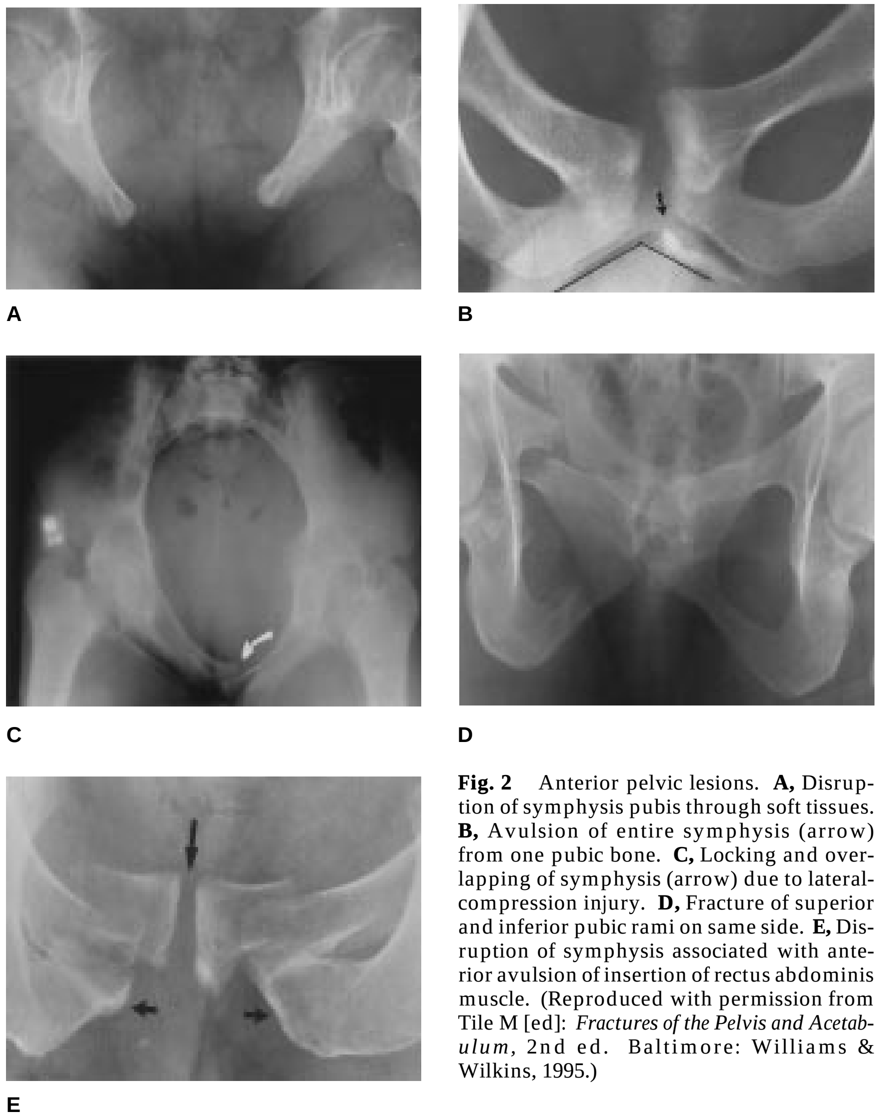


Fig. 2 Anterior pelvic lesions. **A,** Disruption of symphysis pubis through soft tissues. **B,** Avulsion of entire symphysis (arrow) from one pubic bone. **C,** Locking and overlapping of symphysis (arrow) due to lateral-compression injury. **D,** Fracture of superior and inferior pubic rami on same side. **E,** Disruption of symphysis associated with anterior avulsion of insertion of rectus abdominis muscle. (Reproduced with permission from Tile M [ed]: *Fractures of the Pelvis and Acetabulum*, 2nd ed. Baltimore: Williams & Wilkins, 1995.)

Posterior Lesions

Posterior fractures (Fig. 3) may be through the ilium, through the sacroiliac joint (either as a pure dislocation or a fracture-dislocation), or through the sacrum. Anatomic lesions in the sacrum have been classified as being through the lateral mass, lateral to the sacral neural foramina; through the foramina; or medial to the foramina.[11] The highest incidence of nerve injury (40% to 50%) occurs with sacral fractures, especially those medial to or through the foramina.[12-14]

Biomechanics

The type of anatomic lesion is important, especially when considering surgical management, but stability is more important for overall decision making in patient care. As is the case with other fractures, pelvic fractures vary in degree of stability. At one end of the spectrum is the intact pelvic ring; at the other end is a completely unstable pelvis, virtually an internal hemipelvectomy. Other fractures of the pelvis fall between these two extremes. In the pelvic classification based on the assessment of stability, which will be discussed later in this article, the fractures at the stable end of the spectrum are designated type A; those at the unstable end, type C; and those in the middle, with partial stability, type B. Stability is also related to the di-

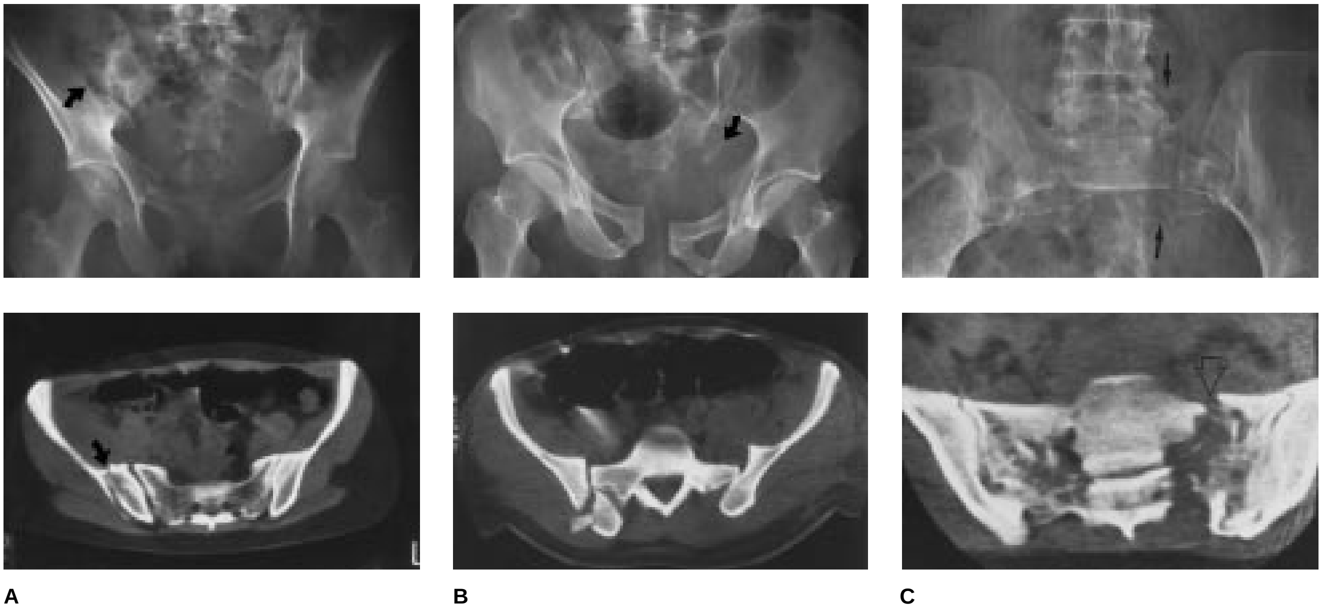


Fig. 3 Radiographs **(top)** and computed tomographic (CT) scans **(bottom)** depicting posterior pelvic lesions (arrows). **A,** Fracture of the ilium. **B,** Fracture-dislocation on the right side and dislocation on the left. **C,** Fracture of the sacrum, with instability due to avulsion of the transverse process of the L5 vertebra. (Reproduced with permission from Tile M [ed]: *Fractures of the Pelvis and Acetabulum,* 2nd ed. Baltimore: Williams & Wilkins, 1995.)

rection of the injurious force (Fig. 4). Retention of some soft-tissue support results in partial stability; loss of this support results in complete instability.

Partial Stability (External-Rotation Forces)

External-rotation forces through the intact femur and anteroposterior-compression forces acting directly on the anterior or posterior iliac spines tend to open the pelvis like a book (hence the term "open-book injury") (Fig. 4, B). Anteriorly, the symphysis pubis may be disrupted or, less commonly, the rami may fracture. As the external-rotation force continues, the pelvic floor ruptures, and the anterior sacroiliac ligaments tear until the posterior iliac spine impinges on the sacrum. If the force stops at that point, the pelvis may externally rotate unilaterally or bilaterally, but major posterior or vertical translation is not possible. The pelvic ring retains partial stability by virtue of the intact posterior sacroiliac ligament complex.

Partial Stability (Lateral-Compression Forces)

If a lateral-compression (internal-rotation) force is applied to the pelvis, the anterior rami often break, and the pelvis rotates internally (Fig. 4, C). If the posterior ligaments remain intact, the anterior sacrum will be compressed. If the bone of the sacrum is stronger than the posterior sacroiliac ligaments, the ligaments may tear, but with this implosion-type force, the pelvic floor remains intact, affording partial stability to the pelvis. With intact pelvic floor ligaments, further internal rotation may occur, but in some cases the sacral compression is so great that no rotation is possible. In both scenarios, major posterior or vertical translation is not possible.

Instability (Shearing Forces)

Shearing forces are generally perpendicular to the soft-tissue structures and the bony trabeculae and may therefore overcome the ligaments of the sacroiliac complex and the pelvic floor, resulting in an unstable hemipelvis (Fig. 4, D). This can occur irrespective of the direction of the original force. External-rotation and vertical or posterior shearing forces disrupt the ligaments more commonly than internal-rotation forces, but I have seen major translation with internal-rotation forces. Therefore, the surgeon must be vigilant for this possibility; otherwise, errors in diagnosis will lead to faulty decision making.

Effect of Force Direction on Soft Tissues

External-rotation and shearing forces tend to disrupt soft tissue, and resultant injuries are likely to cause damage to the visceral and

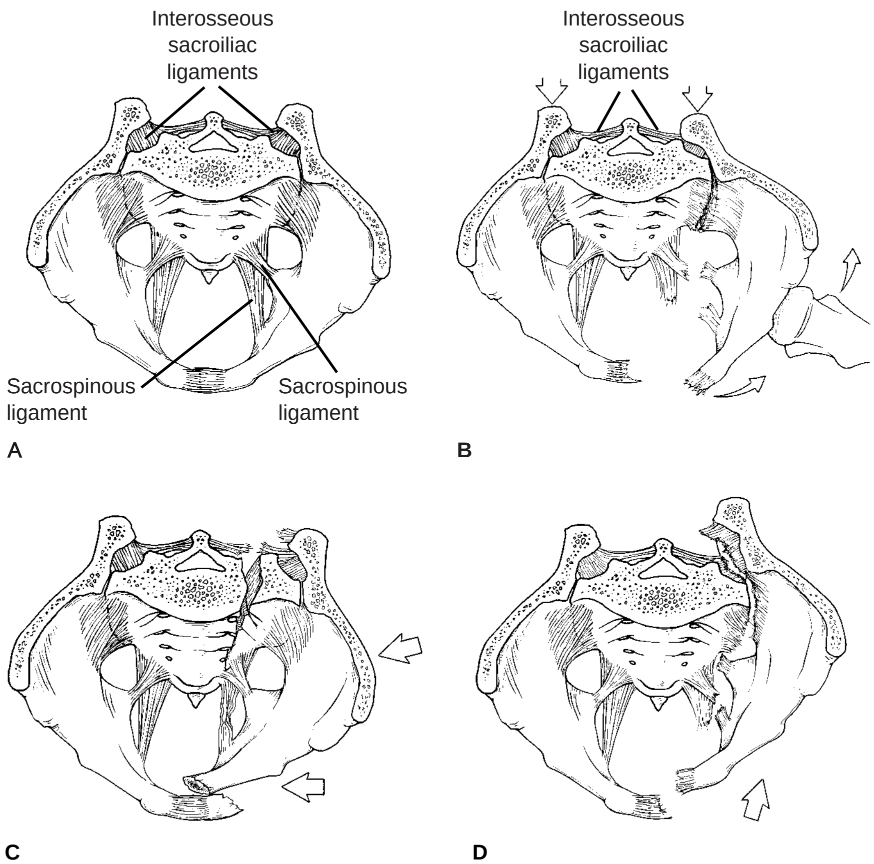


Fig. 4 Forces acting on the pelvis. **A,** Cross section of the pelvis depicts the stabilizing ligamentous structures. **B,** External rotation or anteroposterior compression through the left femur (arrows) disrupts the symphysis, pelvis, and anterior sacroiliac ligament to the impingement of the ilium against the posterior aspect of the sacrum. If the force stops at this level, partial stability of the pelvis is maintained by the interosseous sacroiliac ligaments. **C,** Lateral-compression (internal-rotation) force implodes the hemipelvis. The rami may fracture anteriorly, and posterior impaction of the sacrum may occur with some disruption of the posterior structures but maintenance of partial stability by the intact pelvic floor and compression of the sacrum. **D,** Shearing (translational) force disrupts the symphysis, pelvic floor, and posterior structures, rendering the hemipelvis completely unstable.

arterial structures. Because nerve injuries associated with these forces are usually due to traction, the prognosis must be guarded. Lateral-compression forces may puncture viscera and compress nerves.

Classification of Fractures

The classification of pelvic fractures is based on the concepts of stability, force direction, and pathoanatomy. Although no classification system can provide answers to all the questions regarding a specific injury, the comprehensive classification of fractures of the pelvis shown in Table 1, which was first published in 1988,[15] has been modified and accepted by the AO group.[16,17]

Like all classification systems, this one should be used only as a guide to treatment. The management of the individual patient requires a careful assessment, the ability to trace the fracture lines on a model pelvis, and a thorough understanding of the resultant soft-tissue injuries.

For the purposes of this classification, the pelvis is divided into the posterior arch (located posterior to the acetabular surface) and the anterior arch (located anterior to the acetabular surface). The type of fracture is based on the stability of the posterior pelvic arch (sacroiliac complex), with stability being defined as the ability of the pelvis to withstand physiologic force without deformation. As mentioned previously, the spectrum of pelvic fractures ranges from type A lesions, which are stable, to type C lesions, which are unstable. Anterior lesions are denoted by modifiers and include symphyseal disruptions and combinations of ramus fractures.

Type A Fractures

Type A pelvic-ring lesions do not fracture through the pelvic ring or pelvic soft tissues, but may avulse portions of the pelvis or fracture only the iliac wing. Because the pelvic ring is stable, it cannot be displaced by physiologic forces. Type A1 lesions are avulsion-type fractures, which usually occur in adolescents and do not involve the entire pelvic ring. Type A2 fractures are caused by a direct blow and can involve either an iliac-wing fracture or an anterior-arch lesion. Type A3 fractures are transverse lesions of the sacrum and coccyx and should be considered spinal injuries rather than disruptions of the pelvic ring.

Type B Fractures

Type B lesions are partially stable. They may be displaced by either external- or internal-rotation forces, may exhibit rotational instability (Fig. 4, B), or may be stuck in the displaced impacted position,

Table 1
Classification of Pelvic-Ring Lesions

Type A:	Stable (posterior arch intact)
	A1: Avulsion injury
	A2: Iliac-wing or anterior-arch fracture due to a direct blow
	A3: Transverse sacrococcygeal fracture
Type B:	Partially stable (incomplete disruption of posterior arch)
	B1: Open-book injury (external rotation)
	B2: Lateral-compression injury (internal rotation)
	B2-1: Ipsilateral anterior and posterior injuries
	B2-2: Contralateral (bucket-handle) injuries
	B3: Bilateral
Type C:	Unstable (complete disruption of posterior arch)
	C1: Unilateral
	C1-1: Iliac fracture
	C1-2: Sacroiliac fracture-dislocation
	C1-3: Sacral fracture
	C2: Bilateral, with one side type B, one side type C
	C3: Bilateral

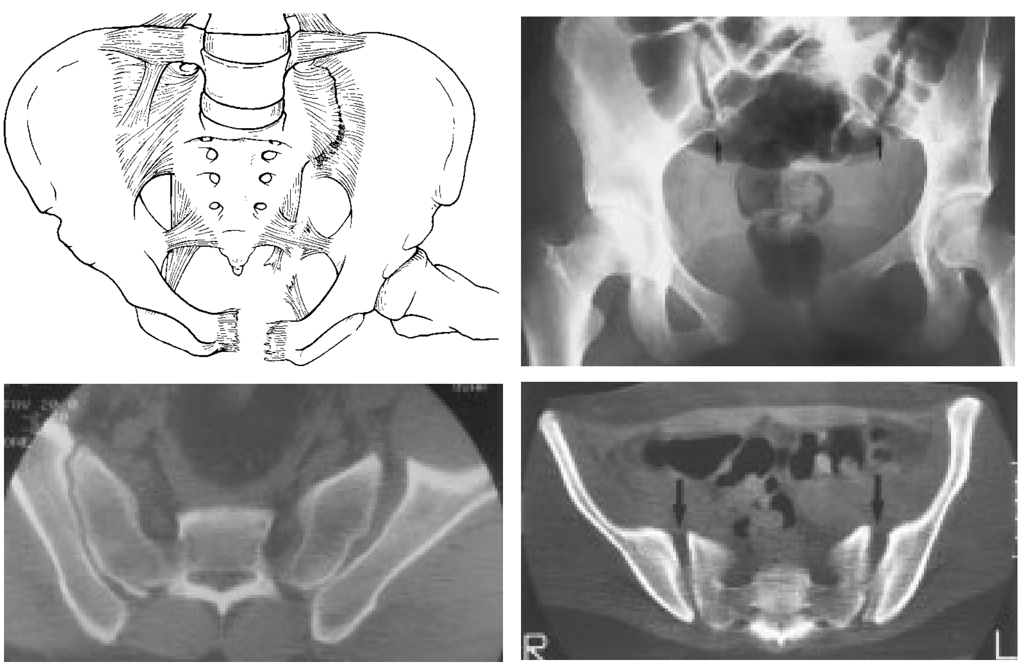
especially as a result of lateral compression (Fig. 4, C). Because the posterior arch retains some inherent stability, posterior or vertical displacement is not possible.

Type B1 Open-Book Injury (External Rotation)

The unilateral open-book injury (Fig. 5, A) is characterized by disruption of the anterior arch of the pelvis, usually through the symphysis pubis but occasionally through the pubic rami. If the symphyseal disruption is less than 2.5 cm (1 inch), the pelvic floor remains intact, as do the sacroiliac joints. This is the same situation that occurs with the passage of the fetus during labor. This particular injury is at the stable end of the spectrum. If the anterior disruption is greater than 2.5 cm, the pelvic floor is disrupted, and the anterior sacroiliac ligaments rupture. However, if the posterior ligaments remain intact, partial stability is maintained, and translation is not possible.

Type B2 Lateral-Compression Injury (Internal Rotation)

Type B2 injuries involve partial disruption of the posterior arch (Fig. 6, A). A lateral-compressive force directed at the pelvic ring can cause two types of injuries: ipsilateral (type B2-1) injuries, which are characterized by anterior and posterior lesions on the same side of



A

B

Fig. 5 Open-book injuries. **A,** External rotation of the left hemipelvis through the femur causes unilateral disruption of the left hemipelvis. **Top,** Note the disruption of the symphysis and pelvic floor, but maintenance of partial stability through the intact posterior tension band. **Bottom,** Computed tomographic (CT) scan. **B,** Bilateral open-book fracture. **Top,** Anteroposterior radiograph shows wide disruption of the symphysis and anterior opening of the sacroiliac joint. **Bottom,** Same bilateral fracture is better visualized on CT scan. (Radiologic images reproduced with permission from Tile M [ed]: *Fractures of the Pelvis and Acetabulum,* 2nd ed. Baltimore: Williams & Wilkins, 1995.)

the pelvis, and contralateral (type B2-2), or “bucket-handle,” injuries, in which there is an anterior lesion on one side and a posterior lesion on the other. In both types, there may be internal rotational instability or a compression fracture in the posterior arch rigidly holding the hemipelvis in the compressed, displaced, internally rotated position. Stability is maintained by a relatively intact pelvic floor and/or retention of the posterior ligamentous structure, as well as the impacted fracture. Type B2 injuries can be further categorized on the basis of the site and whether the injury is anterior or posterior.

In ipsilateral type B2-1 injuries, the anterior lesion is on the same side as the posterior lesion (Fig. 6, A and B). The anterior lesion may be unilateral superior and inferior ramus fractures on the same side as the posterior injury; an overlapped, locked symphysis; or a combination of injuries, such as a superior ramus fracture and a symphysis disruption (tilt fracture). The posterior injury may be a sacral impaction, best seen on computed tomography (CT) (Fig. 6, C), or a sacroiliac joint impaction involving either the ilium or the sacrum.

In type B2-2 (bucket-handle) injuries, the anterior lesion is on the side opposite the posterior lesion (Fig. 6, D–F). The affected hemipelvis rotates not only internally but also superiorly. In this injury, the affected hip joint is elevated, in-

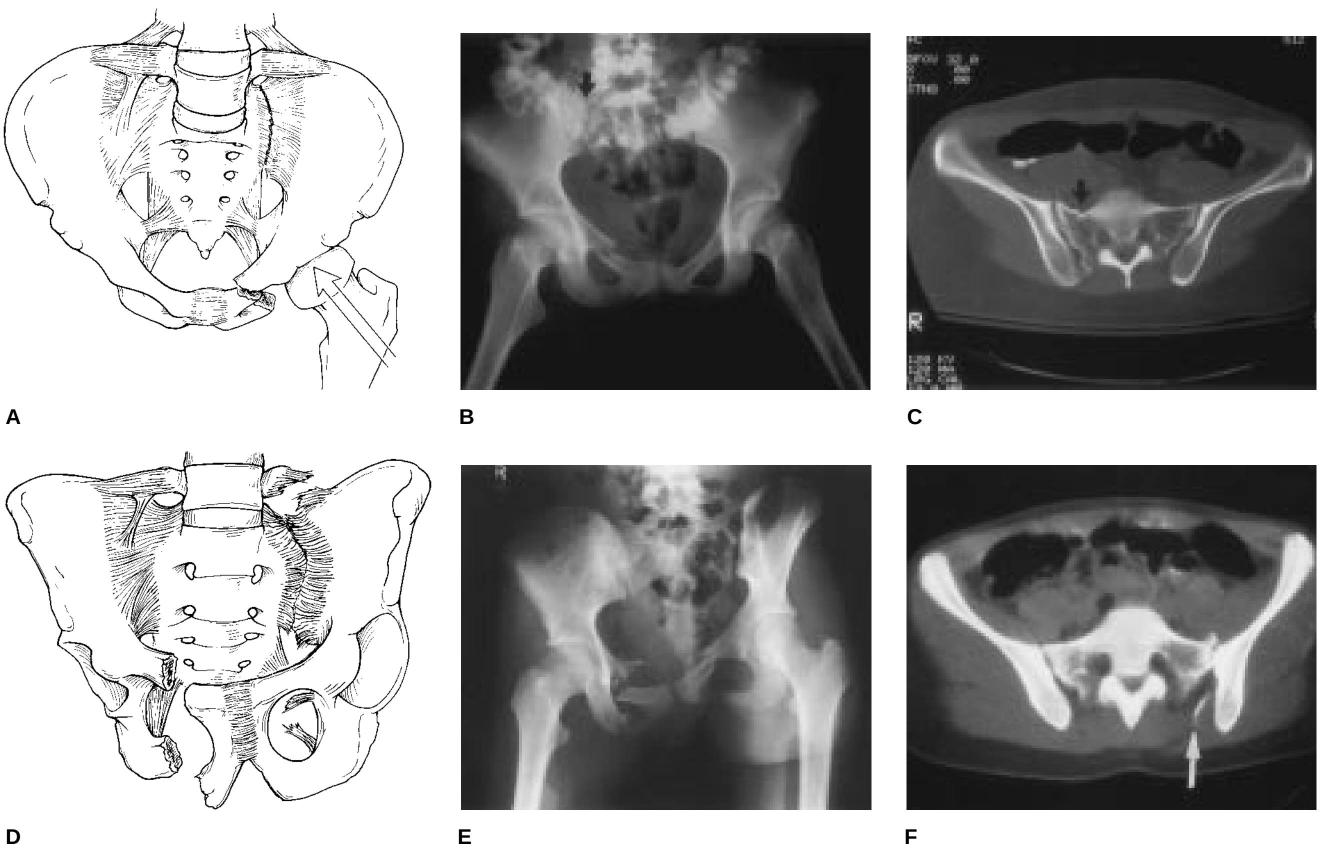


Fig. 6 **A,** Mechanism of ipsilateral type B2-1 injuries. Lateral-compressive force directed against the iliac crest causes the hemipelvis to rotate internally, producing a posterior compressive sacral lesion and injury to the contralateral or ipsilateral (as shown here) anterior structures. **B,** Typical type B2-1 injury. Anteroposterior radiograph shows fracture of the superior and inferior pubic rami with internal rotation of the right hemipelvis. Note overlap of the superior ramus fracture, compression fracture on the left side of the symphysis pubis, and crush injury to the sacrum. **C,** Compressive nature of the sacral fracture is better seen on CT. **D,** Mechanism of type B2-2 bucket-handle injuries. Posterior injury is on the side opposite the anterior ramus fractures. Displacement is not only internal but also superior in rotation. **E,** Typical type B2-2 injury is illustrated in this anteroposterior radiograph of a 16-year-old girl struck from the side in a motor-vehicle accident. Note that the left hemipelvis is internally rotated. Superior rotation is indicated by the superior position of the femoral head, also indicating leg-length discrepancy. **F,** The lesion is more clearly seen on CT, which shows internal rotation of the left hemipelvis, anterior crush at the sacroiliac joint, and avulsion of the posterior apophysis (arrow). (Parts B, C, E, and F are reproduced with permission from Tile M [ed]: *Fractures of the Pelvis and Acetabulum,* 2nd ed. Baltimore: Williams & Wilkins, 1995.)

dicating superior rotation of the anterior hemipelvis. Although all four rami may be involved anteriorly, the displacement is on the side opposite the posterior lesion. Vertical stability is maintained by the relatively intact pelvic floor and the impacted fracture. This fracture pattern is best seen on a CT study and the three standard views of the pelvis.

Regardless of the direction of the inciting force, a lesion can be characterized as a type B injury only if there is inherent stability in the posterior arch. If the force of lateral compression overcomes the soft tissues of the pelvis, causing instability, the fracture is, by definition, a type C lesion. It is only by careful vigilance in the posttrauma period that the exact nature of the lesion can be determined.

Type B3 (Bilateral Injury)

Type B3 lesions are bilateral and partially stable. They include the classic bilateral open-book (B3-1) injuries (Fig. 5, B), bilateral lateral-compression (B2) injuries, and combinations thereof.

Type C Fractures

In the type C pelvic-ring lesion, posterior disruption is complete, as is disruption of the pelvic floor. This allows posterior and vertical translational displacement, resulting in a completely unstable pelvis, either unilaterally or bilaterally.

Type C fractures are almost always caused by high-energy severe trauma associated with motor-vehicle accidents, falls from a height, or crushing injuries (Fig. 7). Complete disruption of the posterior pelvic ring occurs with posterior or vertical translation, with a gap often greater than 1 cm seen on the initial radiograph. However, the surgeon may be misled by the lack of displacement shown on the initial radiograph. This injury is usually associated with marked anterior disruption through the rami or the symphysis. In the most extreme cases, a closed unstable type C lesion may be considered an internal hemipelvectomy. Cases of true traumatic hemipelvectomy have also been reported.[18]

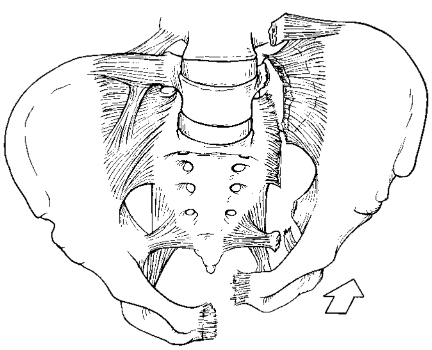
Type C fractures may be unilateral or bilateral. The unilateral type C1 injury may be through the ilium (C1-1); through the sacroiliac complex, usually fracturing the ilium with the dislocation, but occasionally affecting the sacrum (C1-2); or through the sacrum (C1-3). Sacral fractures may be through the foramina, lateral to the foramina, or medial to the foramina.[11] Type C2 injuries are characterized by an unstable fracture on one side and a type B partially stable lesion on the other. Type C3 lesions are bilaterally unstable.

Relative Incidence

In virtually all literature reports, even those from major trauma centers, type A and type B fractures make up 70% to 80% of the total number of pelvic injuries. Type C unstable fractures are much less common. In a major study from 14 German trauma units, Gansslen et al[19] recently confirmed these values.

Summary

The past two decades have seen major advances in our knowledge



A

B

C

Fig. 7 Type C injuries. **A,** Drawing illustrates disruption of the symphysis, the pelvic floor on the left, and a completely unstable left sacral fracture. Avulsion fractures of both the ischial spine and the transverse process are telltale signs of complete instability of the hemipelvis. **B,** Anteroposterior radiograph demonstrates slight vertical and posterior displacement of the right hemipelvis. The exact pathologic nature of the lesion was difficult to determine on this radiograph taken at the time of the patient's admission to the trauma unit. **C,** A CT scan better demonstrates the grossly unstable fracture through the right sacrum with bone fragments in the cauda equina and through the sacral foramina. (Parts **B** and **C** are reproduced with permission from Tile M [ed]: *Fractures of the Pelvis and Acetabulum*, 2nd ed. Baltimore: Williams & Wilkins, 1995.)

of pelvic-ring disruptions due to high-energy injury. Because these potentially lethal fractures often occur in the context of multiple trauma, they cannot be considered in isolation. Therefore, although the classification of pelvic stability on the basis of pathoanatomy, force direction, and stability has become more standardized, it can still serve only as a general guide to treatment, and individualized decision making remains essential. The key to logical decision making is understanding the anatomic and biomechanical basis of acute pelvic fractures.

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