Pelvic ring fractures for dummies, what to look for

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Learning objectives

Review the imaging findings in traumatic pelvic fractures using the Classification System Young and Burgess as a tool for its therapeutic approach and prognosis.
Background

Pelvic fractures are a relatively common entity in the trauma patient and their management still poses difficulties due to their complexity. The treatment of these fractures requires a multidisciplinary approach to early diagnosis and to reduce morbidity and mortality.

Radiologically, it is important to recognize the fracture lines and the stability of the pelvis, which is achieved by the osseoligamentous structures. The supporting pelvic ligaments allow bearing physiological stresses without abnormal deformation, playing a crucial role in stability.

Radiologists must be familiar with the anatomy and biomechanics to understand the pelvic ring disruptions.

The system of Young and Burgess Classification provides a systematic approach to the interpretation of the pelvic ring fractures and stability assessment, based on fundamental force vectors that create predictable patterns. This system provides an algorithm to approach and categorizes lesions as anteroposterior (AP) compression, lateral compression, vertical shear injury or combined. Knowledge of these patterns leads to the identification and diagnosis of other subtle lesions and any associated complications, which helps the orthopedic surgeon to apply corrective forces to stabilize the pelvis.
Findings and procedure details

**EPIDEMIOLOGY**

Fractures of the pelvic ring have been reported to comprise 2% to 8% of all skeletal injuries 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. Among multiply injured patients with blunt trauma, almost 20% have pelvic injuries.

Actually, the incidence is about 23-37/100,000 persons-years in general population and shows a **bimodal distribution**, with a first peak occurring in patients aged 15 to 30 years and a second peak aged 50 to 70 years, which are usually produced by high and low energy trauma respectively.

The incidence in young people is greater in males compared to females, being the majority associated with severe trauma. However, after the age of 55, there is an exponential increase in the incidence of pelvic fracture in both gender, with a higher incidence in elderly females.

In addition, high-energy, unstable pelvic fractures are more common among **younger male** patients; while lower energy, stable fractures types are predominant in **elderly females**.

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 (including the genitourinary system), spine, and the peripheral nervous system.

Mortality rates associated with pelvic fractures range from as low as 5% to 10% to as high as 50% to 60% in the orthopedic surgery and trauma literature.

**ANATOMY AND BIOMECHANICS**
Knowledge of the complex anatomy and biomechanics of pelvic stability may guide appropriate initial management strategies.

Three principal bones compose the adult pelvic ring:

- **Two innominate bones**: formed by the ilium, ischium and pubis. The acetabulum is a bone cavity located on the outside of the iliac bone, where the femoral head is articulated, and is the point where these three segments of the innominate bone are joined. Innominate bones articulate anteriorly at the pubic symphysis.

- **Sacrum**: which transmits the trunk weight to the lower limbs or the ischium and it is joined to the innominate bones at the sacroiliac joint. It articulates in its superior part with the fifth lumbar vertebra and in its inferior part with the coccyx.

Pelvis stability is conferred by the osseoligamentous structures, which bear physiologic stresses without abnormal deformation. They are mainly formed by:

- **Posterior sacroiliac ligaments**: resist both internal rotation and vertical displacement.
- **Anterior sacroiliac ligaments**: resist external rotation of the ilium relative to the sacrum.
- **Sacrospinous ligaments**: provide rotational stability.
- **Sacrotuberous ligaments**: resist vertical shear and flexion forces.
- **Iliolumbar ligaments**: provide a secondary stabilization.

To make it easier, globally it can be said that the horizontally oriented anterior sacroiliac and sacrospinous ligaments resist rotation and the vertically oriented sacrotuberous ligaments resist vertical displacement. Posterior sacroiliac ligaments resist both: rotational and vertical displacement. This is the reason why posterior supporting ligaments provide the majority of support and therefore is why clinical instability is most severe in patients with posterior ring structures injuries.

The pelvic ring consists of **two arches**:

- **THE POSTERIOR ARCH**, a stronger arch that extends behind the acetabular surfaces and includes the sacrum, SI joints, and posterior ilium. The posterior pelvis and sacrum are the keystone elements of the pelvis because they provide structural support and stabilization of the entire pelvic ring.
- THE ANTERIOR ARCH, a weaker arch made of the pubic rami bones and symphysis. The pubic symphysis serves as a strut to improve anterior ring stability during ambulation. However, the pubic symphysis is the weakest point in the pelvic ring, contributing only 15% of intrinsic pelvic stability.

(Figures 1-5)

IMAGING EVALUATION

- Which trauma patient needs imaging? See figure 6.
- Which image technique should we perform?

1º X-ray:

- AP pelvis X-ray as screening exam in all trauma patients. Additional radiographic views may be helpful.
- It is a quick and simple test that will detect the majority of the anterior pelvic fractures while posterior ring injuries are often unseen and require further imaging.

2º Contrast enhancement computed Tomography (CECT):

- It is the modality of choice for accurately depicting and characterization of pelvic ring fractures and visceral injuries.
- Coronal, sagittal, and 3D reformats improve visualization of fractures and are useful to integrate the findings and classify the type of injury.
- It is useful to evaluate vascular or pelvic organ lesions.

3º Magnetic Resonance Imaging (MRI):

- It is helpful in diagnosing acute pelvic ring disruptions and providing additional information on ligamentous injuries.
- It is possible to assess neurological injuries.
MECHANISMS OF INJURY

Firstly, we should consider that the osseous and ligamentous components of the pelvis allow it to biomechanically function as a ring, and disruption of one portion of the pelvic ring must raise suspicion for disruption in a second location.

Pelvic ring fractures respond to different factors: the magnitude of the force, the speed and the direction of the vector. Their combinations create four predictable patterns: lateral compression, anterior-posterior (AP) compression, vertical shear injury or combined.

Globally, pelvic injuries may be identified by two dominant patterns of displacement:

- OPENING AND CLOSING OF THE PELVIS: a result of rotational forces.

- VERTICAL DISPLACEMENT, a result of vertical forces transmitted to the pelvis by axial loading from the lower extremities.

  - The injuries with anterior displacement and an intact posterior ligamentous complex are referred to as being rotationally unstable because the hemipelvis is able to rotate into either internal or external rotation around the posterior ligamentous structures. However, vertical displacement is resisted.
  
  - Fractures of the pelvic ring with a significant involvement of the posterior ligaments SI are much more unstable because the hemipelvis is disconnected from the axial skeleton and can rotate (internally or externally) and move proximally. They are referred to as global or vertically unstable. These lesions are most frequently associated with neurovascular and visceral lesions. Other secondary signs of instability are avulsion fractures of the sacrospinous or iliolumbar ligaments and L5 transverse process avulsion fractures, which indicate that the pelvis was more significantly displaced at the time of injury.
Actually, the Young and Burgess Classification is currently the most used. It provides a systematic approach to the interpretation of the pelvic ring fractures and stability assessment, based on fundamental force vectors that create predictable patterns:

1. **Lateral compression (Figures 7-10)**
2. **AP compression (Figures 11-14)**
3. **Vertical shear (Figures 15, 16)**
4. **Combined mechanism**

Knowledge of these patterns leads to the identification and diagnosis of other subtle lesions and any associated complications, which helps the orthopedic surgeon to apply corrective forces to stabilize the pelvis.

(Figure 17)

**1. LATERAL COMPRESSION:**

It corresponds to the most common morphological pattern, caused by either a direct lateral impact to the innominate bone or indirect transmission of the force by the way of the hip, which causes internal rotation of the hemipelvis toward the midline ("CLOSED BOOK" FRACTURE). Lateral compression injuries differ depending on the point of application and the magnitude of the inciting force. Generally, lateral compression fractures do not cause vascular or visceral lesions unless there is direct injury.

- **TYPE 1**
  - **Mechanism:**
    
    Results from the posterior lateral compression vector relative to the sacrum, which causes a slight internal rotation of the hemipelvis. The net force vector is displaced posteriorly and the sacrum undergoes compression.

    - **Image findings:**
      - Unilateral pubic ramus fracture
      - Sacral crush injury (commonly a "buckle" in the sacral wing)
      - Intact ligaments
- STABLE

-TYPE 2

There is relative ANTERIOR displacement of the lateral compression vector relative to the sacrum.

- **Mechanism:**

The force is directed over the anterior portion of the iliac wing. This force tends to rotate the hemipelvis inward, being the pivot point the anterior SI joint and leaving a small crescent-shaped fracture of the posterior ilium. Because of the firmly attached of the posterior SI ligaments, alternately the rotation can cause forceful opening of the SI joint without sacral or ilium fracture.

- **Image findings:**

- Unilateral pubic ramus fracture
- Fracture of the sacral wing or posterior iliac crescent fracture
- Alternately, disruption of the posterior SI ligaments with widening of the SI joint, instead of fracture of sacral wing or ilium
- ROTATIONALLY UNSTABLE, VERTICALLY STABLE

-TYPE 3

- **Mechanism:**

They occur in high-energy trauma. There is a FORCEFUL lateral pelvic impact with the force vector causing an internal rotation of the hemipelvis on the side of the impact ("closed book fracture") and a corresponding external rotation of the contralateral hemipelvis ("open book" fracture).

- **Image findings:**

- Bilateral pubic ramus fracture
- Posterior iliac wing fracture, extending to SI joint
- Sacral-crush
- Disruption of the anterior and posterior SI ligaments
- Widening of the contralateral SI joint
- Disruption of the contralateral sacrotuberous and sacrospinous ligaments
- GLOBALLY UNSTABLE

Examples of lateral compression pelvic ring fractures (figures 18-36)

2. AP COMPRESSION:

AP compression pelvic ring fractures are the second in frequency. An anterior-posterior force vector causes the pelvis to open like a book around the sacrum (varying degrees of pubic symphysis diastasis) and associated widening of the SI joints. They are classified into 3 types of AP compression fractures according to the force of the vector.

Hematoma and arterial bleeding are most prevalent with AP compression injuries.

- **TYPE 1**
  - **Mechanism:**
    An anterior-posterior **SLIGHT** force vector causes the pelvis to open like a book around the sacrum.

  - **Image findings:**
    - Pubic symphysis mild diastasis (<2.5 cm)
    - Mild widening of the sacroiliac joints
    - Anterior sacroiliac ligaments remain intact
    - **STABLE**

- **TYPE 2**
  - **Mechanism:**
    An anterior-posterior **MODERATE** force vector causes the pelvis to open like a book around the sacrum.
• **Image findings:**

- Pubic symphysis moderate diastasis (>2.5 cm)
- Widening of the sacroiliac joints
- Disruption of the sacrospinous, sacrotuberous and anterior SI ligaments
- ROTATIONAL UNSTABLE, VERTICALLY STABLE

**-TYPE 3**

• **Mechanism:**

An anterior-posterior **FORCEFUL** vector causes the pelvis to open like a book around the sacrum.

• **Image findings:**

- Pubic symphysis severe diastasis (>5 cm)
- Dramatic widening of a single sacroiliac joint
- Disruption of the sacrospinous, sacrotuberous and anterior SI ligaments
- Disruption of posterior SI ligaments
- GLOBALLY UNSTABLE

Examples of AP compression pelvic ring fractures (**Figures 37-39**)

3. **VERTICAL SHEAR:**

• **Mechanism:**

Vertical shear fractures are caused by cranially directed high-energy forces from violent axial loading of the hemipelvis, such as occurs when one falls from a height and lands on an extended leg. An elevation of the affected hemipelvis occurs, causing a complete dissociation of the ipsilateral sacroiliac joint. The exact fracture pattern depends on both the amount of force applied and the relative strength of the bone and ligamentous structures. Visceral, neural and vascular injuries are associated.
• **Image findings:**

- Pubic symphysis diastasis
- Elevation of the ipsilateral pubic ramus
- Anterior and posterior sacroiliac ligaments DISRUPTED
- COMPLETE DISSOCIATION and elevation of the ipsilateral sacroiliac joint
- Disruption of the sacrotuberous and sacrospinous ligaments
- COMPLETE INSTABILITY

Examples of vertical shear injuries *(Figure 40).*

**4. COMBINED MECHANISM:**

Combined pelvic ring fractures are those involving elements of more than one pattern. These injuries result from a very high-energy trauma, being the most common type of combined mechanism lateral compression and vertical shear injury.

Examples of combined mechanism *(Figures 41,42)*

Possible complications of pelvic ring fractures *(Figures 43,44)*
Fig. 1: Three-dimensional CT image which shows the principal structures of the pelvic ring anatomy.

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Fig. 2: Three-dimensional CT image shows the stabilizing structures of the pelvic ring. The bony pelvic ring (red circle) formed by two innominate bones and sacrum. The stabilization is provided by the SI (a), sacrospinous (b), and sacrotuberous (c) ligaments and secondary by the iliolumbar ligaments (d). Clinical instability is more severe in patients with posterior ring structures injuries.

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Fig. 3: Three-dimensional CT image. Pelvic ligaments seen on an anterior view of the pelvis. The horizontally oriented anterior sacroiliac and sacrospinous ligaments resist rotation. The vertically oriented sacrotuberous ligaments resist vertical displacement.

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Fig. 4: Three-dimensional CT image. Pelvic ligaments seen on a superior view of the pelvis. The posterior sacroiliac ligaments are the most important structures for pelvic stability.

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Fig. 5: Three-dimensional CT image. Pelvic ligaments seen on a posterior view of the pelvis. The most vital structures for preservation of pelvic ring stability are short and long posterior sacroiliac ligaments. Secondary stabilization is provided by the iliolumbar ligament (note the attachment to the transverse process). An avulsion fracture at this site may be a sign of the posterior ligamentous disruption.

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Fig. 6: Radiologic evaluation and initial treatment in patients with a suspected pelvic fracture.

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**Fig. 7:** Mechanism of lateral compression type 1 injuries, which result from the posterior lateral compression vector relative to the sacrum. Posterior injuries result in a crush-type fracture of the sacrum, with disruption of the anterior ring, usually in the form of ipsilateral pubic rami fractures.

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Fig. 8: Mechanism of lateral compression type 2 injuries. There is relative anterior displacement of the lateral compression vector relative to the sacrum. Anterior injuries result in either a fracture of the iliac crest that extends through the SI joint or widening of the ipsilateral SI joint with disruption of the posterior SI ligaments (more severe pelvic instability). In both injuries there is a disruption of the anterior ring, usually ipsilateral pubic rami fractures.

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**Fig. 9:** Mechanism of lateral compression type 3 injuries, which occur in high-energy trauma. There is a forceful lateral pelvic impact with the force vector causing a lateral compression "closed book" pattern on the side of impact and a corresponding AP compression "open book" fracture pattern on the contralateral side.

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Fig. 10: Three-dimensional CT images showing the three types of lateral compression pelvic fractures.

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Fig. 11: Mechanism of AP compression type 1. An anterior-posterior force vector causes the pelvis to open like a book around the sacrum (varying degrees of pubic symphysis diastasis) and associated widening of the SI joints. AP compression type 1 injuries are characterized by mild diastasis and widening of the SI joints, with no significant anterior SI ligament injury.

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**Fig. 12:** Mechanism of AP compression type 2 injuries. Moderate symphysis diastasis with widening of a single SI joint. Rotational instability.

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Fig. 13: Mechanism of AP compression type 3 injuries. Severe symphysis diastasis with dramatic widening of a single SI joint. Concomitant disruption of the sacrospinous, sacrotuberous and anterior and posterior SI ligaments. Complete instability.

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**Fig. 14:** Three-dimensional CT images showing the three types of AP compression pelvic fractures.

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**Fig. 15:** Mechanism of vertical shear injuries. Elevation of the affected hemipelvis is the key finding and indicates disruption of the sacrospinous, sacrotuberous, and anterior and posterior SI ligaments. Complete instability.

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Fig. 16: Three-dimensional CT images showing the vertical shear injury.

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<table>
<thead>
<tr>
<th>Type of injury</th>
<th>Morphologic Characteristics</th>
<th>Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>LATERAL COMPRESSION</td>
<td>Transverse overlapping obturator ring fractures</td>
<td>Head injury; direct vascular, neural and bladder injuries.</td>
</tr>
<tr>
<td>1</td>
<td>Sacral impaction (buckle), intact ligaments</td>
<td>Stable</td>
</tr>
<tr>
<td>2</td>
<td>Iliac crescent fracture</td>
<td>Rotationally unstable, vertically stable</td>
</tr>
<tr>
<td>3</td>
<td>Lateral compression type 1 or 2 on one side and AP compression injury on the opposite side.</td>
<td>Globally unstable.</td>
</tr>
<tr>
<td>AP COMPRESSION</td>
<td>Diastasis of the pubic symphysis without anterior fracture</td>
<td>Substantial hemorrhage</td>
</tr>
<tr>
<td>1</td>
<td>Less than 2.5 cm pubic diastasis.</td>
<td>Stable</td>
</tr>
<tr>
<td>2</td>
<td>More than 2.5 cm pubic diastasis, widening of anterior SI joint</td>
<td>Rotationally unstable, vertically stable</td>
</tr>
<tr>
<td>3</td>
<td>Often more than 5 cm pubic diastasis, widening of both anterior and posterior SI joints</td>
<td>Globally unstable.</td>
</tr>
<tr>
<td>VERTICAL SHEAR</td>
<td>Vertical displacement of hemipelvis, fractures of pubis and SI joint</td>
<td>Visceral injuries, unstable</td>
</tr>
<tr>
<td>COMBINED</td>
<td>Complex fracture with combined elements of AP compression, lateral compression or vertical shear</td>
<td>Variable</td>
</tr>
</tbody>
</table>

**Fig. 17:** Key characteristics of the Young and Burgess Classification of Pelvic Ring Injury.

Fig. 18: Lateral compression type 1. Axial and coronal CT and three-dimensional reconstructions images which show a transverse overlapping superior and inferior pubic rami fracture left-sided and a buckle fracture of the left anterior sacrum. No widening of the SI joint.

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**Fig. 19:** Lateral compression injury. (A,B,C) Three-dimensional volume-rendered and (D,E,F) MIP CT images in a traumatic patient. Overlapping horizontal superior and inferior pubic rami fractures left-sided (white arrows), a buckle fracture of the left anterior sacrum and a fracture disrupting the neuroforamen (black arrows). No widening of the SI joint.

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**Fig. 20:** Lateral compression type 1 in a trauma patient. Axial (A, B, C) and coronal (D) CT images which show a transvers fracture of the superior and inferior pubic ramus left-sided (arrows) and a sacral fracture with no widening of the SI joint (head arrow). Patient was conservatively treated because of the stability of the fracture pattern.

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Fig. 21: Lateral compression type 1 in a 42-year-old woman who suffered a traffic accident. Axial (A, B) and coronal (C) CT images which show an overlapping pubic ramus fractures left-sided (arrows) and a sacral fracture with no widening of the SI joint (head arrow). Patient was conservatively treated because of the stability of the fracture pattern.

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Fig. 22: Lateral compression type 1 in the same patient as figure 21. Three-dimensional volume-rendered CT images which show an overlapping pubic ramus fractures left-sided (arrows) and a sacral fracture with no widening of the SI joint (head arrow). Patient was conservatively treated because of the stability of the fracture pattern.

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Fig. 23: Three-dimensional reconstructions (A, B) and axial and coronal CT images. Lateral compression pelvic fracture type 1 which shows inferior pubic rami fracture right-sided (D). Concomitant iliac and acetabular fracture.

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Fig. 24: AP pelvic radiography in a trauma patient with lateral compression injury type 2. Note the characteristic right sacral impaction or buckle fracture with minimally widening of the SI joint and the overlapping pubic rami fractures right-sided. The sacral fractures might be subtle on radiographs.

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**Fig. 25**: Axial and coronal CT images and three-dimensional reconstructions in the same patient as figure 24 with lateral compression injury type 2. Right sacral impaction or buckle fracture with minimally widening of the SI joint. Note the crescent fracture of the posterior segment of the iliac and the overlapping superior and inferior pubic rami fractures right-sided.

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Fig. 26: Axial and coronal CT images and three-dimensional reconstructions in the same patient as figure 24 and 25 which show the right sacral impactation and the crescent fracture of the posterior segment of the iliac.

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**Fig. 27:** Axial CECT image in the same patient as figure 24-26. Right perivesical hematoma which partially compresses the bladder.

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**Fig. 28:** Three-dimensional volume-rendered CT images in patient who suffered a traffic accident. Fractures of the bilateral superior and inferior pubic rami (white arrows), and a compression fracture through the left sacrum (head arrow), a finding consistent with a lateral compression injury. Note the widening of the SI joint.

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Fig. 29: Coronal and axial CT images in the same patient as figure 28 which show bilateral superior and inferior pubic rami (white arrows), and a compression fracture through the left sacrum (head arrow), a finding consistent with a lateral compression injury (type 3). Note the widening of the SI joint (C).

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**Fig. 30:** Axial CT images in the same patient as figure 28-29 which show a thickening of the right pyramidal muscle. An active extravasation of contrast material is seen (red circle) as a complication of lateral compression injuries.

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**Fig. 31:** Axial CT images and three-dimensional reconstructions show bilateral pubic rami fractures and a small avulsion sacral fragment at the site of the anterior SI ligament attachment right-sided. Posterior SI ligaments are intact. No significant widening SI joint. These findings are suggestive of lateral compression.

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Fig. 32: Three-dimensional volume-rendered CT images. Lateral compression pelvic fracture type 2 which shows superior and inferior pubic rami fracture right-sided. Concomitant ipsilateral iliac and acetabular fracture.

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Fig. 33: Axial CECT image in the same patient as figure 32. Inferior pubic rami fracture right-sided (D). Concomitant iliac and acetabular fracture. Axial CT image obtained with soft-tissue window settings shows a large right-sided extraperitoneal hematoma.

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**Fig. 34:** Three-dimensional volume-rendered CT images showing a lateral compression type 3 injury. Medial displacement of the right hemipelvis, fractures of the bilateral superior and inferior pubic rami and a compression fracture through the left sacrum. Widening of the contralateral left SI joint with mild external rotation of the right iliac wing is also seen.

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Fig. 35: Axial CECT images in the same patient as figure 34. Lateral compression type 3 injury. Medial displacement of the right hemipelvis, fractures of the bilateral superior and inferior pubic rami and a compression fracture through the left sacrum. Widening of the contralateral left SI joint with mild external rotation of the right iliac wing is also seen.

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Fig. 36: Axial CECT image (A) and arteriography (B). Right-sided extraperitoneal hematoma with an active extravasation contrast material (A), which was proved and embolized by arteriography (B).

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Fig. 37: MIP coronal (A) and axial (C) CT images and three-dimensional reconstructions. Pubic symphysis diastasis of 2 cm and no apparent posterior pelvic ring injury, findings consistent with an AP compression type 1 injury.

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Fig. 38: AP pelvic radiography and its correlation with the 3D image. They show pubic symphysis diastasis and significant asymmetric widening of the left SI joint. These findings are suggestive of an open hemipelvis, which is seen in AP compression type 2 injuries. Bilateral pubic rami fractures are also seen.

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Fig. 39: Axial and coronal CT images in the same patient as figure 38. They show pubic symphysis diastasis (2.8 cm) and significant asymmetric widening of the left SI joint. Small avulsion sacral fragment is seen at the site of the anterior SI ligament attachment. The posterior SI ligaments are intact.

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**Fig. 40:** Axial CT images (A, B) and three-dimensional reconstructions (C, D, F) show vertical shear injury. There is a cephalad displacement of the right hemipelvis with a complete dissociation of the SI joint. Widening of the pubic symphysis, left and right sacral fractures, and a fracture of the right L5 transverse process are also seen.

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Fig. 41: Coronal and axial CT images which show a catastrophic pelvis caused by a combined mechanism of lateral compression and vertical shear injury.

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Fig. 42: Three-dimensional volume-rendered CT images in the same patient as figure 41. Catastrophic pelvis caused by a combined mechanism of lateral compression and vertical shear injury.

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Fig. 43: Complications of a lateral compression injury. Axial CECT images show pubic rami fractures left-sided and concomitant iliac and acetabular fractures (A, B). An active extravasation of contrast material from an obturator artery branch left-sided is also seen (C) as a result of a direct bone injury.

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Fig. 44: Angiography in the same patient as figure 44. The presence of contrast extravasation originated from branches of the left obturator artery was confirmed, and later embolized supraselectively.

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Conclusion

Pelvic ring fracture is an emergency that requires computed tomography to define the type, extent and complexity, and to assess the possible associated injuries. Young and Burgess Classification allow us to classify these fractures and establish a medical-surgical orientation to prioritize lesion severity and allow rapid and effective action.
References