Diagnosis and Classification of Sacral Fractures

Mohammed F. Shamji MD, PhD
VuMedi Webinar
Toronto Western Hospital – Spinal Neurosurgeon
University of Toronto – Assistant Professor
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Learning outcomes

• By the end of this session, participants will be able to:

  • Optimal diagnostic tests to investigate sacral fractures
  • Classification schemes to describe sacral fractures
  • Biomechanics of stable and unstable sacral fractures

Sacrum

• Large triangular bone at the base of the lower spine, angled forward in the sagittal plane

• Name derived from Latin (sacrum) translated from Greek (hieron) = sacred or strong bone
  • Part of the animal offered in sacrificed
  • Belief that the soul of the man resides there

• Slavic languages and German (“the cross bone” – Kreuzbein) and in Dutch (“the holy bone” – Heiligbeen)
Sacral Anatomy – Osteology - I

- Formed by fusion of the 5 sacral vertebrae
  - Initially unfused, begin to fuse age 16-18 and completes at 34
  - Initially ~20° forward angulation, increases during adulthood

- The pelvic surface is concave
- The dorsal surface is convex
- The lateral surface is broad above and narrows below
- The broad base is directed upward and forward
- The tapered apex is directed downward

Sacral Anatomy – Osteology - II

- Articulations
  - Proximally – L5 vertebra
  - Distally – coccyx
  - Laterally – ilium

- The vertebral canal is triangular in shape superiorly and inferiorly the posterior wall is often incomplete from undeveloped laminae and spinous processes

- Contains 4 foramina on each side that transmit sacral nerves

Sacral Anatomy – Ligaments

- Anterior SI joint
  - Resists external rotation

- Posterior SI joint and interosseous SI ligament
  - Posterior tension band stabilization

- Iliolumbar ligaments
  - Augment posterior stability

- Sacrospinous ligament (anterior sacrum to ischial tuberosity)
  - Resists external rotation

- Sacrotuberous ligament (sacrum behind sacrospinous to ischial tuberosity)
  - Resists shear and flexion
Sacral Anatomy – Biomechanics

- Cadaveric studies unreliable
- Radiographic studies limited in utility
- Implanted tantalum spheres into bones of pelvis
  - Range of SI motion < 2°
- Rigid externally fixed devices
  - Range of SI motion < 1°
- No muscles act on the SI joint to produce active physiologic movements

Stress-relieving joint
- Transmits load via first sacral segment through iliac wings to acetabulum

Sacral Anatomy – Neurology

- L5 nerve root runs on top of sacral ala
- S1-4 nerve roots transmitted through the sacral foramina

- L5 nerve root
  - Dermatome – dorsal foot to great toe
  - Myotome – EHL, gluteus medius
  - Reflex – medial hamstring reflex
- S1 nerve root
  - Dermatome – lateral and plantar foot
  - Myotome – gastrocnemius, soleus
  - Reflex – Achilles’
- S2-5 nerve roots
  - Bowel and bladder function
  - Unilateral preservation normally adequate for control

Clinical Presentation

- History
- Physical Examination
- Diagnostic Tests

Plain radiographs
- Sensitivity ~30%
  - AP pelvis
  - Inlet view (40° caudad)
  - Outlet view (40° cephalad)
  - If not overt, then suspect based on symphysis widening or L5 TP fractures

CT scan
- Choice test for diagnosis

MRI scan
- Choice test for neurological deficits

Mechanism
- Motor vehicle accident
- Fall from height
- Repetitive stress

Symptoms
- Peripelvic pain
- Neurological deficits

Inspection
- Soft tissue trauma

Palpation
- Test pelvic ring stability
- Assess for SC fluid mass

Neurological examination
- Light touch – LE and sacral
- DRE + anal wink reflex
- Bulbocavernosus, cremasteric reflex

Vascular examination
- Distal pulses
Choice CT Planes to Assess Fracture

<table>
<thead>
<tr>
<th>Measurement</th>
<th>CT Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP Displacement</td>
<td>Axial</td>
</tr>
<tr>
<td>Vertical Translation</td>
<td>Coronal</td>
</tr>
<tr>
<td>AP Translation</td>
<td>Sagittal</td>
</tr>
<tr>
<td>Sagittal Angulation</td>
<td>Sagittal</td>
</tr>
<tr>
<td>Canal Occlusion</td>
<td>Axial</td>
</tr>
</tbody>
</table>

≥ 1 cm of displacement (either static or on loading) generally marker of pelvic instability

Conceptual Approach to Sacral Fractures

- Presence of active bleeding
- Presence of open fracture
- Neurological injury
- Pattern and stability of the skeletal injury
- Systemic injury load

Classification Schemes

- Denis classification
  - Denis Zone-I fractures
  - Denis Zone-II fractures
  - Denis Zone-III fractures
- Roy-Camille subclassification
  - Denis Zone-III fractures
- Complex sacral fractures
  - Denis Zone-III fractures
- Tile classification
  - Global pelvic stability
- Isler classification
  - Involvement of lumbosacral articulation
Denis Classification – Overview

• Retrospective review (1988): 11 years, 236 patients

• Medial fracture excursion was closely associated with mechanism of injury and neurological deficits

• Confirmed by Pohlemann (1992) with series of 377 patients, but neurological deficit more correlated with Tile classification of pelvic stability

Shortcoming – does not inform about mechanical stability

Denis Classification – Type I

• Location – fracture lateral to the sacral foramina

• Frequency – most common, 50%

• Neurological injury – infrequent, 6%, typically involves L5 nerve root

• Entrapment of L5 nerve root between the upwardly migrated fracture fragment and the L5 transverse process
  • Reduction of the sacral ala may promote L5 recovery

Denis Classification – Type II

• Location – fracture through the sacral foramina

• Frequency – second most common, 34%

• Neurological injury – common, 28%, frequently involves L5, S1, or S2 nerve roots

• Bladder dysfunction is rare
Denis Classification – Type III

- Location – fracture medial to the sacral foramina
- Frequency – least common, 16%
- Neurological injury – frequent, 57%, bowel, bladder, sexual function impairment in 76% of those with neurological injury
- Vertical – almost always associated with pelvic ring fracture
- Horizontal – significant displacement produces severe deficit

Roy Camille Subclassification – Denis Type III

- Injury severity, likelihood of neurological injury, and therapeutic implications directly related to increasingly severe types
- Type 1 – flexion deformity of the sacrum
- Type 2 – partially translated and hyperkyphotic
- Type 3 – completely translated and no fracture overlap
- Type 4 – segmental S1 comminution

Complex Sacral Fractures – Denis Type III

- H-type
- U-type
- Lambda-type
- T-type
Tile Classification of Pelvic Stability

<table>
<thead>
<tr>
<th>Tile</th>
<th>Fracture Type</th>
<th>Fracture Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Stable</td>
<td>Acute pelvic, sacral wing, pelvic ring, Underlay autolysis.</td>
</tr>
<tr>
<td>B</td>
<td>Rotational unstable, Vertically static</td>
<td>Upward pubic ramus with posterior acetabular view, Bucket handle.</td>
</tr>
<tr>
<td>C</td>
<td>Rotationally unstable, Vertically unstable</td>
<td>Bilateral pelvic, bilateral acetabular, or bilateral pelvic.</td>
</tr>
</tbody>
</table>

Isler Classification – Lumbosacral Articulation

- Isler 1 - fracture occurs lateral to the L5/S1 facet
- Isler 2 - fractures line involves the L5/S1 facet
- Isler 3 - fracture line extends medially to the L5/S1 facet

Question 1

- 37F with history of major depression

  History
  - Suicide attempt, jump from 3rd floor

  Physical
  - No open lacerations
  - Lower extremity power intact
  - Absent rectal tone
  - Patellar anesthesia
  - Urinary retention

  Classification
  - Pattern?
  - Neurology?
  - Stable or unstable?
Pelvic Ring Injuries

Purpose

• Mechanism of Injury
  – Pelvic
  – Sacrum
• Classification
• Treatment

Mechanism of Injury

• High energy trauma
• Multiple injuries
• Significant soft tissue injury
Bone Anatomy

- Paired ilia
- Sacrum
- No inherent stability

Biomechanical Function

Sacrum

- Keystone

Resist outward movement
Rest of pelvic ring

Biomechanical Function

Sacrum

- Inlet view
  - Reverse keystone
  - Sacrum displaced internally
Biomechanical Function
Sacrum

• Keystone
• Inlet view
  – Reverse keystone
    Sacrum displaced internally
• Outlet view
  – Keystone

Important Stabilizing Ligaments

• Illiolumbar (LS)
• Sacroiliac ligaments
  – Posterior
  – Anterior

• Sacrotuberous
• Sacrospinous
• Very strong
• Essential to pelvic stability
Important Stabilizing Ligaments

- Symphyseal
- Fibrocartilagenous joint
  - Disc
  - Reinforcing capsule

Internal Anatomy

- Lots of stuff!!!
- Don’t go there

Pelvic Ring Fracture

90% sacral fractures
Pelvic ring injuries
Mechanism of Injury

- Force direct to pelvis
  - Ilium
  - Pubis
  - Ischium
- Indirect forces
  - Hip / femur

Classification Pelvic Ring Injuries

- Morphology – Letournel
- Mechanism/ stability
  - Young-Burgess
  - Tile
- AO/ OTA
  - Very complicated

Young - Burgess

- Anteroposterior compression (APC)
- Lateral compression
- Shear
Anteroposterior Compression

- APC 1
  - Symphysis disruption
  - Posterior intact

APC 1
Tile JAAOS 1996

Anteroposterior Compression

- APC 1
  - Posterior intact
  - Symphysis disruption
- AP 2
  - Partial lig disruption

APC 2
Tile JAAOS 1996

Anteroposterior Compression

- APC 1
  - Posterior intact
  - Symphysis disruption
- APC 2
  - Partial lig disruption
- APC 3
  - Complete sacroiliac disruption

Tile JAAOS 1996
Lateral Compression

• LC 1
  – Sacral compression
  – Pubis overlapping

LC 1
Tile JAAOS 1996

Lateral Compression

• LC 1
  – Sacral compression
• LC 2
  – Iliac wing fracture

LC 2
Tile JAAOS 1996

Lateral Compression

• LC 1
  – Sacral compression
• LC 2
  – Iliac wing fracture
• LC 3
  – Windswept pelvis

LC 3
Tile JAAOS 1996
Vertical Shear

• Highly unstable
• Complete sacroiliac disruption
• High degree nerve injury
• L5-S1 disruption
  – Facets
  – Spondylolisthesis
• Multiple TP fx

Treatment of Pelvic Ring Fractures

Goals

• Reduce pelvis volume
• Correct hip malalignment
  – Leg length
  – Center of head displacement
• Stability
  – Load transfer
  – Sitting
  – Standing/walking

Indications

• Large topic
• Poor agreement
• Asc sacral fracture
  – Assess pelvic ring
  – Unstable
  – Consider stabilization
    • Pubis
    • Acetabulum (if fractured)
    • Posterior SI joint and sacrum
Temporary Stabilization

- Hemodynamic instability
- Reduce pelvic volume
- Correct pelvic displacement
- Stabilize to allow clotting

Anterior Techniques

- External fixation
  - Unfavorable
  - Infections
  - Poorly controls posterior
- Infix
  - Pedicle screws systems
  - Percutaneous

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Anterior Techniques

- Internal Fixation
  - Pubic symphysis plating
  - Screws
  - Pelvic brim plating

Posterior Fixation

- Old techniques
  - Plate across posterior ilium
  - Trans-iliac rods
  - Anterior plate SI joint
- Iliac ORIF

Posterior Fixation

- Sacroiliac screws
- Iliolumbar fixation
Posterior Fixation

- Sacroiliac screws
- Iliolumbar fixation

Conclusion

- Pelvis ring injuries
- Component of sacral fractures
- Team approach
Indications

- Very little in the literature
- No Level 1 or 2 studies
- There are no clear guidelines
- Treatment usually done on case by case basis

Deciding Factors

- Pattern/Mechanism
- Energy
- Associated injuries
- Bone Quality
- Lever arms
Energy
- Stress fracture
- Low energy fall
- High energy
- As energy increases so does damage to soft tissue, displacement, neurologic injury and deformity
- As energy increases likelihood of surgery increases

Pattern/Mechanism
- What was the dominant force exerted in the injury?
- The human spine does not tolerate shear well
  - If the fracture occurred as a result of shear forces or if unstable in shear then risk of progression
- Is this a Pelvic fracture or a distal spinal fracture?
  - Look for associated fractures in the pelvic ring
- U or H-type fractures with
  - >1 cm displacement
  - >20(?) degrees angulation

Associated injuries
- Will surgical treatment of the sacral fracture assist the recovery of the associated injuries?
- Will treatment of the associated injuries affect the healing of the sacral injury? (i.e. protected weight bearing)
**Bone Quality**

- Osteoporotic sacral fractures often low energy and have less associated soft tissue injury
- Risk of fixation failure higher
- Tends towards non-operative treatment

**Lever Arms**

- Sacral fractures often occur below lumbar fusions
- The longer the adjacent level the higher the risk of further displacement
- Sacral kyphosis leads to loss of sagittal balance which increases deforming forces

**Algorithm for Treatment**
Case #1

- 54yo male
- Hi speed MVC
- Mulit extremity injuries
- Head bleed
- Pelvic ring with sacrum
- ? Neuro

MetroHealth Department of Neurosciences
Case #2

- 19yo female
- Car vs pedestrian
- Isolated injury
- Searing R le pain
- 0/5 plantar flexion R
Case #2

- 42yo male
- Hi speed MVC
- Multiple injuries
- Neuro intact
What is the most important anatomic landmark to see when inserting iliac bolts?

- Superior end plate of S1
- Superimposed sciatic notches
- Femoral heads
- PSIS starting point
- Teardrop