Fossilized synsacrum of the Ankylosaur, Euoplocephalus tutus, Upper Cretaceous 76-70 million years old. Specimen collected by B. Brown and P.C Kaisen, Red Deer River Alberta Canada, 1914. Natural History Museum, New York City, USA

“To what natural laws or secondary causes the orderly succession and progression of such organic phenomenon may have been committed we as yet are ignorant. But if, without derogation of the Divine power, we may conceive the existence of such ministers, and personify them by the term “Nature”, we learn from the past history of our globe that she has advanced with slow and stately steps, guided by the archetypal light, amidst the wreck of worlds, from the first embodiment of the Vertebrate idea under its old Ichthyic vestment, until it became arrayed in the glorious garb of the Human form.”

Sir Richard Owen,
On the Archetype and Homologies of the Vertebrate Skeleton 1848.
This colossal fossilized dinosaur bone belongs to the armoured Ankylosaur, Euoplocephalus tutus. It resides in the Natural History Museum of New York City and is around 75 million years old. The ankylosaurs were massive four legged, heavily armor-plated, ornithischians that first appeared in the Middle Jurassic. Paleontologists divide these creatures into two groups, based primarily on the presence or absence of a bony club at the end of the tail. Those with a club constitute the family of the Ankylosauridae and those without, the Nodosauridae. The most impressive specimens are seen in the Ankylosaurus group. Individuals could reach up to ten meters in length and weigh many tons. Colossal bony spikes and plates covered these animals in a great variety of arrangements and combinations, acting as protection against the monstrous predators of their day.

A more different creature to a human being can scarcely be imagined, yet strangely when the fossilized dinosaur bone above is viewed by any medical student with even the most rudimentary knowledge of anatomy there is an immediate feeling of familiarity. The bone is known as a synsacrum, an unfamiliar term, yet its general morphology is unmistakably similar to a human sacrum. The sacrum of the Ankylosaur has been modified when compared to a human to adapt for its very different needs. The most startling difference is its size, at about two meters, compared to a human sacrum which measures about ten centimetres! It articulates with the ilium as in the human, but in the horizontal plane as opposed to the vertical reflecting the Ankylosaur’s four legged gait. The dorsal neural spines are fused into a vertical sheet of bone for attachments of its massive hind leg musculature. The last 3-4 lumbar vertebrae are fused to the sacral segments, thus forming a synsacrum, a reinforced structure to hold the ligamentous attachments of the animal’s tail with its massive end club.

The Ankylosaur synsacrum and the sacrum of a human demonstrate the concept of “homology” of structures. The concept of “homology” of structures was coined by the great Victorian anatomist Sir Richard Owen in the early Nineteenth century. Early comparative anatomists were puzzled by the fact that seemingly utterly different vertebrate creatures externally could have such obviously related skeletons internally. Indeed it was recognized that most vertebrates appeared to share the same individual bones and that each of these articulated with the same corresponding bones in different animals. The only real differences appeared to be in the relative sizes and specific shapes of the individual bones. It seemed clear that all vertebrates were somehow closely related, and this even applied, most uncomfortably, to human beings. A human’s individual bones can in general terms for example be correlated bone for bone with that of an ankylosaur! Richard Owen termed this correlation homology. Just exactly what homology meant however was one of the great paleontological, philosophical, even theological debates of the early Nineteenth century.

Richard Owen held that all vertebrate animals were constructed according to a primal “blueprint” (“archetypal light”) that was laid out from the dawn of time by the great “first cause”, namely God. He did concede that natural “secondary causes” then diversified the primal archetype to produce an astounding array of variation over time. Just how this occurred however he frankly admitted total ignorance... “To what natural laws or secondary causes the orderly succession and progression of such organic phenomenon may have been committed we as yet are ignorant”. He was in no doubt
however that the secondary causes were acting in accordance with a preordained divine plan, for if God ordained the archetype, he certainly knew of all potential subsequent potential modifications in advance, he knew that human beings therefore would eventually come into existence. “The recognition of an ideal Exemplar for the vertebrated animals proves that the knowledge of such a being as man must have existed before man appeared”, he wrote, “for the Divine mind also fore-knew all its modifications”. Contrary to what people may think of Owen today, he was a brilliant anatomist and even more advanced in his thinking than many people today give him credit for. He did believe in “evolution” (though he would not have called it as such) by means of “secondary causes” of “nature” at a time when most people believed in the single and instantaneous biblical creation of all animals, who then remained unaltered for eternity. It was the mechanism by which his secondary causes achieved change, which he admitted he was at a loss to explain. One way or another however, he did believe that these secondary causes were predetermined or guided by the influence of the “first cause”.

Charles Darwin explained Owen’s secondary causes in the “Origin of Species” in 1859. Darwin wrote “the bones of a limb might be shortened and widened to any extent, and become gradually enveloped in thick membrane, so as to serve as a fin; or a webbed foot have all its bones, or certain bones, lengthened to any extent, so as to serve as a wing; yet in all this great modification there will be no tendency to alter the framework of bones or the relative connexion of the several parts. If we suppose that the ancient progenitor, the archetype, as it may be called, of all mammals, had its limbs constructed on the existing general pattern, for whatever purpose they served, we can at once perceive the plain signification of the homologous construction of the limbs throughout the whole class”. In Darwin’s interpretation homology became evidence of descent from a common ancestry, and this common ancestry became the very reason for homology. Darwin explained Owen’s secondary causes by “natural selection”, and this in turn was determined by the animal’s ability to adapt and survive in an ever changing environment. Richard Owen accepted the fact of evolution, he never however accepted Darwin’s explanation of it.
Introduction

Isolated sacral fractures are uncommon, they are usually seen in association with other fractures of the pelvic ring.

Sacral fractures are commonly missed on initial plain radiological examination.

**The preferred imaging for sacral fracture is CT scan**

Sacral fractures can be associated with serious cauda equina neurological injury, although this is surprisingly uncommon.

Mechanism

Sacral fractures are produced by high energy mechanisms of injury.

Vertical and transverse fractures usually result from direct A-P compression.

U-shape fractures usually result from axial loading

Sacral fractures will frequently be associated with other fractures of the pelvic ring.

Classification of sacral fractures

The predominant sacral fracture types include:

1. **Vertical fractures:**

   Simple vertical sacral fractures represent the most common type of sacral injury and form the basis of Denis’ 3 zone classification system, (see above).

   **Zone I**
   - The fracture line runs vertical, lateral to the sacral foramina

   **Zone II**
   - The fracture line runs vertically, through the sacral foramina

   **Zone III**
   - The fracture line runs vertically, through the spinal canal
2. **U-shaped fractures:**

Typical U-shaped sacral fractures, have bilateral longitudinal components coursing through the foramina, (zone II) connected by a transverse component running through zone III, (see B above).

Camille’s classification of U-shaped sacral fractures is as follows, (see above):

*Type I*
● There is minimal or no displacement.

Type II

● Displacement occurs in flexion, (upper segments lie posterior to the lower sacral segments).

Type III

● Displacement occurs in extension, (upper segments lie anterior to the lower sacral segments).

3. **Horizontal fractures:**

● Isolated horizontal fractures through the sacrum.

**Complications**

Neurologic injury is surprisingly uncommon in sacral injuries. The following patterns of injury however, may be seen:

Zone I fractures across sacral ala can cause L5 nerve root impingement.

Zone II fractures through the neuroforamina can cause unilateral sacral anesthesia.

Zone III fractures through the body of sacrum cause the highest incidence of neurological injury. Injury is to the cauda equina and can result in a neurogenic bladder.

**Clinical Features**

A sacral fracture should be suspected in any patient with pelvic ring trauma associated with a neurological deficit in the sacral distribution of spinal nerves.

Assessment of sacral neurological injury includes:

1. Voluntary motor:
   
   ● Determination voluntary rectal sphincter contraction.

2. Sensation:
   
   ● Light touch and pinprick sensation along the perianal concentric dermatomes of S2 through S5.

3. Specific sacral reflexes include:
   
   ● Perianal wink reflex.
• Bulbocavernosus reflex.
• Cremasteric reflex.

**Investigations**

*Plain Radiography:*

All patients suffering high energy mechanism injuries should receive an A-P pelvic radiograph, in accordance with routine ATLS guidelines.

Sacral fractures can be difficult to detect on plain radiography as the sacrum is usually obscured by bowel shadows and gas.

Views include:

• A-P
• Lateral
• Specific pelvic “inlet” and “outlet” views will improve visualization of the sacrum and rami.
  
❤ Pelvic inlet views will show the sacral spinal canal and a superior view of S1
  
❤ Pelvic outlet views will provide true A-P visualization of the sacrum.

Subtle indicators of sacral fracture include:

• Disruption of the sacral **arcuate lines:**
  
❤ The sacral foramina should be checked for disruption, in particular the upper 3 arcuate lines (which form the edge of the sacral foramina) should be traced.
  
❤ Both sides should be compared; the lines should be smooth and unbroken.
  
❤ Asymmetry indicates significant injury to the sacrum:

• Fracture of the **transverse process of L5:**
  
❤ A fractured L5 transverse process, which lies just above the sacrum, may suggest an occult sacral fracture especially in the absence of an obvious fracture of the iliac crest:

• Widening of the S-I joint:
The SI joints are normally relatively wide in adolescents but should be only 2–4mm in adults. An increase suggests disruption:

Discontinuity of the right sacral arcuate lines compared to the left, indicating a sacral fracture.

See appendix 2 below for normal radiology of the sacrum.

**CT scan:**

CT scanning is the preferred modality for diagnosing any suspected or known posterior injury to the pelvic ring.

CT scan will therefore always be required to:

- Confirm the presence of a sacral fracture.
- To fully define the extent of injury.

**MRI:**

MRI is the preferred imaging modality if the patient has neurological signs.

**Management**

1. **ABC**
   - As for any multi-trauma assess and treat any immediately life threatening injuries
   - IV fluid resuscitation in particular will be the immediate priority in isolated pelvic injuries.

2. Stabilize the pelvis:
• This may be done via a simple wrap around sheet, as for any unstable pelvic injury

• Alternatively the application of a temporary external fixator may be required

3. Analgesia:

• Titrate IV opioid analgesia, as required.

4. Orthopedic referral:

• ORIF may be required in significantly displaced, unstable or complex fractures.

5. Angiographic embolisation:

• Angiographic embolisation of bleeding pelvic vessels may be required if the patient remains haemodynamically unstable.
Appendix 1 Anatomy of the sacrum:

Left: Sacrum anterior surface. Right: Sacrum dorsal surface.

Left: Sacrum, lateral surface. Right: Sacrum, superior surface. (Gray’s Anatomy 1918).
Appendix 2  Plain radiology of the sacrum
CT Views of the Sacrum
Above: The armoured head and right forelimb of Euoplocephalus tutus. Left: the massive bony club at the end of the tail that was used as a defensive weapon against the monstrous predators of its day.

Natural History Museum, New York City, USA
References


Dr J. Hayes
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