Fractures of the talus: A pictorial review

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1. Learning objectives

- To review talar anatomy and talar blood supply with reference to trauma

- To recognise the different types of talar fractures, with emphasis on mechanisms of injury and associated injuries

- To demonstrate the imaging features of talar fractures

2. Background

- Talar integrity is critical for normal function of the ankle, subtalar and transverse tarsal joints.

- Although they are uncommon, talar fractures can interfere with normal coupled motion of these joints and can result in long-term disability due to pain, loss of mobility and deformity.

- A high index of suspicion, combined with an awareness of the injury patterns encountered, is often necessary to diagnose them.

- Because of the complex anatomy of this region, these fractures may be difficult to detect by standard radiographs, and thus cross-sectional imaging has become invaluable in the demonstration of most talar injuries.

- We present a pictorial review of the salient features of talar anatomy, with particular reference to trauma, the mechanism of injury and the types of fractures that are encountered.

3. Imaging findings OR Procedure details
The Talus - Anatomy and Blood Supply
- The talus transmits the axial load of the body into the foot and is essential for normal function of the ankle (dorsal and plantar flexion), sub-talar and transverse tarsal joints (eversion and inversion of the foot)

- It consists of a head, neck and body. The body of the talus can be further sub-divided into the body ‘proper’, dome (trochlea), lateral process, and posterior process. The posterior process consists of medial and lateral tubercles which contribute to the posterior facet of the sub-talar joint (Figures 1 - 4)

- Articulations (Figures 5 & 6):
- The talar dome and lateral process articulate with the distal tibia and fibula respectively to form the ankle joint

- The talar head articulates with the navicular to form the talo-navicular joint

- The anterior, middle and posterior calcaneal facets articulate with the calcaneum to form the sub-talar joint

- 60 – 70% of the talus is covered by articular cartilage. It gives no attachment to tendons or muscles, but has various ligamentous attachments, which are essential in maintaining congruity of the talar joints. In particular, the posterior talocalcaneal ligament is critical in maintaining congruence of the sub-talar joint in talar neck fractures (1)

- The talus receives blood supply (Figures 7 & 8) from all three major vessels of the leg:

  The posterior tibial artery provides two branches:
  - deltoid branch - supplies the medial part of the body
  - tarsal canal artery - is the main blood supply to the body

  The anterior tibial artery continues as the dorsalis pedis artery which gives rise to:
  - network of branches over the talar neck - provides a rich anastomotic supply to the head
  - sinus tarsi artery which anastomoses with tarsal canal artery – the perforators arise from this anastomosis and retrogradely supply the bulk of the body and dome

  The peroneal and posterior tibial arteries form a sparse anastomosis supplying the posterior aspect of the talus (1, 2)

- Similar to the scaphoid bone, the talus has a retrograde intraosseous blood supply. There is a fairly rich network of anastomosing blood vessels surrounding the talus. Despite this, there is a risk of interruption of the blood supply to the body, particularly the lateral aspect of the talar dome, in the event of trauma to the talar head and neck. This may result in avascular necrosis (AVN) (Figure 9)

Classification of Talar Fractures
Fractures of the talar body (including the body, dome, lateral and posterior processes)

- Including osteochondral fractures account for 40% of all talar fractures (1)

- Classification (Sneppen et al) (1, 3)

<table>
<thead>
<tr>
<th></th>
<th>Transchondral</th>
<th>Osteochondral</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Coronal</td>
<td>Sagittal or Horizontal shear</td>
</tr>
<tr>
<td>II</td>
<td>Posterior process</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Lateral process</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Crush fracture</td>
<td></td>
</tr>
</tbody>
</table>

Type I - Osteochondral fractures of the talar dome (5, 6, 7)

- Account for about 1% of talar fractures
Mechanism of injury - Inversion +/- dorsiflexion injury of the ankle - this causes shearing of an osteochondral fragment (anterolateral osteochondral fracture), while inversion + plantar flexion results in posteromedial osteochondral fracture. Repetitive trauma (stress) has also been implicated (8).

Classification - The commonly used classification is that of Berndt and Harty (modified) (6, 8, 9)(See Figures 10 - 17)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Plain films</th>
<th>MRI (T2 – weighted)</th>
<th>Arthroscopic correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal subchondral compression</td>
<td>Diffuse high-signal intensity (marrow oedema)</td>
<td>Normal Focal cartilage softening</td>
</tr>
<tr>
<td>2</td>
<td>Semicircular lucent line</td>
<td>Semicircular low-signal line (incomplete separation of fragment)</td>
<td>Partially-detached osteochondral flap</td>
</tr>
<tr>
<td>2a*</td>
<td>Subcortical round lucency</td>
<td>High-signal fluid within fragment (subchondral cyst)</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>Semicircular linear lucency</td>
<td>High-signal surrounding fragment (unattached, undisplaced fragment)</td>
<td>Completely detached but undisplaced osteochondral fragment</td>
</tr>
<tr>
<td>4</td>
<td>Loose body</td>
<td>Defect in talar dome, sometimes loose body is visible</td>
<td>Cartilaginous defect and loose body</td>
</tr>
</tbody>
</table>

*Stage 2a – A variant type where a cyst forms within subcortical bone

Associated injuries - lateral collateral ligament injuries (in up to 45% of cases)

Plain films - AP, mortise views

Further imaging - MRI to evaluate cartilage and presence of a loose fragment. CT is less sensitive to subchondral changes

Treatment - Arthroscopic drilling, repair or removal of fragment, depending on stage

Complications - Secondary osteoarthritis Type II - Fractures of the talar body ('proper') (4)

Mechanism of injury - Axial loading or shearing forces, forced dorsiflexion

Associated injuries – Fractures of the talar neck, tibia or calcaneum

Plain films - AP, mortise, lateral and Broden views (Figures 18, 21 & 24)

Further imaging - CT with multiplanar reformats (MPR) (Figures 19, 20, 22, 23, 25 & 26)

Treatment – Open, accurate reduction and internal fixation is crucial to reducing the likelihood of sub-talar arthritis

Complications – High incidence of sub-talar arthritis, AVN

Type III - Fractures of the posterior process (1, 12)

Shepard's fracture - isolated fracture of the lateral tubercle of the posterior process
Mechanism of injury – Forced equinus or inversion. Seen in ballet dancers, athletes

Associated injuries - talar body fracture, injury to the flexor hallucis longus tendon (runs between medial and lateral tubercles)

Plain films – Lateral view – beware the os trigonum (accessory ununited portion of the lateral tubercle!) (Figures 27 & 28)

Further imaging- Not usually required

Treatment – Conservative. Excision of fragment, if persistent pain due to either non-union or arthrosis (the inferior surfaces of the tubercles comprise 25% of the posterior facet of the sub-talar joint) (19)

Complications - Chronic pain due to nonunion or arthrosis

Type IV - Fractures of the lateral process (snowboarder's fracture) (10)

Increasing in incidence with increasing popularity of the sport. Comprise up to 24% of talar body fractures in some series.

40% may be missed initially on plain films alone (18)

Mechanism of injury – Inversion with forced dorsiflexion, with shear forces from the calcaneum transmitted to the lateral process. The fracture may extend into the posterior facet of the sub-talar joint. Less commonly, forced eversion may impact the lateral process between the tip of the lateral malleolus and the calcaneum (11)

Classification – (Hawkins) (11)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Chip fracture of the anterior and inferior portion, not extending to the talofibular joint</td>
</tr>
<tr>
<td>Type II</td>
<td>Non-comminuted fracture extending from the talofibular joint into the subtalar joint</td>
</tr>
<tr>
<td>Type III</td>
<td>Comminuted fracture involving both joint surfaces and the entire lateral process</td>
</tr>
</tbody>
</table>

Associated injuries – sub-talar dislocation, vertical fracture of the medial malleolus, talar neck fracture

Plain films - AP and lateral views, in addition to Mortise or Broden views, which best demonstrate this fracture. These may be normal (Figures 29 & 31)

Further imaging - CT is useful in identifying occult fractures and in assessing any extension into the sub-talar joint (Figures 30 & 32)

Treatment – Type I fractures can be treated conservatively. Type II should be reduced and internally fixed. If comminuted, excision is performed

Complications – High incidence of nonunion if not reduced (with chronic pain and disability). Secondary osteoarthritis of the sub-talar joint, if articular extension is not reduced

Fractures of the talar neck (13)(Figures 33 - 41)
· Account for up to 50% of talar fractures

· Most frequent cause is high velocity trauma

· Mechanisms of injury (14):

1. Commonest mechanism is forced dorsiflexion with impaction of the talar neck on the anterior tibial lip, resulting in fracture

2. Forced ankle inversion, with direct impingement of the talar neck against the medial malleolus

3. Direct blunt trauma to the dorsum of the talus

· Classification – as described initially by Hawkins, with subsequent modification by Canale et al (15, 16):

| Modified Hawkins classification of Talar Neck Fractures (after Canale & Kelly) |
|---------------------------------|---------------------------------|-----------------------------|
| Type  | Imaging finding | Incidence of AVN |
| I     | Undisplaced fracture | 10%           |
| II    | Displaced fracture, plus subluxation or dislocation of subtalar joint | 20-50%         |
| III   | Displaced fracture, dislocation of subtalar and tibiotalar joints | 70-100%        |
| IV    | Displaced fracture as in III, plus disruption of talonavicular joint | 100%           |

· Plain films - Lateral view most useful, as subtle on AP view. Canale and Kelly's view (17) in pronation is difficult to do in the acute phase, and has probably been superceded by the advent of MDCT with MPR. Serial plain films are valuable in follow-up for the presence of Hawkins sign (subcortical lucency caused by subcortical bone resorption due to local hyperaemia in response to the fracture) (16). If this is seen, it is a good predictor that AVN is unlikely to develop

· Further imaging - CT is essential in defining extent of fracture, fragments, configuration and displacement prior to surgery

· Treatment – Anatomic reduction and fixation

· Complications - AVN and subsequent collapse of the talar body, with secondary arthritis of the ankle. Subtalar arthritis if anatomic reduction not effected

Fractures of the Talar Head

· 5-10% of talar injuries (1)

· Mechanism of injury - Axial compression with the foot in plantar flexion
• Associated injuries - Talonavicular joint dislocation, fractures of other tarsal bones
• Plain films - AP and lateral views. The fracture will often be oblique (Figure 42)
• Further imaging – Oblique views / CT may be helpful in identifying fractures and assessing the talonavicular joint (Figure 43)
• Treatment – Conservative if undisplaced, surgical reduction and fixation if displaced
• Complications – Secondary osteoarthritis, if anatomical reduction not achieved. AVN is rare (10%) (1)

4. Conclusion

• Knowledge of talar anatomy including blood supply is crucial when considering the types of fractures encountered and the risk of potential complications, such as avascular necrosis

• Plain film findings may be subtle, so awareness of the common injury patterns and mechanisms in addition to their imaging features aids earlier identification of fractures

• Cross-sectional imaging is invaluable for many types of fractures in order to determine fracture type, associated injuries and to assist orthopaedic surgeons in planning further management

5. References

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6. Personal Information

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7. Figures

Figure 1: Anatomy, lateral aspect
Figure 2: Anatomy, medial aspect

Figure 3: Anatomy, inferior aspect

Figure 4: Anatomy, superior aspect

Figure 5: Normal anatomy, AP X-ray

Figure 6: Normal anatomy, Lateral x-ray
Figure 7: Talar blood supply - superior aspect

Figure 8: Talar blood supply - medial aspect

Figure 9: AVN: Lateral Xray of the ankle demonstrating sclerosis and flattening of the talar dome, subsequent to a previous fracture of the talar body. Note the marked osteopaenia in the rest of the talus and surrounding bones.

Figure 10: Stage I osteochondral defect - normal AP x-ray

Figure 11: Stage I osteochondral defectCoronal STIR image - note the high signal in the talar dome with intact overlying cortex.
Figure 12: AP x-ray - Stage III osteochondral defect in medial talar dome

Figure 13: Coronal CT reformat - another example of a Stage III osteochondral lesion in the lateral talar dome

Figure 14: Coronal STIR image, demonstrating a Stage III osteochondral lesion in the lateral dome of the talus, with associated high signal in the corresponding portion of the distal tibia

Figure 15: AP X-ray of the ankle joint, demonstrating a lateral defect in the dome of the talus (Stage IV lesion)
Figure 16: Lateral X-Ray demonstrating a Stage IV osteochondral defect

Figure 17: MR arthrogram. Sagittal scan, demonstrating a Stage IV osteochondral defect in the talar dome

Figure 18: Lateral X-ray demonstrating a vertical fracture of the body of the talus (coronal plane)

Figure 19: Sagittal CT Reformat demonstrating the coronal element of the talar body fracture seen in the previous Figure (18)
Figure 20: A coronal CT reformat of the fracture demonstrated in Figures 18 & 19, showing sagittal and horizontal elements of the fracture of the talar body.

Figure 21: Lateral X-ray demonstrating another example of a vertical shear fracture of the talar body (coronal plane).

Figure 22: Sagittal CT reformat of the same patient as in Figure 21 demonstrates the coronal plane fracture.

Figure 23: Coronal CT reformat of the same fracture demonstrated in Figures 21 & 22, shows a horizontal element traversing the talar body.
Figure 24: AP X-ray of the ankle, demonstrating a comminuted, oblique fracture of the distal tibial plafond, with an associated vertical fracture through the lateral aspect of the talar body (sagittal plane).

Figure 25: Coronal CT reformat of the patient with the fracture in the previous figure (Figure 24) demonstrates the sagittal plane fracture.

Figure 26: Axial CT image of talar body fracture following a gun shot injury to the ankle. Note the soft tissue blebs of gas and the extensive comminution. Subsequent amputation was performed due to the extent of the injuries.

Figure 27: Lateral X-ray of the ankle demonstrating a fracture of the posterior process of the talus. Note the increased opacity in Kager’s fat pad (the triangle of fat lying anterior to the Achilles tendon), which helps differentiate this fracture from an os trigonum (Figure 28).
Figure 28: An example of an os trigonum. Note the smooth borders, and the well-corticated appearance of this accessory ossicle. Note the clarity of Kager's fat pad in this case.

Figure 29: AP X-ray demonstrating a Type II lateral process fracture of the talus

Figure 30: Coronal CT reformat, demonstrating a Type II lateral process fracture

Figure 31: Another example of a lateral process fracture
Figure 32: Coronal CT reformat of lateral process fracture in Figure 31

Figure 33: Diagram demonstrating a Type I Hawkins fracture of the talar neck

Figure 34: Lateral X-ray of a Hawkins Type I fracture of the neck of the talus

Figure 35: Diagram showing a Hawkins Type II fracture of the talar neck, with subtalar joint dislocation
Figure 36: Lateral x-ray demonstrating a Hawkins type II fracture of the talar neck, with subtalar dislocation.

Figure 37: AP X-ray of the same patient with a Hawkins type II fracture of the talar neck, as in the previous figure (36), demonstrating the subtalar joint subluxation.

Figure 38: Diagram showing a Hawkins Type III fracture of the talar neck, with subtalar and tibiotalar joint dislocation. Note how the body is displaced posteriorly to lie adjacent to the Achilles tendon.

Figure 39: Lateral x-ray of the ankle, demonstrating subtalar joint dislocation in a patient with a Hawkins type III fracture of the talar neck. Note the posterior displacement of the talar body.
Figure 40: AP X-ray of the ankle, demonstrating subtalar and tibio-talar dislocation in the same patient as in Figure 39, with a Hawkins Type III fracture of the talar neck.

Figure 41: Diagram showing a Hawkins Type IV fracture of the talar neck, with subtalar joint dislocation and talonavicular joint dislocation.

Figure 42: AP X-ray of foot, demonstrating a fracture of the talar head with extension into the talonavicular joint.

Figure 43: Axial CT of talar head fracture in Figure 42.