

BRIEF REPORT

Lateral Fracture–Dislocation of the Calcaneus: Case Reports and a Systematic Review

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Objective: To report a case series of calcaneal fracture–dislocations, which have not been described previously in China, and to provide a systematic review to explore the clinic manifestations, methods for diagnoses, and treatments.

Methods: Between January 2018 and December 2019, 4 patients (4 men; average age, 33.0 ± 16.67 years; range, 15–50 years) were diagnosed with fracture–dislocation of the calcaneus and treated by surgery. We also reviewed published cases and studies of calcaneal fracture–dislocations through the databases of PubMed and Web of Science between January 1977 and December 2019.

Results: Between January 2018 and December 2019, 4 cases were identified as calcaneal fracture–dislocations in our hospital. The main clinical manifestations include hindfoot pain, swelling, and deformity. The diagnoses were confirmed via radiographic examination. Two patients underwent open reduction and internal fixation (ORIF) and two were treated with a minimally invasive approach. Diagnosis had been missed in one patient and, consequently, presented with early signs of post-traumatic arthritis, which may require extra subtalar arthrodesis in the future. Two patients were diagnosed inaccurately but achieved satisfactory outcomes through open reduction and internal fixation. The average follow-up period was 9.75 ± 5.19 months. Except for the 1 misdiagnosed patient, the other 3 patients showed functional improvement. Only 23 fracture–dislocations of calcaneus cases were reported in the literature between January 1977 and December 2019. There were 15 Sanders type II fractures (65.22%) and 7 (30.43%) Sanders type III fractures, and there was 1 grade II open calcaneal fracture. Among them, 1 was a medial dislocation and 2 were “joint-elevation” dislocations; the rest of them (20/23, 86.96%) were lateral dislocations. A total of 11 patients (47.83%) exhibited the double-density sign, and varus tilt of the talus was revealed on plain radiographs for 9 patients (39.13%). Increased Bohler’s angle was evident in lateral X-ray films for 2 patients (2/23, 8.70%). A total of 21 cases (86.96%) were treated with surgical intervention and achieved satisfactory outcomes. Only 1 patient was treated with external fixation. Another 2 patients were treated conservatively and had poor clinic outcomes.

Conclusion: Calcaneal fracture–dislocation is a rare injury that is challenging to treat. Clinical manifestations such as fibular tendon dislocation, the double-density sign on profile radiography, and abnormal talar tilt in the distal talofibular joint are important signs that may indicate this rare injury pattern. Timely surgical intervention is essential for satisfactory clinic outcomes. Orthopaedic surgeons should be aware of this uncommon injury to avoid misdiagnosis or inappropriate treatment.

Key words: Calcaneal fracture; Calcaneus; Fracture–dislocation; Intraarticular fracture; Subtalar joint

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Introduction

Calcaneal fractures are the most common tarsal bone fractures. They comprise 2% of all fractures, and approximately 75% of calcaneal fractures are intraarticular fractures^{1, 2}. However, fracture–dislocation of the calcaneus or part of it is a rare injury due to the geometric bone stability and the strong ligaments that connect the calcaneus to the talus and cuboid bone^{2, 3}. Different from the typically reported subtalar dislocations, calcaneal fracture–dislocations are calcaneal fractures with a non-dislocated sustentaculum fragment and a laterally dislocated posterolateral fragment that then wedges in the talofibular joint or makes contact with the tip of the fibula². Fracture–dislocations generally occur with high-energy trauma, such as a fall from height or a motor vehicle accident. Fractures are typically Sanders type II or III fractures of the posterior facet and usually involve a unilateral foot, sometimes complicated with ipsilateral talar or fibular fractures, lateral ligamentous complex rupture, fibular tendons dislocation, entrapment of the flexor hallucis longus, and other fractures of the body^{2–7}. Due to the lack of recognition of this injury pattern, atypical clinical indication, and inadequate radiographic evaluation, the true incidence might be considerably higher. This injury is frequently overlooked or misdiagnosed at the first presentation and then presents as late malunions^{8–10}.

This condition was first described by Merle D'Aubigne and Wilmoth in 1936¹¹, and then in 1977, Biga and Thomine referred to this injury as fracture–dislocations of the calcaneus⁷. Its rarity is emphasized by the fact that only small series of these fracture–dislocations have ever been reported^{6, 7}. Biga and Thomine reported on 4 laterally locked cases; 2 of their 4 cases were treated conservatively, with poor results⁷. The first report in the English literature was in 1986, by Court-Brown *et al.*, who reported on 2 cases of calcaneal fracture–dislocations⁶. Carr reported on a case of locked calcaneal fracture–dislocation associated with fracture of the contralateral calcaneus. However, the latter was not classified as a fracture–dislocation¹². Eastwood *et al.* treated 4 cases of locked calcaneal fracture–dislocation with cortical cannulated screws or lag screws and a Y-plate¹³. Ebraheim *et al.* reported on 2 calcaneal fractures with lateral subluxation of the posterior facet⁴. Turner and Haidukewych treated 2 patients with laterally locked fracture–dislocations of the calcaneus by minimal open reduction and percutaneous fixation¹⁴. Frasen *et al.* reported on 3 laterally dislocated cases; 1 of them was complicated by skin necrosis, which was treated by debridement and antibiotics². Faroug *et al.* reported on a 7-year-old boy with left calcaneal fracture–dislocation, who was treated with closed reduction using Ilizarov half-rings and Kirschner wires¹⁵. In 2018, Oliveira *et al.* reported on a case with bilateral fracture–dislocation³. All of the patients mentioned above were diagnosed with lateral fracture–dislocation. In 2015, Miller and Kwon reported on 2 cases with elevation of a portion of the posterior facet above the posterior talus, which they called “joint-elevation” calcaneal fracture–dislocation. The only case with a medial

luxation was reported by Anglen and Gehrke, who described interposition of the flexor hallucis longus tendon. Kim and Berkowitz focused on radiographic evaluation and suggested a double density sign variant as a meaningful clue for diagnosis. Schepers *et al.* retrospectively studied 16 patients' functional outcomes and then drew the conclusion that through an extended lateral approach, patients with calcaneal fracture–dislocations may have had higher rates of secondary subtalar fusion.

Although many scholars have described this rare injury pattern in the English-language literature, there are no similar cases reported or studies in China. There was no classification system that could help with diagnosis, treatment, and prognosis either. The purpose of this article is to: (i) report the clinical treatment process and prognoses of four patients diagnosed with fracture–dislocation of the calcaneus; and (ii) review the reported cases and studies of calcaneal fracture–dislocation to summarize clinical manifestations, diagnostic methods, and treatment options.

Materials and Methods

Patients' Information

Between January 2018 and December 2019, 4 patients were diagnosed with calcaneal fracture–dislocation in our hospital. All patients were male, with an average age of 33.0 ± 16.67 (range, 15–50) years. Among these 4 patients, 1 was misdiagnosed and, consequently, treated with inappropriate surgery methods. Another 2 patients were improperly diagnosed but treated appropriately. One was classified as Sanders type II_C, which had not been described in the published literature previously.

All patients were treated with surgical intervention in the lateral position. Preoperative and postoperative X-rays and CT scans were taken to evaluate the effect of the operations. One patient was treated with a minimally invasive approach and percutaneous fixation and one underwent internal fixation through sinus tarsi incision. Two patients underwent traditional open reduction and internal fixation. Patients were followed up at 1 month, 3 months, 6 months, and 1 year after surgery. The average follow-up period was 9.75 ± 5.19 (range, 5–16) months.

Case 1

A 44-year-old man fell from a height of 2 m. He complained of great pain and limited movement of bilateral hindfeet. On arrival at the hospital, his bilateral hindfeet were swollen and deformed. Neurovascular examination was normal. Preoperative X-ray films revealed a left calcaneal tuberosity fracture and a right calcaneal comminuted fracture, with a suspected calcaneal dislocation that was misdiagnosed at the first presentation (Fig. 1A). Subsequently, CT scans demonstrated a dislocated fragment of the posterolateral facet, which we did not notice at first (Fig. 1B). At 7 days after the injury, percutaneous reduction and cannulated screw fixation were applied in the lateral position under spinal anesthesia.

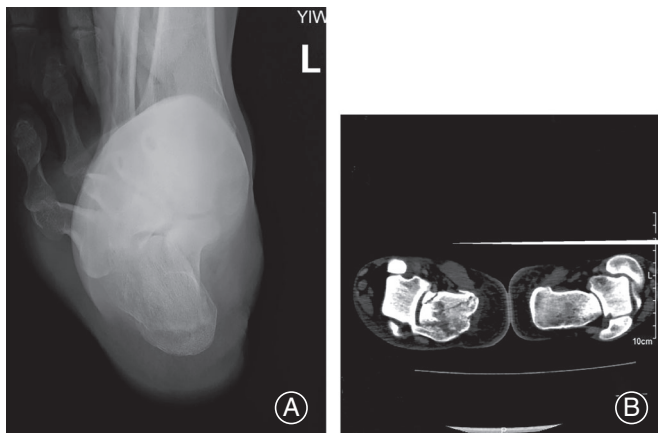


Fig. 1 (A) Preoperative X-ray films showed right calcaneal comminuted fracture with a suspected calcaneal dislocation. (B) Preoperative X-ray films showed a right calcaneal comminuted fracture with a suspected calcaneal dislocation.

Case 2

A 23-year-old man fell from a height of 5 m. He complained of severe pain in the lumbar region and exhibited deformity of bilateral hindfeet with pain, swelling, and limited movement, in addition to skin lacerations on the jaw with active bleeding. The patient did not present with neurovascular deficits of the lower limbs. After admission to the emergency department, the patient was subjected to debridement and sutures to the skin of the jaw. Preoperative X-ray films revealed a compression fracture in L₃, bilateral fractures of the calcaneus, and a fracture of the right talus. CT scans showed left fractures of the calcaneus and talus with a suspected cuboid avulsion fracture, and fractures of the right distal fibula, cuboid, and lateral cuneiform, and fracture-dislocation of the right calcaneus (Fig. 2). At 8 days after injury, the patient underwent a definitive surgery of the bilateral calcaneus and right lateral malleolus under general anesthesia.

Case 3

A 15-year-old male was involved in a motor vehicle accident at high speed. He complained of severe pain in the lumbar region and exhibited deformity of bilateral feet accompanied by pain and swelling, with active bleeding on the surface of the left foot. Radiographs taken at a local hospital showed explosion fractures in L₄ and L₅, a right calcaneal comminuted fracture, and an open fracture of left foot. Before admission to our hospital, the patient was subjected to ordinary cleaning and debridement of the open fracture and then temporary stabilization for bilateral feet; antibiotics were also given at the local hospital. Radiography taken at our hospital confirmed the fracture-dislocation of the right calcaneus and fractures of left talus and bilateral cuboid bones (Fig. 3). Eight days after the trauma event, the patient underwent osteosynthesis of the lumbar spine. Then, 10 days after first surgery, osteosynthesis of the bilateral calcaneus was applied.

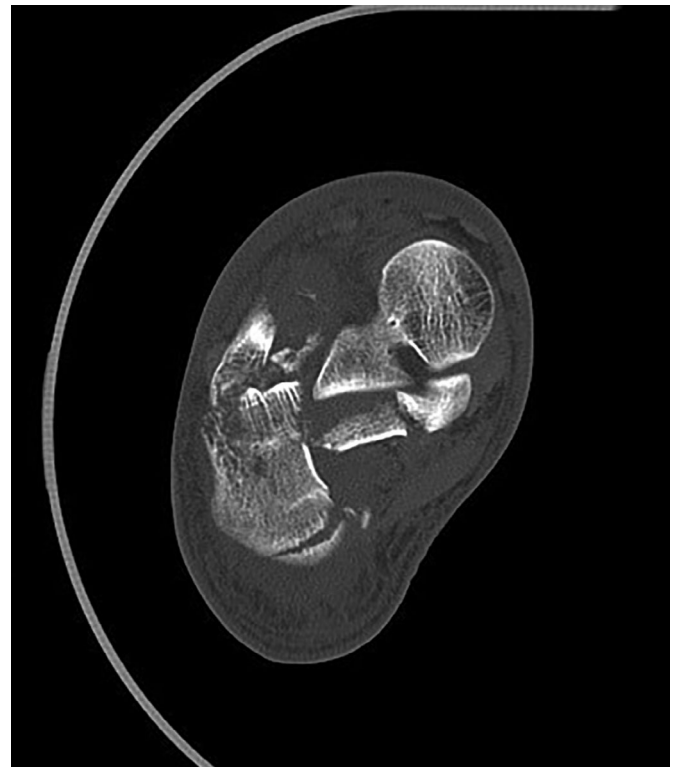


Fig. 2 CT scans showed significant fracture-dislocation of right calcaneus with a non-dislocated sustentaculum fragment.

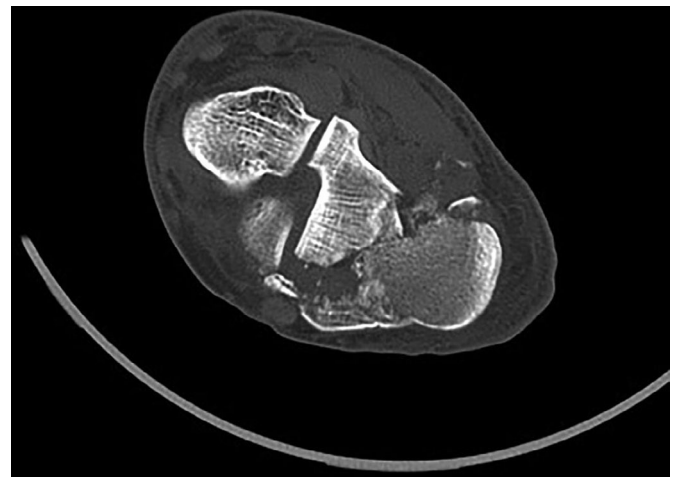


Fig. 3 CT scans taken at our hospital showed that the posterolateral fragment was dislocated laterally and compressed.

Case 4

A 50-year-old man fell from a height of 3 m. He complained of severe pain, numbness, and limited movement on his left foot. On arrival at the hospital, his left foot was severely swollen and deformed with hypoesthesia of the skin. Neurovascular examination was normal. Radiographs that were

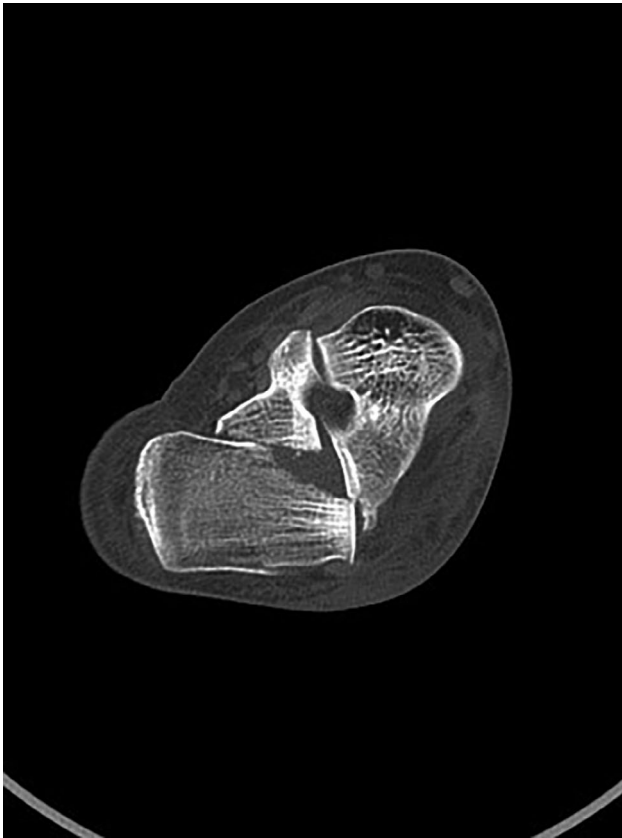


Fig. 4 CT scans showed fracture–dislocation of the calcaneus with talar fracture.

taken in the emergency department revealed fracture–dislocation of the left calcaneus, with left talar fracture (Fig. 4). After improvement in the skin condition of the left foot, the patient underwent the operation of the calcaneus, 6 days after the trauma.

Systematic Review

The inclusion criteria for studies included in this review were: (i) diagnosis of calcaneal fracture–dislocation; and (ii) literature published in English. The exclusion criteria were: (i) diagnosis of subtalar dislocation; (ii) fracture–dislocation of the talus; (iii) duplicated literature; and (iv) studies not published in English.

The queried databases included PubMed and Web of Science. We reviewed studies that were published between January 1977 and December 2019. “Fracture–dislocation of the calcaneus” and “calcaneal fracture–dislocation” were used as key words.

The initial database queries produced 224 published studies; 211 articles were excluded, including those that were duplicates, descriptions of subtalar dislocations, descriptions of talar fracture–dislocation, and non-English reports. We

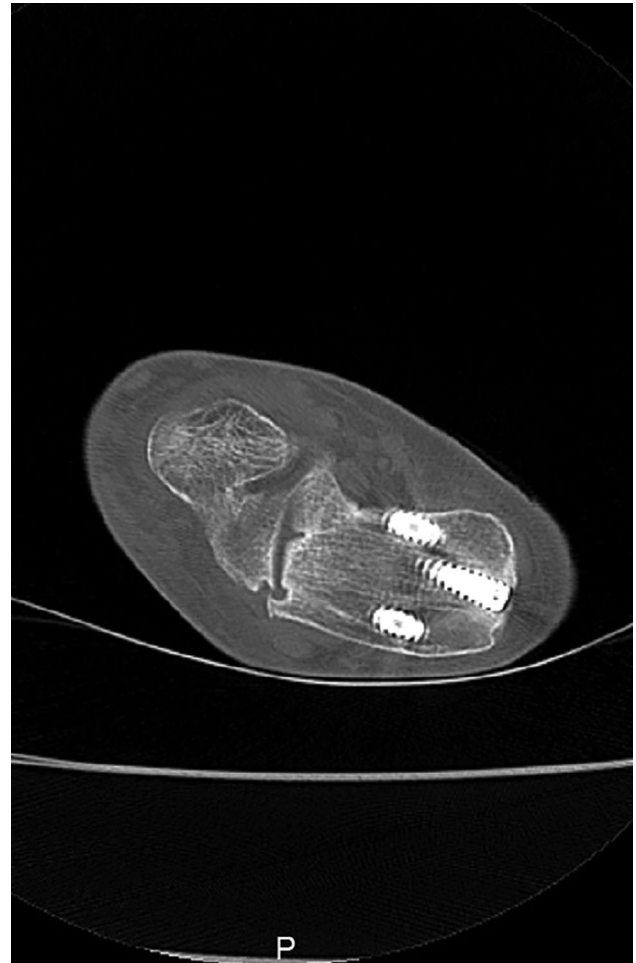


Fig. 5 Postoperative CT scans showed that the lateral fragment was still locked by the right talus.

identified 23 cases of calcaneal fracture–dislocations described in the 13 selected articles. The analysis index included: age, gender, fracture type, direction of dislocation, clinic manifestations (pain, swelling, deformed hindfoot, and soft tissue injuries) and concomitant diseases, radiographic evaluation, methods of treatment, and postoperative complications.

Results

Clinical Outcomes of the Cases

Case 1

The patients’ symptoms were alleviated after the operation. However, 4 months after the operation, the patient complained of pain in the right calcaneus during activity. Radiographs were taken, but the locked fragment was not picked up by the local hospital. At 11 months after surgery, the patient complained of exacerbated pain in the right calcaneus and went to our hospital. Physical examination showed that

he had 5° of dorsiflexion and 30° of plantarflexion in the ankle. Radiographs revealed that the posterolateral fragment was still locked by the right talus (Fig. 5). The American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale was 76 points at that time. Subtalar arthrodesis may be expected in the future due to the early signs of post-trauma arthritis.

Case 2

During the surgery, we observed that the posterolateral fragment totally dislocated outside the fibula. The fracture was classified as Sanders type II C, which was previously undescribed in the literature. Then the dislocation and fractures were reduced by anatomic locking plates, Kirschner wires, and cannulated screws. The patient remained immobilized with a bilateral plaster slab for 1 month. Postoperative X-ray films and CT scans showed satisfactory reduction (Fig. 6A,B). The Kirschner wires were removed 1 month after the operation. At 3 months after surgery, physical therapy was initiated to improve range of motion and to allow progressive loading. No surgical wound infections were observed. Sixteen months after surgery, the plates and screws were removed and the patient had a painless gait.

Case 3

During the surgery for the patient, we found that the posterolateral fragment was compressed and mildly inclined laterally. Subsequently, anatomic locking plates, Kirschner wires, and cannulated screws were used to stabilize the reduction of the calcaneus and subtalar joint. Postoperative radiographs showed satisfactory reduction (Fig. 7). Eleven days after the second surgery, the patient transferred to the rehabilitation department and rehabilitated therapy was immediately initiated. No surgical complications were observed. At last follow-up, 6 months following his injury, the patient had slight pain and limited movement. He was still undergoing rehabilitation therapy. The final outcome requires long-term follow up and evaluation.

Case 4

During surgery for the patient, a 3-cm sinus tarsi incision was made to expose the subtalar joint. The dislocated fragment was identified and reduced with a periosteal elevator. Three cannulated screws were imbedded to maintain the reduction, and one of them was placed to maintain the sustentaculum tali fragment. Postoperative radiographs demonstrated that the subtalar joint is congruous (Fig. 8). Six days after surgery, the patient was allowed to discharge. At last follow up 5 months after injury, he returned to work and had mild pain with activity. The final outcome requires long-term follow up and evaluation.

Systematic Review

A total of 13 reports were reviewed in this study, including 23 cases of calcaneal fracture-dislocations (Table 1). Most of the 13 studies were case reports and literature reviews, with 1 study focused on radiographic features and 1 on functional outcomes of calcaneal fracture-dislocations.

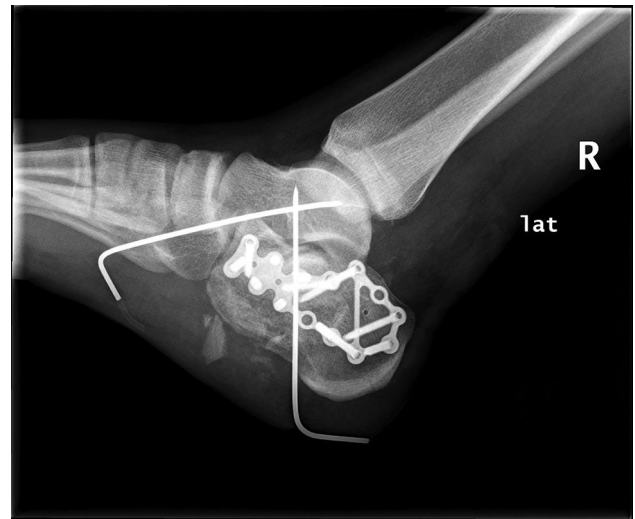


Fig. 7 Postoperative X-ray films showed satisfactory reduction.

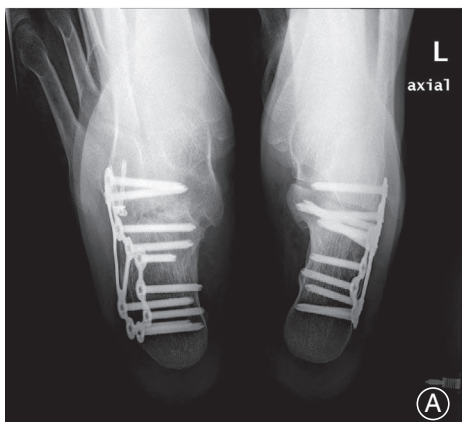


Fig. 6 (A) Postoperative X-ray films showed a satisfactory position after open reduction and internal fixation. (B) Postoperative CT scans showed a satisfactory position after open reduction and internal fixation.

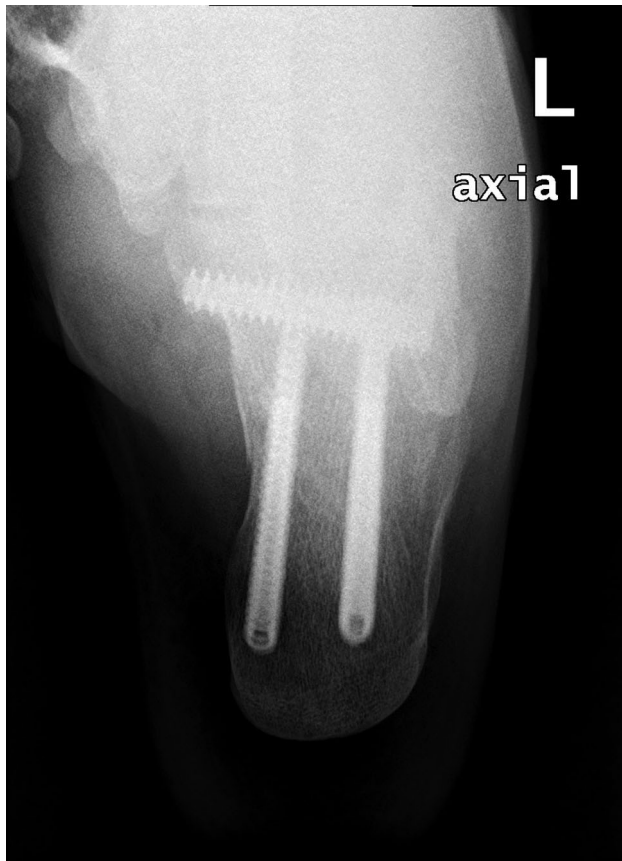


Fig. 8 Postoperative radiographs showed satisfactory reduction with cannulated screws.

All 23 patients had a history of injury. Their ages ranged from 7 to 84 years, with an average age of 42.81 ± 18.40 years. There were 13 males, 8 females and 2 with no details. There were 2 patients in the <20-year-old group, 9 in the 20–39-year-old group, 7 in the 40–59-year group, 2 in the 60–79 group, and 1 in the >80-year-old group. Fifteen patients (65.22%) were classified as having Sanders type II fractures and 7 (30.43%) as Sanders type III fractures. Most were lateral fracture–dislocations (20/23, 86.96%); 2 patients were diagnosed with “joint-elevation” fracture–dislocations and only 1 patient suffered medial subluxation. We have summarized the typical clinical manifestation, radiographic findings, treatment methods, and complications reported in the literature.

Clinical Manifestations and Concomitant Diseases

All of the patients exhibited pain, swollen joints, and deformed hindfeet. Ten patients (43.48%) experienced soft tissue injuries, such as ecchymosis, blistering, and active bleeding. Among the patients, 2 (8.70%) had checkrein deformity and 2 patients exhibited palpable displacement of fibular tendons.

One of the typically reported concomitant diseases was fractures in other parts of the body, such as lateral malleolus fractures (4/23, 17.39%), lumbar fractures (2/23, 8.70%), and fractures of the tibial plateau (1/23, 4.35%). Other common complications included the rupture of collateral ligaments (5/23, 21.74%) and pneumothorax (2/23, 8.70%). Interposition of peroneal tendons was confirmed in 2 patients during surgery.

TABLE 1 Characteristics of patients with fracture–dislocation of the calcaneus

Author	Cases	Gender (M/F)	Mechanism of injury	Fracture type	Direction of dislocation	Treatment
Biga	4	1:1	HVT (1) LVT (1) RTA (2)	Two-part calcaneus fracture (4)	Lateral (4)	Surgery (2) Conservative (2)
Carr	1	M	HVT	Grade II open calcaneal fracture	Lateral	First cast, after 2 years surgery
Count-Brown	2	1:1	LVT (1) RTA (1)	Two-part fracture (2)	Lateral (2)	Surgery (2)
Eastwood	4	3:1	LVT (3) RTA (1)	Two-part fracture (2) Three-part fracture (2)	Lateral (4)	Surgery (4)
Ebraheim	2	No details	No details	Three-part fracture (2)	Lateral (2)	Surgery (2)
Turner	2	1:1	HVT (1) RTA (1)	Two-part fracture (2)	Lateral (2)	Minimally invasive surgery (2)
Anglen	1	F	RTA	Two-part fracture	Medial	Surgery
Fransen	3	2:1	HVT (2) RTA (1)	Three-part fracture (2) Two-part fracture (1)	Lateral (3)	Surgery (3)
Faroug	1	M	RTA	Two-part fracture	Lateral	Iliizarov half-rings, K-wire
Miller	2	1:1	HVT (2)	Two-part fracture (2)	Posterior (2)	Surgery (2)
Oliveira	1	M	HVT	Bilateral three-part fracture	Lateral	Surgery
Zhang	4	M (4)	LVT (1) HVT (2) RTA (1)	Two-part fracture (3) Three-part fracture (1)	Lateral (4)	Surgery (4)

HVT, high velocity trauma; LVT, low velocity trauma; RTA, road traffic accident.

Radiographic Evaluation

From the literature we collected, two meaningful radiographic findings that indicated fracture-dislocation of the calcaneus were variant double-density sign and the varus tilt of the talus. Among the 23 cases we identified, 11 (47.83%) exhibited the double-density sign and 9 patients (39.13%) had varus tilt of the talus. Two patients (2/23, 8.70%) exhibited increased Bohler's angle in the lateral X-ray films. All of the patients underwent CT scans. MRI was performed for 1 patient and showed dislocation of the fibular tendons.

According to a retrospective study by Schepers *et al.* on 17 cases of calcaneal fracture-dislocation (1 patient suffered bilateral fracture-dislocation) between 2000–2011, 94% of all patients exhibited the double-density sign on lateral radiographs of the ankle, while only 10 of 16 patients (approximately 59%) had varus tilt of the talus.

Treatment

Except for 2 patients (2/23, 8.70%) who were treated conservatively, the rest of the 21 patients underwent surgery and achieved satisfactory outcomes. One patient was first treated by cast, then underwent subtalar bone block fusion 2 years later¹². Most patients were treated through the traditional lateral route; 3 of them (3/23, 13.04%) were treated with a minimally invasive approach. Two patients (2/23, 8.70%) were treated with K-wires and only 1 patient was treated by external fixation. Osteosynthesis of the calcaneus was not performed on 1 patient, due to an open fracture lesion and adequate reduction². One patient did not achieve anatomical reduction due to fracture comminution and the long post-trauma period³.

Postoperative Complications and Outcomes

Based on the literature that we collected, except for the 2 patients who underwent conservative treatment⁷, most patients achieved satisfactory outcomes with surgical intervention. One patient presented with a urinary tract infection³. One patient suffered skin necrosis after surgery and was treated by debridement and antibiotics². A few patients continued to experience slight pain (4/23, 17.39%), various movement limitation (3/23, 13.04%), and abnormal gait (1/23, 4.35%)^{2, 3, 6, 14}. Other commonly reported postoperative complications include post-traumatic subtalar arthrosis, calcaneal fracture malunion, and peroneal tenosynovitis *et al.*¹⁶

A retrospective study by Schepers *et al.* evaluated the outcomes of calcaneal fracture-dislocations. They drew the conclusion that the patient-related outcomes of locked calcaneal fractures are similar to the outcomes for other displaced intraarticular calcaneal fracture types. However, a higher rate of secondary subtalar arthrodesis can be expected due to the fracture-dislocation being a more severe injury¹⁷.

Discussion

Calcaneal fracture-dislocations are calcaneal fractures with a non-dislocated sustentaculum fragment and a

laterally dislocated posterolateral fragment that wedges in the talofibular joint or beneath the lateral malleolus. It is a rare injury pattern and must be distinguished from the more commonly occurring subtalar dislocation, in which the subtalar and talonavicular joints are dislocated simultaneously from under the talus¹⁸. It is also different from a calcaneal dislocation, an extremely rare injury that involves dislocation of the calcaneocuboid and subtalar joints without significant fracture and without talonavicular injury¹⁸.

Mechanism of Injury Pattern

Most scholars believe that the mechanism of fracture-dislocations of the calcaneus involves axial compression on an inverted foot (Fig. 9A)^{2-4, 6, 11, 13, 14, 16}. When an axial load is applied to an inverted foot, the calcaneus is divided into anteromedial and posterolateral fragments as the posterolateral edge of the talus is driven down (Fig. 9B). This primary fracture line runs forward and laterally from a point on the medial side at a variable distance behind the sustentaculum tali^{6, 12}. At this point, the superolateral fragment remains contiguous with the lateral wall and posterior tuberosity. If the residual force is still applied to the foot, the ligament will be disrupted and the posterolateral fragment may dislocate laterally, with or without talar or fibular fractures (Fig. 9C,D)^{4, 6}.

Miller and Kwon reported on 2 cases with elevation of a portion of the posterior facet above the posterior talus, which they referred to as “joint-elevation” calcaneal fracture-dislocation. They pointed out that the increased lamellar density at the superior portion of the posterior facet may result in this rare variation of calcaneal fracture-dislocation^{1, 19}. Anglen and Gehrke reported on a single case with a medial luxation, but they did not describe the mechanism of this injury pattern in detail⁵. Due to the rarity of this injury, further research is needed to illustrate the mechanism.

Diagnosis of Calcaneal Fracture-Dislocation

These complex fracture-dislocations need to be recognized immediately^{1-7, 12-15}. Physical examination may reveal enlargement and flattening of the hindfoot, and obvious hindfoot inversion deformity, and palpable fibular tendons displaced from their usual region^{3, 16}. Patients with interposition of the flexor hallucis longus tendon may present with checkrein deformity⁵. The absence of a pulse or neurological deficits may indicate the interposition of the medial neurovascular bundle, which requires special care²⁰. Although many scholars describe clinical features of calcaneal fracture-dislocations, there is still no classification system that can guide treatment or predict prognosis.

Radiographs provide overwhelming evidence for the accurate diagnosis of calcaneal fracture-dislocations. X-ray films play an important role in the early diagnosis^{1-5, 13, 14, 16, 21}. According to Eastwood *et al.*, when a patient presents with marked hindfoot swelling and plain radiographs show varus tilt of the talus with lateral malleolus fractures, this indicates the possibility of a calcaneal fracture-dislocation¹³.

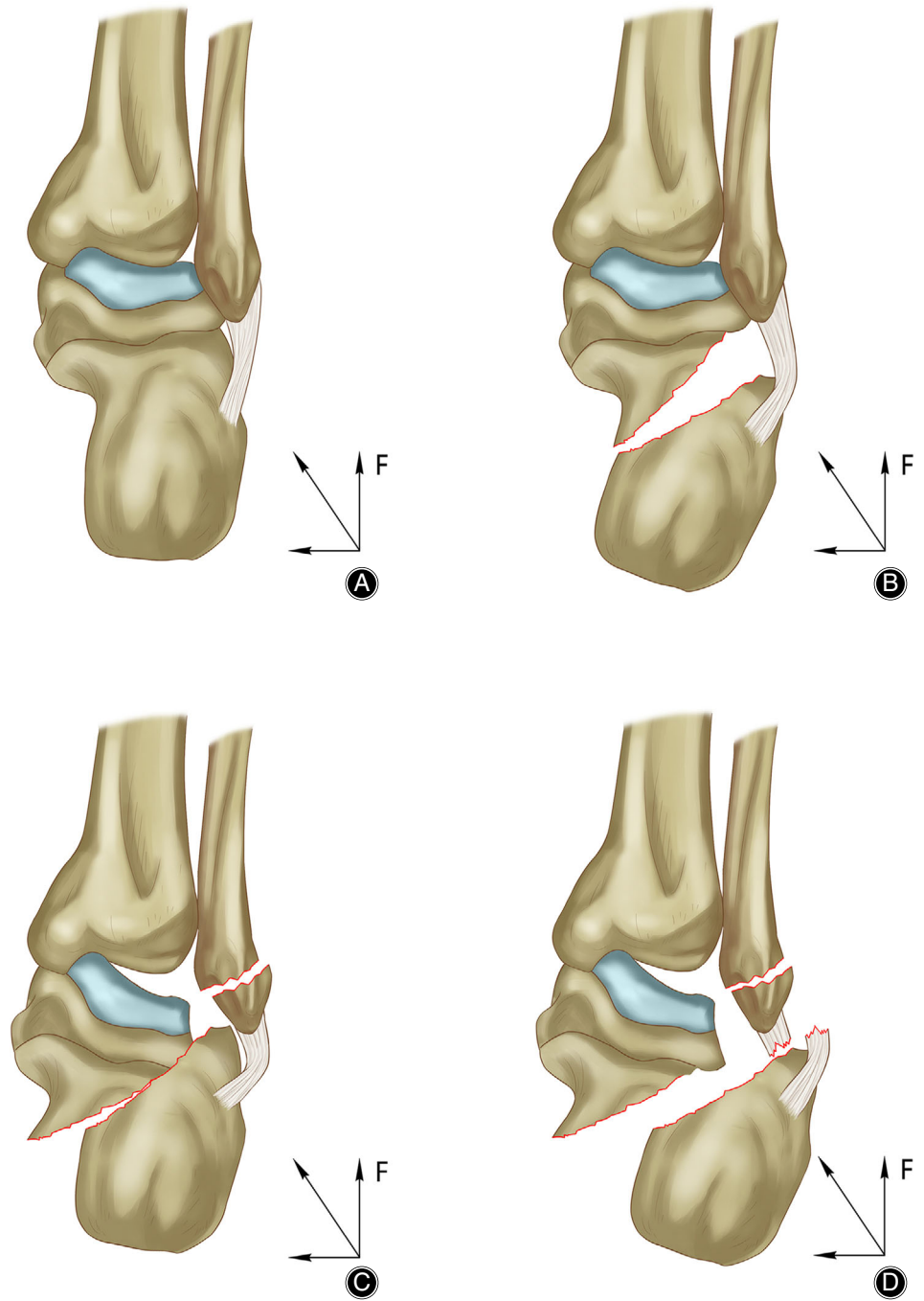


Fig. 9 (A) An axial loading applied on the inverted foot. (B) The violence produces the primary shear fracture and divides the calcaneus into anteromedial and posterolateral fragments. If the lateral ligament remains intact, significant lateral dislocation will not occur. (C) If the residual force is still applied to the foot, the fragment will wedge into the talofibular joint, with or without talar or fibular fractures. (D) If the residual force is still applied on the foot, the lateral ligament may be disrupted and the posterolateral fragment dislocate beneath the fibula, usually complicated with fibular fractures.

Kim and Berkowitz emphasize the importance of lateral radiography of the ankle. They describe a variation of the Sanders' double-density sign²² on lateral radiographs of the ankle corresponding to calcaneal overlap due to elevation of its lateral wall and displacement toward the fibula, thus facilitating diagnosis²¹. In addition to the double-density sign and the varus tilt, imaging may show a bony fragment wedged in the talofibular joint or dislocated laterally beneath the tip of the fibula due to the rupture of lateral ligament

complex, with or without distal fibular fractures¹². In lateral radiography of the ankle, in contrast to common calcaneal fractures, the measured Bohler's angle in calcaneal fracture-dislocations may increase or be within the normal range due to the relatively upward dislocated fragment¹.

CT scans have advantages in evaluating fracture-dislocations, showing small fragments and whether the injury involves the calcaneocuboid joint¹⁴. For this reason, Oliveira *et al.* suggested that CT should always be requested as a

complementary tool for diagnosis and surgical planning, if available³. Miller and Kwon also recommend that surgeons have a lower threshold to obtain CT imaging of any obvious calcaneus fracture that exhibits an increased Bohler's angle¹. Calcaneal MRI is performed for complementary evaluation of soft-tissue injuries, confirming dislocation of the fibular tendons, lateral ligamentous injury, and interposition of the flexor hallucis longus tendon³.

Treatment with Surgery

Due to the poor outcomes of 2 patients who underwent conservative treatment^{7, 12}, surgical intervention has become a consensus^{1-7, 11-15}. Which surgical method should be applied for patients depends on the general situations of patients and doctors' operative skills. The most frequently used methods include traditional ORIF, the mini-open approach and percutaneous reduction, or external fixation. The lateral approach is widely used because disrupted collateral ligaments enable good visualization of the articular surface of the calcaneus. A second medial incision could be made during the operation to ensure adequate reduction⁶. When fracture-dislocation occurs in patients with high risks of soft-tissue complications (e.g. diabetics, smokers, and the elderly), minimally invasive approaches such as tarsal sinus incision or the percutaneous technique for reduction could be considered¹⁴. The limb is usually immobilized post-operatively in a padded Weber splint and later in a short-leg non-weight-bearing cast for 6 weeks. Then patients could switch to an elastic compression stocking and fracture boot, and exercises were initiated. Weight-bearing is permitted only when radiographic union is confirmed¹¹.

Due to ignorance of this rare injury pattern at the first presentation, the long-term outcome of patients with calcaneal fracture-dislocations is usually malunion. This deformity is always type IV in the Zwipp/Rammelt classification, which they termed fracture-dislocation deformity¹⁰. For this type of deformity, Zwipp and Rammelt recommended using a corrective multiplanar osteotomy^{8, 23} and a modified Romash technique to treat these patients²⁴. Patients remain immobilized postoperatively in a below-knee cast with partial weight-bearing of 20 kg for 10 to 12 weeks until radiographic union. Weight-bearing is gradually increased thereafter, and active and passive range-of-motion exercises are initiated¹¹.

All of our patients were treated by surgery. However, the clinical outcomes of Case 1 may not achieve our expectations. We hypothesize that the choice of inappropriate surgical method without careful radiographic evaluation is the main reason. We overlooked the posterolateral fragments locked by the talus and then used a minimally invasive approach and percutaneous fixation without reducing the dislocated fragment. It resulted in postoperative pain in the first patient. However, we chose the traditional ORIF to treat Cases 2 and 3. Reduction was satisfactory because the traditional lateral approach provided a better operative view. Thus, indications for surgery should be strictly selected with comprehensive radiographic evaluation.

Causes of Missed Diagnosis or Misdiagnosis

We report on 4 cases of calcaneal fracture-dislocations. The first was a missed diagnosis at first presentation and likely will result in extra subtalar arthrodesis in the future. Although Cases 2 and 3 were not diagnosed accurately, they achieved satisfactory outcomes with traditional ORIF surgery. We summarize some probable reasons for missed diagnosis or misdiagnosis.

Atypical radiographic signs make the diagnosis more difficult. Different from the cases we reported, cases reported previously were usually diagnosed as "locked fracture-dislocation" with typical radiographic findings. However, our patients did not present with typical radiographic signs such as double density signs or varus tilt of the talus. This may mislead us to consider this injury as a common calcaneal fracture or subtalar dislocation. For example, we found that the posterolateral fragment was locked by the talus in Case 1, but the patient did not have the double density sign or varus tilt of the talus. We supposed that it may be attributed to the scale of the dislocated fragment being too small.

Schepers *et al.* showed that more patients presented with the double-density sign than varus tilt of the talus in X-rays films. They supposed that the dislocated lateral fragment needs to be of sufficient width to push the talus into the varus¹⁶. This conclusion was in accord with our findings. The differences in the data between two studies may attribute to the differences in the inclusion and exclusion. Due to this result, we regarded the double-density sign as a more predictive radiographic finding, and X-rays and CT scans should be the normal examination methods, if available.

Other reasons for missed diagnosis may include limited recognition of the injury and doctors' oversight. For instance, radiography of Case 2 showed significant displacement of posterolateral fragments with a non-dislocated sustentaculum fragment. However, we overlooked the sustentaculum fragment and misdiagnosed it as the more commonly occurring subtalar dislocation. With the improving recognition of this rare injury and more comprehensive examinations, Case 4 was correctly diagnosed and achieved satisfactory outcomes after surgical intervention.

Limitations

This study had several limitations. First, the number of patients included in this study was small. This may be attributed to the specificity of this rare injury. Second, the follow-up periods of some patients were not sufficient. Third, not all patients were evaluated using scales such as the AOFAS ankle-hindfoot scale. Therefore, we cannot accurately evaluate the true effect of the operation. In addition, most of the studies in the literature were case reports. Finally, due to the lack of posterior and medial fracture-dislocation cases, we focused more on lateral fracture-dislocations. This may mean that our article is not comprehensive enough.

Conclusion

In conclusion, calcaneal fracture–dislocation is a rare but challenging injury to treat. Fibular tendon dislocation, the double-density sign on profile radiography, and abnormal talar tilt in the distal talofibular joint are important clinical signs that may indicate this rare injury pattern. Therefore, X-rays and CT scans should be performed. Timely surgical intervention and rigid internal fixation could achieve satisfactory clinic outcomes. No matter

which surgery is applied, we recommend that rigid internal fixation should be placed parallel to the posterior facet articular surface to fix the sustentaculum process if the condition of soft tissues is accepted. Misdiagnosis may result in malunion or post-traumatic arthritis, which may critically affect the function of limbs and the quality of life of patients. Orthopaedic surgeons should be aware of this uncommon injury to avoid misdiagnosis or inappropriate treatment.

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