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CONTINUING EDUCATION

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Ankle Distortion Related Lesions. Emphasis on Failed Radiographic Diagnosis

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Introduction

Acute ankle distortion trauma is very frequent, it accounts for about 10% of emergency room admissions. In the acute setting, the Ottawa foot and ankle clinical decision rules are widely used to decide whether or not radiographic evaluation is needed. Although radiographs easily detect displaced fractures, occult fractures may occur. Also, sprains and peroneal tendon dislocation may go undetected using plain radiography. It is the purpose of this overview to briefly discuss ankle distortion related lesions with emphasis on failed radiographic diagnosis.

Discussion

Acute ankle distortion with inversion or eversion trauma is very frequent, it accounts for about 10% of emergency room admissions (1). In about 85% of ankle distortions, lateral collateral ligament lesion is present. A fracture is detected in about 15% (1) of cases. In the acute setting, the Ottawa foot and ankle clinical decision rules are widely used to decide whether or not radiographic evaluation is needed. By using these rules, about 35% of radiographic examinations can be avoided with a low rate of false negatives (1). Radiographic evaluation includes mortise and lateral views of the ankle and three-quarter views of the foot. An anteroposterior view of the lower leg is added in case of pain on palpation at the level of the proximal half of the fibula. These radiographs easily detect displaced fractures at the medial, lateral or tertiary malleolus, the fibula metaphysis and diaphysis, the fifth metatarsal, at the talus neck or dome and the posterior talus processus or os trigonum. Also grade III sprains of the syndesmosis may be detected on plain radiography. Appreciation of radiographs with the Lauge Hansen classification of ankle trauma has a major advantage compared to the Weber classification as it includes the trauma mechanism and position of the foot at the time of the injury (Fig. 1). Therefore, it gives a clue to accompanying ligament lesions and grades the lesion at the distal tibiofibular and ankle joint as being stable or unstable (2-7). In case of supination-adduction trauma (Weber A type), the presence of an

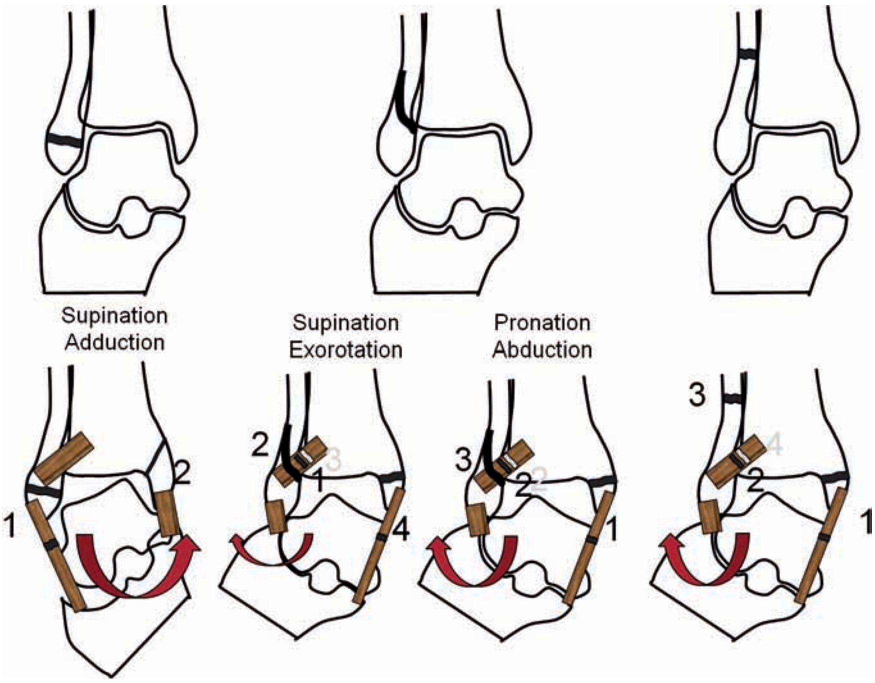

Fig. 1. — Weber and Lauge Hansen ankle trauma classification. In the Weber the higher the level the more chance for syndesmotic rupture and instability. The system by Lauge-Hansen (1950) is based on the position of the foot at the time of injury and the direction of the force on the talus with respect to the leg resulting in basic fracture-types. It gives more insight in the trauma mechanism and associated injuries. In the Lauge Hansen classification the lesions are sequentially numbered.

Supination-Adduction.
- Stage 1. Transverse fracture of lateral malleolus, at or below the level of anterior talo-fibular ligament or a tear of LCL structures with the anterior talofibular ligament disrupted most often and frequently the calcaneofibular ligament also torn.
- Stage 2. Oblique fracture of medial malleolus.

Supination-External (Eversion) Rotation
- Stage 1: Rupture of anterior inferior tibiofibular ligament.
- Stage 2: Oblique fracture or spiral fracture of the lateral malleolus.
- Stage 3: Rupture of post tibiofibular ligament or fracture of posterior malleolus of tibia.
- Stage 4: Transverse (sometimes oblique) fracture of medial tibial malleolus.

40% - 70% of all ankle fractures

Pronation-Abduction
- Stage 1: Rupture of the deltoid ligament or transverse fracture of the medial malleolus.
- Stage 2: Rupture of the anterior and posterior inferior tibiotalofibular ligaments or bony avulsion.
- Stage 3: Oblique fracture of the fibula at the level of the syndesmosis.
  Less than 5% of ankle fractures.

Pronation-Eversion
- Stage 1: Rupture of the deltoid ligament or transverse fracture of the medial malleolus.
- Stage 2: Rupture of the anterior nferior tibiotalofibular ligaments or bony avulsion.
- Stage 3: Spiral/Oblique fracture of the fibula above the level of the syndesmosis.
- Stage 4: Rupture of the posterior inferior tibiofibular ligament or fracture of the posterior malleolus.

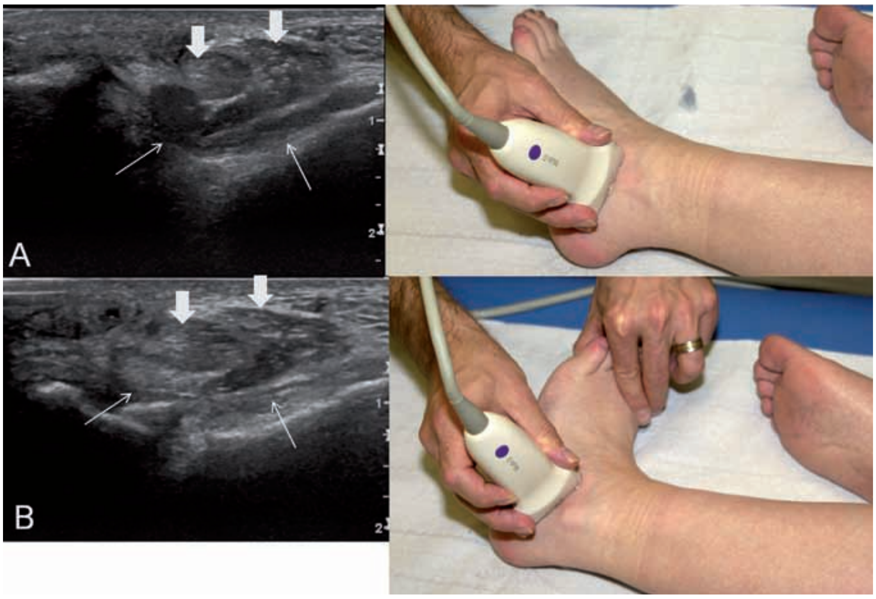

Fig. 2. — Fibulocalcanear ligament evaluation. Dynamic ultrasound examination of the fibulocalcanear ligament. A. Neutral position. The fibulocalcanear ligament (thin arrows) is slack with the peroneal tendons (thick arrows) superficial to the ligament. B. Foot in dorsiflexion and eversion position. In this position the fibulocalcanear ligament (thin arrows) is stretched with superficial displacement of the peroneal tendons. This superficial displacement is absent in torn (sprain grade III) or slackened (sprain grade II) ligaments. In case of retinaculum peroneorum superius tear or avulsive fracture the peroneus tendons may dislocate anterior relative to the lateral malleolus.

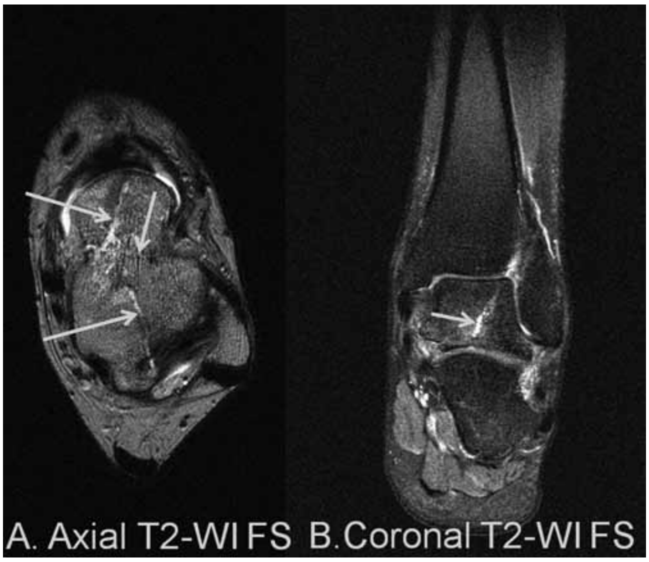

Fig. 3. — Talar neck fracture. Male, 53 y old. Magnetic resonance T2-WI sequences with fat suppression in axial (A) and coronal (B) planes. Complex talar fracture, sagittal and coronal hyperintense fractures (arrows).

oblique (push off) fracture of the medial malleolus includes a major lateral lesion. As a consequence, in the absence of a transverse (avulsive) fracture of the malleolus lateralis, a sprain grade III of the anterior talofibular ligament and grade II or III of the fibulocalcanear ligament is present. In case of supination-exorotation trauma (Weber B type), a spiral fracture (push off type) of the fibula at the level of the syndesmosis implies a sprain grade III of the anterior inferior tibiofibular ligament. If no accompanying avulsive (transverse) fracture of the medial malleolus is detected, a grade III (complete) tear of the deltoid ligament components is implied. In case of pronation-exorotation trauma (Weber C type), a fracture of the fibula metaphysis or diaphysis includes a tear of the anterior inferior tibiofibular ligament. If no accompanying transverse (avulsive) fracture of the medial malleolus is detected also a tear grade III of ligamentum deltoïdeum components are implied. In conclusion, this Lauge Hansen system is able to discriminate stable and unstable lesions at the level of the distal tibiofibular and talocrural joint and makes acute ligament evaluation by ultrasound or MRI obsolete in de acute setting. Despite the low rate of false negative radiographs in the acute setting, occult fractures may occur and recent reports calculate that 39% of ankle and midfoot fractures in ankle distortions are being missed on radiographs (8). Failed radiographic diagnosis does not only include non displaced fractures, but also minor sprains of medial and lateral ankle ligaments,syndesmosis and also, sprains or avulsive fractures of the dorsal calcaneocuboidal ligament, the ligamentum bifurcatum and the retinaculum peroneorum superior with possible peroneal tendon dislocation and concomitant tendinopathy. An undefined number of patients develop a sinus tarsus syndrome after ankle distortion. The frequency, clinical relevance and diagnostic and therapeutic management implications of failed diagnosis is dissimilar. These radiographically occult fractures can be visualized with MRI or CT. One week after acute ankle distortion, most patients (71%) declare symptom relief (8). In a prospective study in 38 patients without obvious fractures or syndesmosis lesions seen on radiographs, MRI detected ligament lesions in 63% of cases, 92% of them include LCL lesion (54.5% with single ATFL; 41% with ATFL and FCL lesion and 4.5% with lesions of all components of the LCL), 8% with MCL lesion and 8% with syndesmosis lesion (9). In this study, bone bruise was present in 8% (calcaneus, medial malleolus and calcaneus), osteochondral fracture of the medial talus in 8% and malleolus tertius fracture in 4% of cases. All these presented with effusion at the talocrural joint (9). A lesion is called highly significant if no return to sports activities was achieved after 12 months. This was the case in talar fractures and in case of complete calcaneofibular ligament tear (9). This can be explained by the stabilizing function of this ligament not only at the level of the talocrural joint but also at the level of the subtalar joint. Indeed, an association of sinus tarsus syndrome and subtalar intstability is well known (9). The fibulocalcanear ligament is best evaluated with dynamic ultrasound (Fig. 2). In another study (8), one week after the initial trauma, 0.4% of patients presented with residual clinical edema at the ankle, difficulty to bear weight and local tenderness above the anterior tibiofibular ligament while the ankle was held in plantar flexion and internal rotation. In these patients, non displaced talar neck fracture was detected with MRI (Fig. 3). Besides typical peroneal tendondislocation (Fig. 4), a so called ' intrasheath' dislocation of the peroneal tendons may occur and be the cause of retromalleolar pain and clicking sensation (Fig. 5) (10). In this entity, the peroneal tendons switch place permanently or during ankle dorsiflexion and foot eversion maneuver. A longitudinal tear of the peroneus brevis may be

Fig. 4. — Peroneal tendon dislocation. Male, 29y old. Multislice CT examination of the right ankle with coronal and axiale reconstructions in bone algorithm. Avulsive fracture of the retinaculum peroneorum superius with dissociated fracture fragment (long thin arrow) lateral-posterior to the distal fibula (triangle) with interposition and anterior dislocation of peroneal tendons (thick arrow).

associated. This can easily be demonstrated with dynamic ultrasound. Anterior inferior tibiofibular ligament, calcaneocuboidal ligament, ligamentum bifurcatum and retinaculum peroneorum lesions may easily be evaluated with ultrasound.

Additional evaluation is restricted to patients with residual pain during reevaluation one week after trauma. MRI or CT is used to detect occult fractures in case of residual talocrural joint effusion with anterior talar tenderness during endorotation and plantar flexion. Ultrasound is used in case of local tenderness posterior and inferior to the lateral malleolus to evaluate the fibulocalcanear ligament and the superior peroneal retinaculum.

Conclusion

By using the Ottawa rules in the acute setting after ankle distortion, about 35% of radiographic examinations are avoided with a low rate of false negatives. Additional imaging evaluation is restricted to patients with residual pain during reevaluation one week after trauma and should focus on the detection of lesions that may go undetected using plain radiography. MRI or CT is used to detect occult fractures. Ultrasound is used in case of local tenderness posterior and inferior to the lateral malleolus to evaluate the fibulocalcanear ligament and the superior peroneal retinaculum.

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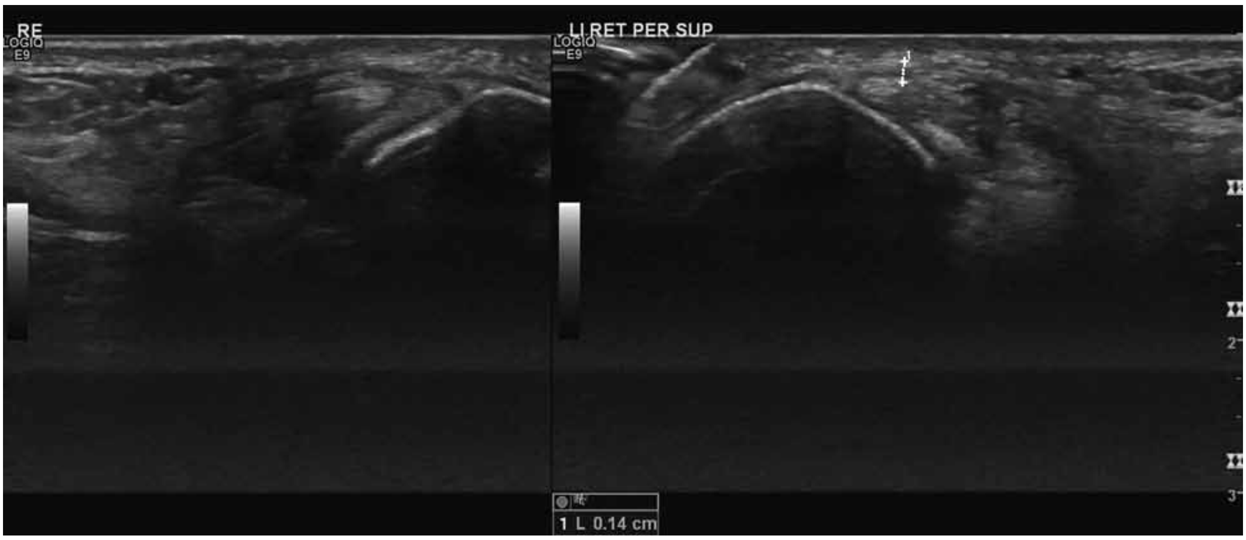

Fig. 5. — Intrasheath dislocation of peroneal tendons. Male, 28y old. Old inversion trauma with residual pain and clicking sensation during walking at left retromalleolal level. Ultrasound examinations in axial imaging plane at left retromalleolar level, right for comparison. At the left ankle the peroneus longus (oval) tendon is in contact with the malleolus lateralis with posterior displacement of the peroneus brevis (dotted line) tendon and muscle. At the normal right side the peroneus brevis (dotted line) is interposed between the malleolus lateralis and the peroneus longus (oval) tendon. Superficial to the tendons a normal thin retinaculum peroneorum superius is recognized with normal attachment to the fibula (arrow).

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A challenging cause of mono-arthritis of the ankle

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Case report

A 24-year-old male presented with pain and swelling of the right ankle. He was diagnosed with mono-arthritis of unknown origin and treated with non-steroidal anti-inflammatory drugs (NSAIDs) and intra-articular steroid injections. Four years later, due to insufficient effect of the treatment, he returned with persistent complaints.

The initial conventional radiographs showed no abnormalities (not shown). An oblique radiograph (Fig. 1A) two years later showed a subtle juxtacortical lesion (arrow) on the superior side of talar neck. On MRI performed four years after the onset of symptoms, a significant joint effusion (asterisk) in the ankle joint was detected with extensive bone marrow edema (arrowheads) of the talus on fat-suppressed (FS) T2-weighted images (WI) (Fig. 1B). A juxtacortical, nodular lesion (arrow) of 10 mm was detected at the anteromedial aspect of the talar neck. The lesion was of intermediate signal intensity on T1-WI (Fig. 1C) and inhomogeneous with both high and low signal areas on FS T2-WI. The adjacent soft tissues showed reactive changes with high signal intensity on FS T2-WI (Fig. 1B). A follow-up conventional radiograph (Fig. 1D) showed a juxtacortical osteolytic lesion (arrow) in the medial talus surrounded by subtle sclerosis. The diagnosis of an intra-articular osteoïd osteoma (O.O.) was

Fig. 1. —

made. The lesion was successfully treated with radiofrequency ablation and the patient was symptom-free two week after treatment.

Comment

O.O. is a benign bone-forming tumor accounting for 12% of all benign skeletal neoplasms. The tumor has a male to female ratio of 2-3:1 and is most commonly found in adolescents or young adults (10-25 years). The classical O.O. is located in the cortex of the diaphysis of long bones. Patients typically present with pain starting at rest and worsening during the night responding very well to NSAIDs. The diagnosis on imaging is usually straightforward on plain films or even better on CT-scan. A small osteolytic lesion (the nidus) with variable central ossification surrounded by sclerosis and subperiosteal new bone formation is seen within the cortex. The scintigraphic hallmark of an O.O. is the 'double density sign', characterized by intense accumulation of the radionuclide centrally in the nidus and less activity peripherally in the reactive sclerotic bone. The treatment of choice for O.O. consists of radiofrequency ablation.

However, in approximately 13% the O.O. is located in the subperiosteal juxta- or intra-articular location with different clinical and diagnostic presentation resulting in a diagnostic challenge. The hip joint is most commonly affected, followed by the ankle, elbow, wrist and knee. Intra-articular O.O. presents with symptoms similar to any mono-articular inflammatory arthritis with joint tenderness, soft-tissue swelling, joint effusion and synovitis. The pain is often indistinguishable from other arthropathies and the night pain is usually absent or less typical. Moreover, intra-articular O.O. is less responsive to NSAIDs. On plain radiographs the sclerosis around the nidus is less striking or even absent due to the anatomical location of trabecular bone in the epi/metaphysis. Therefore, the nidus is often overlooked on the initial plain radiograph. As periosteum is not present within the joint capsule, periosteal new bone formation is absent or may occur distant from the lesion. On scintigraphy a nonspecific diffuse activity is seen instead of the 'double density' sign, due to associated synovitis and hyperaemia. On MRI, a small nidus is lost in the surrounding reactive changes. The variable signal intensity of the nidus on MRI depends on size, vascularity, maturity and the degree of surrounding sclerosis. Furthermore, the joint effusion and bone marrow edema are prominent and misinterpreted as signs of arthritis and not as a reactive phenomena of an intracapsular nidus. CT remains the preferred modality for identifying the nidus. The different clinical and radiological characteristics frequently result in a diagnostic delay of 2,5 to 3,5 years. Due to this delay, secondary osteoarthritis may complicate an intra-articular O.O.

In conclusion, intra-articular O.O. must be included in the differential diagnosis of joint pain in the young adult, especially when conventional treatment fails.

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Calcaneal stress fracture revisited

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Introduction

Classically stress injuries of the calcaneus have been related to repetitive trauma, like long distance marching in military recruits, first described in 1939. However, with current trends of an increasingly health conscious society, which often undertakes new and unsupervised exercise regimes, calcaneal stress injuries may be underdiagnosed. Especially older people performing recreational sport activity and also patients with an (extended) medical history including diabetes and immunosuppressant therapy are at risk. Stress injuries of the calcaneus often show a nonspecific clinical presentation and therefore the radiologist may play a key role in the early detection of abnormalities and early diagnosis of stress injury.

Illustrative case series

Case 1

51-year-old male. The medical history revealed a liver transplantation due to a primary biliary cirrhosis necessitating admittance in the intensive care unit with good recovery despite a critical illness polyneuropathy. Four months before the clinical presentation the patient performed extensive exercise by making a new wooden floor in his living room on his own. Since that time he has been complaining of increasing pain and swelling of his foot. Clinically a Charcot foot was suspected. Radiographs (Fig. 1A) and Magnetic Resonance (MR) images (Fig. 1B-C) showed a classic stress fracture dorsally in the calcaneus. Patient confirmed local compression tenderness over the calcaneus.

Case 2

18 year old male treated with radiofrequency ablation (RFA) for an osteoblastoma in the calcaneus five years before. He presented with new local complaints and a local recurrence was suspected clinically. MRI was performed showing no local recurrence but instead a stress fracture dorsal in the calcaneus was seen (Fig. 2A-C). Additional history revealed a recent strong increase of physical activity. He had recently resumed an intense training schedule to be able to participate in a field hockey competition.

Case 3

60-year-old female known with diabetes mellitus complicated by a foot ulcer with prolonged cast immobilisation. Patient complained of increasing of pain over the calcaneus during mobilisation. Radiographs showed subtle changes consistent with a stress fracture (Fig. 3A). However MRI showed clearly two stress fracture lines in the calcaneus with an associated stress reaction in the distal tibia (Fig. 3B-C).

Clinical symptoms and risk factors

The symptoms of stress injuries are nonspecific and often consist of an insidious onset of increasing of pain and tenderness over the calcaneus. Initially pain does not interfere with normal physical activity; however pain increases during the physical activity. If the physical activity continues the healing process fails and a stress fracture occurs.

Risk factors include repetitive trauma like prolonged marching and long distance running. However other conditions like nutritional disorders, especially in young (female) athletes, osteoporosis, hormonal disorders, neuropathy, arterial vascular disease, tarsal coalition and immunomodulating drugs are related with the development of stress fractures (1-4).

Epidemiology

In military recruits in a large study from Finland the incidence of calcaneal stress fractures was of 2.6/10.000 person years (5). Calcaneal stress fractures may be the most common tarsal stress injury in children (6). There are no studies considering the incidence of stress injuries in populations at a higher risk of insufficiency fractures.

Classification and imaging characteristics

Stress reactions are classically divided into fatigue and insufficiency fractures. Fatigue fractures occur when excessive repetitive stress is applied to normal bone. Insufficiency fractures occur when normal stress is applied to abnormal or weakened bone (Case 1). In practice stress reactions usually are a combination of both (Case 2 and 3). Stress reactions can also be divided into several types based on the degree of severity represented by MRI characteristics. This scheme was originally developed for tibial stress fractures but seems to be applicable to other sites of stress injuries as well (7) (Table I). However other staging systems have been proposed (8). None of these has been correlated to prognosis. A

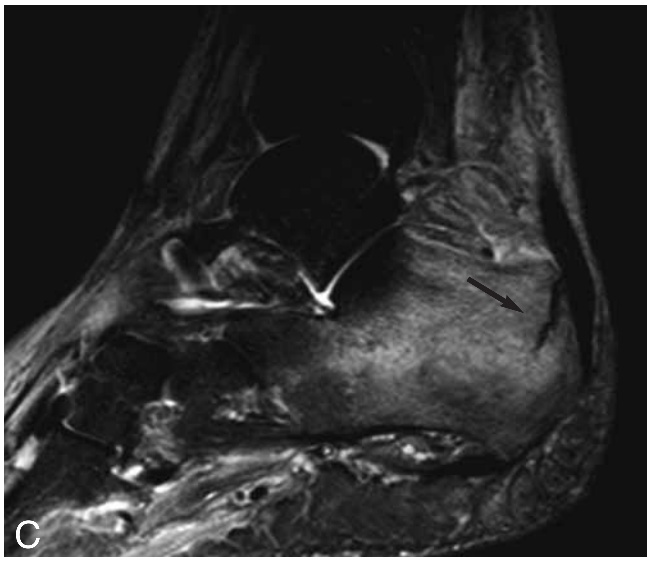

Fig. 1. — Case 1. Lateral radiograph (A), T1 (B) and T2 (C) TSE weighted sagittal MR image of the calcaneus. A clear fracture line, surrounded by edema is visible (arrow).

Table I. — Table with grading of stress injuries by MR characteristics according to Fredericson (7).

Grade of stress injury	MR Imaging characteristics
Grade 0	No abnormality
Grade 1	Periosteal edema. No associated marrow abnormalities
Grade 2	Periosteal edema and mild edema like lesions of trabecular bone, only visible on T2-weighted images
Grade 3	Periosteal edema and extensive edema like lesions of trabecular bone, visible on both T1 and T2-weighted images
Grade 4	All of the above and intracortical signal abnormality

spectrum of abnormalities can be detected with MRI, ranging from subtle periosteal increased signal intensity on T2 weighted images (stress reaction or 'pre-fracture') to a real fracture line (Fig. 1). The increased signal intensity on T2 fat saturated images with associated decreased signal intensity on T1 weighted images is classically called 'bone marrow edema'. This bone marrow edema has been correlated with the presence of clinical symptoms in some studies. However increased signal intensity at certain sites may also occur in asymptomatic athletes (9) and the term 'edema like lesions' is probably a better descriptor. The presence of a fracture line or cortical signal abnormalities seems to correlate better with the duration of the symptoms (10). In the calcaneus high grade injury with a clear fracture line represents only about 10% of stress injuries, in almost 90% only edema like lesions are found (11). To our knowledge no studies correlating these changes to clinical outcome in the calcaneus are performed.

Most fatigue fractures of the calcaneus are found in the upper and dorsal part of the calcaneus, however fractures can occur in other locations(5). It has been hypothesized that most of the stress fractures are oriented in the same plane as the traction or compression trabeculae of the calcaneus (12).

Imaging protocol

The sensitivity of radiographs for stress fractures is low, initial radiographs have a sensitivity of 15-30% to detect stress fractures in general, increasing to 30-70% at follow up. Stress reactions only become apparent after signs of healing are present like sclerosis, bone formation and periosteal reaction, often difficult to visualize in the calcaneus, therefore these numbers are probably even lower in the calcaneus. Radiographs are however useful to exclude other causes of pain.

Ultrasound may give an indication that fracture is present by hyperaemia and thickening of the periosteum, is however non specific (13). Nuclear imaging has a high sensitivity but low specificity for this type of injury.

MRI is the gold standard for imaging stress injuries (14). Stress injuries can be detected in an early stage. A dedicated protocol involving high resolution imaging with an appropriate field of view should be used, including the whole ankle, to identify possible concomitant stress injury. It is recommended to place a marker (vitamin pearl) over the painful area in order to correlate the evaluation of the radiological abnormalities with the clinical symptoms. T1-weighted sequences TSE images for anatomical purposes and fluid sensitive sequences (T2 TSE fat suppresed or STIR sequences) to detect "edema like" lesions. A good interobserver agreement has been shown for T2 weighted and STIR imaging (15). The more widely use of an MR extremity scanner can make MRI easily accessible.

Aetiology/Pathophysiology

In normal cancellous or trabecular bone a certain amount of trabecular microfrac-

Fig. 2 . — Case 2. Sagittal T1 weighted TSE (A) and coronal T1 weighted TSE (C) and axial STIR images (B) of the calcaneus show intraosseous edema and a fracture line in the inferior part of the calcaneus. Anteriorly the sequellae of previous radiofrequent ablation of an osteoblastoma are visible.

tures is present during physical activity. These fractures heal with the formation of microcallus and woven bone. If accumulation of these fractures occurs exceeding the healing capacity of the bone, a stress injury may occur. The accumulation of microfractures or stress injuries can finally result in a complete fracture (16).

Normal fracture healing is complex, involving three phases, an inflammatory phase, a proliferative phase and a remodelling phase. The inflammatory phase involves bleeding, and the invasion of macrophages and attraction of mesenchymal stem cells. After 24 hours the proliferative phase starts with the differentiation of stem cells into an osteogenic and a chondrogenic lineage. The proliferative phase normally lasts three weeks. After three weeks the remodelling phase involves the replacement of woven bone by an organised lamellar bone. In this phase healing osteoclasts are dominant in achieving a normal bone structure with sufficient stability (17). At which stage of the healing process the normal healing of cancellouos bone is interrupted, leading to a stress fracture is not known, but most probable the proliferative phase is compromised with insufficient response in the remodelling phase.

The hallmark of stress injuries is an increased signal on T2 and a decreased signal on T1 reflecting “edema like” lesions. Histopathologically these signal changes can reflect transient bone marrow edema due to interstitial edema with increased osteoblastic activity and fibrosis and woven bone formation as seen in bone marrow edema syndrome or a process of increased osteoclastic activity with fibrosis as seen in avascular necrosis or the hemorrhage and trabecular destruction seen in bone bruise (18).

Treatment and complications

Calcaneal stress fractures in military recruits were associated with other stress injuries in 65% (11). Most of them were fractures of the navicular.

In fatigue injuries the prognosis of these fractures is good with military recruits resuming and completion of duty within 2 years of diagnosis (5). Even with limited measures calcaneal insufficiency fractures in athletes belong to the lesions at low risk of non union (19). There is no evidence regarding prognosis and best treatment options for insufficiency fractures.

Conclusion

Calcaneal stress reactions may have a non specific, prolonged clinical presentation. The diagnosis can be easily made by MR, and allows classification of the stress reaction into low grade injuries represented by “edema like” lesions, or higher grade injury in which progression to a fracture line has occurred. Early diagnosis allows timely clinical measures to prevent progression to complete fracture. The implementation of readily available MR extremity scanners might be of additional value.

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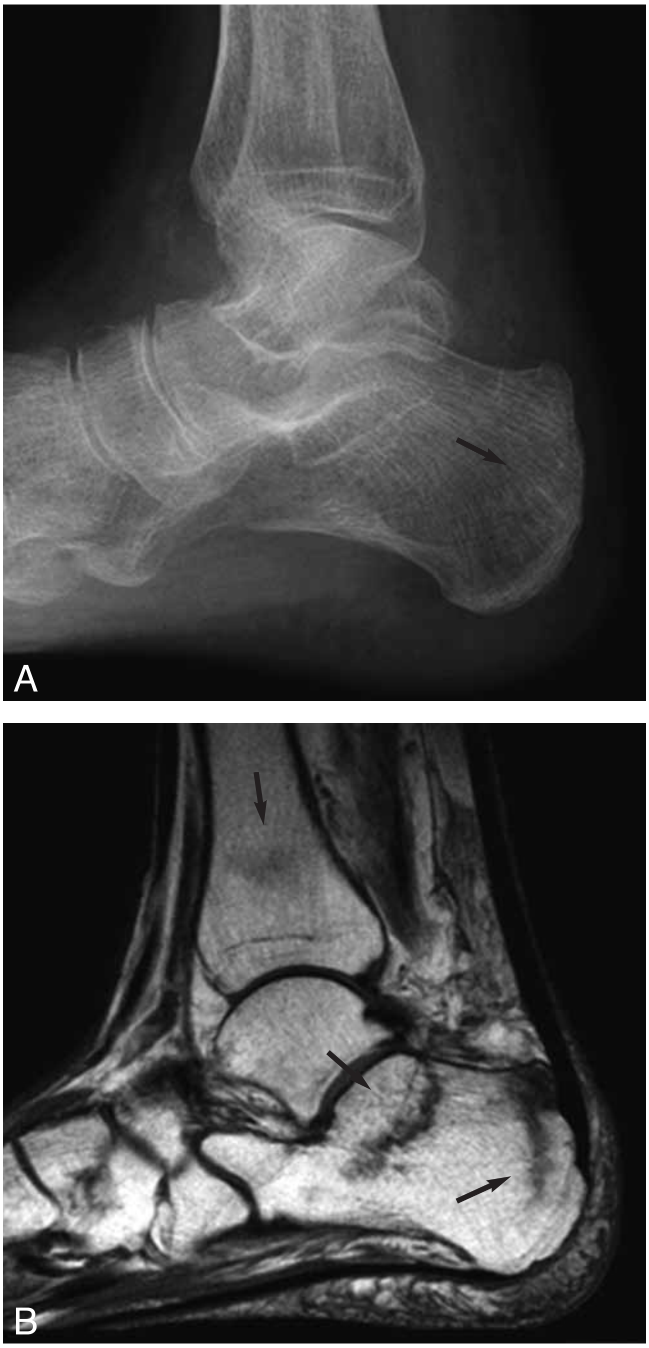

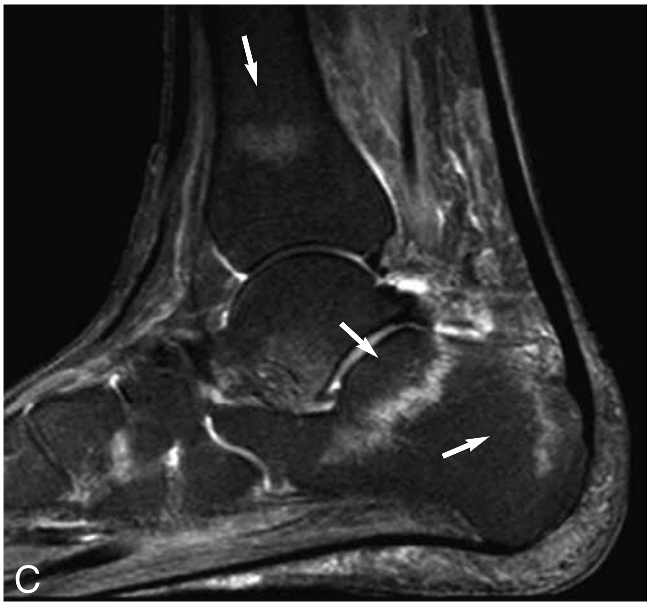

Fig. 3. — Case 3. Lateral radiograph shows a subtle sclerotic change (A), more conspicuous when comparing with previous radiographs a month earlier which showed no abnormalities (not shown). Sagittal T1 weighted TSE (B) and STIR images (C) show two fracture lines in the calcaneus and a concomitant stress reaction without an overt fracture line in the tibia. (arrows).

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