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Conservative approach benefits calcaneal fracture treatment

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The vascularity of the calcaneus makes it less dependent for healing on the compressive forces of ORIF.

For the past several decades, treatment for calcaneal fractures has been extensively reported on. Some agreement can be reached concerning extra-articular calcaneal fractures. The treatment of intra-articular calcaneal fractures, however, remains a subject of much debate. The literature concerning this topic is replete with controversy. There is disagreement among authors concerning the treatment of these fractures on every level except one, which is the fact that the intra-articular calcaneal fracture is one of the most disabling injuries a patient can endure. In most cases, it leads to long-term disability and can be economically disastrous for the individual. In the last century many authors expressed discontent and frustration with treating calcaneal fractures, especially intra-articular fractures. Bankart in 1942 described them as "rotten."1 McLaughlin in 1959 described treating calcaneal fractures and likened it to "nailing a custard pie to a wall."2 Others have described them as "hopeless" and stated that "nothing should be done" concerning their treatment.3 This attitude started to change late in the century as advances in technology, imaging techniques, and our understanding of the biomechanics of these injuries were made.

Associated injuries

Calcaneal fractures represent up to 60% of major tarsal injuries. They occur with such frequency because the calcaneus serves as the base of support for initial body-to-ground contact.2,4,5 Seventy-five percent of the fractures are secondary to a fall from a height with an average distance being 14 feet.4,6 (According to Newton's second law of motion, force = mass x acceleration. A 154-pound object falling from a height of 32 feet will have generated a force of 4928 pounds x feet/sec2 when it hits a hard surface.) The remaining fractures are from motor vehicle accidents, soft tissue avulsions, stress fractures, and direct blows to the heel.5 The age range when the injury occurs most frequently is 30 to 50. Male patients tend to be more affected than female patients by a ratio of five to one.4,7,8

Clinical findings

The calcaneus is a relatively hollow osseous structure with an abundance of cancellous bone. This type of bone carries with it a very good vascular supply. That blood supply will enhance healing, but when the bone is injured, a great deal of edema and ecchymosis will be seen. In addition, the practitioner must be aware of the potential for compartment syndrome as well as the development of fracture blisters. The edema associated with these fractures can obscure the normal contours of the medial and lateral aspects of the arch as well as the inferior concavity of the lateral malleolus. Edema normally collects on the medial and plantar aspects of the foot, and ecchymosis is predominately seen on the plantar aspect. Extensive discoloration and bruising of the rearfoot secondary to ecchymosis has been referred to as Mondor's sign.9,10 Pain is present with palpation of the fractured os calcis. Stress fractures of the heel can be diagnosed by cupping the heel with the hand(s) and applying side-to-side pressure, which induces pain. Antalgic, propulsive gait is normally seen with splinting of the heel in either varus or valgus in an attempt to keep pressure off the fracture site. In some cases the patient will plantar-flex the ankle joint and flex the hip and knee joints as a form of compensation to avoid heel strike. Muscle spasm can be seen in many of these cases, again as a result of efforts to protect the injured calcaneus (for example, peroneal spasm is commonly seen in a Rowe Ic fracture).2,4,5,11 The Rowe and Essex-Lopresti classification systems are commonly used for categorizing calcaneal fractures (Tables 1 and 2).5,11 Range of motion of the subtalar, ankle, and midtarsal joints can be preserved, reduced, or absent, depending on the patient, the amount of splinting, and the type and severity of calcaneal fracture. In specific types of fractures, range of motion can elicit a painful response (dorsiflexion of the hallux in Rowe Ib and II fractures, for example). Hoffa's sign (superior displacement of the tuber relaxes the triceps and decreases its plantar-flexory power) is seen in more destructive types of fractures, along with decreased-to-absent ankle joint plantar flexion.5,12 Frontal plane motion can also be helpful in diagnosing the type of calcaneal fracture as well as a way to differentiate soft tissue versus bony injuries. For example, in Rowe Ib fractures pain is elicited with inversion, whereas eversion usually causes pain in a patient with an isolated deltoid ligament tear. Examination of the heel and its surroundings, including the Achilles tendon, is important. Heel height and length can be decreased; the width of the heel, on the other hand, is usually increased. Swelling in this injury, as stated earlier, commonly masks the arch. A negative calcaneal inclination angle can also obliterate the arch in more destructive types of os calcis fractures, when collapsing of the bone occurs. The lateral wall at times can be palpated and can expand as far as the fibula secondary to lateral wall blowout (described below). This can adversely affect the peroneal tendons and their function.

Mechanism of injury

The qualities of cancellous bone that make it susceptible to edema and ecchymosis, as well as its structural characteristics, also leave it vulnerable to collapse when exposed to high mechanical loads. This tarsal bone with its thin cortical shell, sparse trabeculae, and intraosseous hydrostatic pressure provide a momentary elastic cushion for the body during ambulation. Compressive forces upsetting this triad of dynamic functional structure can generate massive damage to its anatomical framework.13 The strength of the calcaneus is imparted by the arrangement of its compressive and tensile trabeculae, which resist compressive and tensile forces, respectively. Beneath the posterior facet, however, there is a paucity of these trabeculae inferior to the lateral process of the talus, so that a downward force by the talus can result in impaction of the outer two thirds of the posterior facet of the heel into the body of the calcaneus. When the calcaneus strikes the ground hard enough to cause injury, the force of body weight is applied to the sustentaculum tali, causing the heel to move into valgus. This allows the lateral process of the talus to hit and split off the lateral two thirds of the posterior facet of the calcaneus, driving it into the calcaneal body. The lateral two thirds of the posterior facet remain impacted in the calcaneus, which can be seen as an abnormal step-off on an axial radiograph. This fragment needs to be elevated to restore normal continuity of the posterior facet of the calcaneus and subtalar joint. McReynolds and Palmer described such fractures producing four fragments (Figure 1, page 35).14,15 These are the superomedial fragment, the anterolateral fragment, the lateral fragment or thalamus, and the tuber fragment. As the talus drives down into the calcaneal body, its lateral process displaces the lateral portion of the posterior facet into the depths of the calcaneus. When the posterior facet sinks into the calcaneal body, it simultaneously shears away from the lateral wall and cleaves the body of the calcaneus, producing "lateral wall blowout." A secondary fracture line hugs the posterior rim of the facet and allows the facet to completely separate from the tuber fragment (in joint depression fractures) or exit posteriorly as the superior portion of the tuberosity (in tongue fractures). Finally a step-defect (3 to 10 mm in depth) is created after the sustantaculum tali undergoes a reflex varus posture called "elastic recoil." The superomedial fragment (considered the primary fragment) stays in close contact with the talus and resists dislocation because of its soft tissue attachments, specifically the deltoid and interosseous talocalcaneal ligaments, as well as the suspensory action provided by the flexor hallucis longus tendon. This provides stability to the superomedial fragment and is why that fragment is used to anchor other fragments when the fractured calcaneus is reduced and fixated. The tuber fragment, fixed in varus, is pulled into equinus by the contracture of the Achilles tendon. Achilles contracture results from loss of opposition to plantar-flexory mechanical forces at the tendon insertion. This causes the superomedial fragment to override the tuber fragment. At times a secondary sagittal plane fracture exits anteriorly into the anterior neck of the calcaneus or the cuboid facet. This mechanism can show a discrepancy depending on the different variables involved that cause each fracture to differ slightly from the next (the amount of force on impact is the most common variable). Since Palmer's 1948 description of this mechanism of action, little has changed. A recent study by Vogler, however, offers some new insight and information concerning calcaneal fractures.5,16 Some of his conclusions include:

- *All calcaneal fractures in his study were pronating fractures regardless of the foot type (pes cavus, pes planus, etc.) in that all specimens reached maximum pronation at impact.*
- *Intra-articular fractures in vivo required a near perpendicular uniaxial load. Deviation from this angle resulted in medial or lateral ankle joint fractures or, at times, tibial fractures.*

- *The most significant ligaments in guiding the fracture were the calcaneofibular, lateral talocalcaneal, and interosseous. In his study, none of these ligaments ruptured or avulsed even with the more severe comminuted fracture types.*
- *An intact plantar fascial band was required to produce calcaneal fractures. He found that sectioning of the plantar fascial band leads to dislocation rather than fracture of the calcaneus.*
- *Female patients failed at a load one half that required for male patients. This most likely can be explained by the difference in bone mineral content.*
- *Intact lateral ligament and extensor retinacular attachments may prevent the lateral wall from forcing the posterior facet into the calcaneal body. As the posterior facet descends into the calcaneal body, it occupies a large amount of intramedullary space. This creates a force of hydraulic tangential burst, which can only be relieved through the expansion of the lateral wall, thereby creating the lateral wall blowout deformity.*

Complications

There are a large number of potential sequelae stemming from calcaneal fractures. Table 3 lists some of these complications. During treatment, in many cases most of the attention is given to the bony architecture and to reducing the calcaneus and the subtalar joint. It is imperative that the practitioner not lose focus on the soft tissue structures. Soft tissue morbidity is a common sequela after these fractures.2,4 One of the most common causes is recalcitrant heel pain. Lateral heel pain is usually caused by injury to the peroneal tendon and or the peroneal retinaculum. Compromise of the retinaculum can induce scar tissue formation, which can impair normal peroneal tendon gliding function, cause nerve entrapment, or adversely affect vascularity in this area. Medial heel pain is usually from an injury to the flexor hallucis tendon and/or the flexor retinaculum. An entrapped tendon can lead to tenosynovitis, tendon hypertrophy, intratendinous lesions, and partial- or full-thickness tendon tears. Causes of plantar heel pain include an anatomically altered fat pad, osseous pain secondary to periosteal injury and proliferation of bone, damaged nerve endings, scar tissue formation, and a nonanatomical pitch angle (the reversal of the tuber angle induces pressures that are applied on the plantar tissues anterior to the calcaneal tuberosity instead of on the fat pad). According to Cohen, this pain can also be secondary to the increased tension placed on the plantar fascia.17

Conservative treatment for calcaneal fractures

Treatment in the past has ranged from doing nothing to casting to total removal of the os calcis.18 Hermann in 1937 developed a technique called "disimpaction," in which the calcaneus is crumbled with a mallet and remolded into shape.19 Traditionally, however, calcaneal fractures have been treated with conservative measures. Many surgeons advise conservative treatment almost exclusively, regardless of the fracture type, because of the lack of reliable information and the presumed inevitability of a poor outcome. Some authors agree on conservative treatment for all calcaneal fractures except severe fractures with profound displacement and or comminution. Conservative treatment can lead to successful outcomes for calcaneal fractures (even those that are displaced) for many reasons. Calcaneal bone is rich with vascularity, so the healing of these fractures depends less on the compressive forces generated by open reduction and internal fixation (ORIF) techniques than do long bones or other bones whose blood supply is not as rich. In addition, there is much less trauma to surrounding soft tissues during nonsurgical repair. Conservative treatment also allows early range of motion and weight-bearing of the affected extremity. Recovery is generally quicker with conservative care than with operative management. It is largely agreed in the surgical community that calcaneal fractures with central depression inevitably progress to fusion of the subtalar joint, which in turn leads to a very morbid and painful post-traumatic course. This course is worsened by the possibility that this joint (unlike the calcaneus itself) may not progress to complete fusion, requiring arthrodesis of the subtalar joint or subsequent triple arthrodesis to stabilize the entire rearfoot. Conservative treatment allows, in some cases, for the natural fusion of this joint to be hastened by immobilization of the joint, thus decreasing morbidity and helping the patient avoid surgical procedures at a later date. Some studies, specifically those by Crosby and Fitzgibbons and Kitaoka et al, have also shown that additional treatment (surgical or nonsurgical) is rarely needed or is needed to a lesser degree after conservative treatment than after nonconservative treatment.20,21 Other advantages include a lower complication rate and increased safety for both the patient and the treating physician.2,14,17,20-22 One must be very experienced in ORIF to treat calcaneal fractures surgically. Conservative methods offer a safe, effective treatment for the physician inexperienced in these techniques. In some cases, open surgical techniques are contraindicated. These include cases involving patients known or suspected to be noncompliant, which can adversely affect the outcome of a procedure already known to produce results that are far from perfect and fraught with potential complications.3,5,20,21,23,24 Severe comminution is considered by many to be a contraindication since better anatomical reduction and outcomes are not usually seen with surgical intervention than with conservative treatment.2,3,5,11,20,21,24 The presence of infection or fracture blisters associated with broken calcanei is an obvious indication for conservative care. Open fractures are also contraindicated because surgery will only increase the risks of infection. The insertion of subcutaneous hardware, which devascularizes an already-compromised soft tissue envelope, may lead to delayed healing or nonhealing. Other contraindications for surgical intervention include active Charcot arthropathy, coexisting compartment syndrome, and peripheral vascular disease. Conservative treatment can be divided into five areas:

- *Soft cast immobilization with an Unna boot or a Robert-Jones dressing. The use of soft cast immobilization can help to reduce swelling and aid in preventing some of the disuse osteopenia seen to a higher degree with fiberglass casting5,11 (especially if weight-bearing is preserved). The patient is allowed to walk with the soft cast using a post-op shoe or a cam walker. Nonweight-bearing or partial weight-bearing may be desired with or without the use of assistive devices such as crutches or a walker. Hanam in 1985 reported good to excellent results in 75% of the patients in his study using soft cast immobilization.25 Rowe Ic fractures (anterior process fractures) can be treated very efficiently in this fashion if there is minimal to no displacement of the fracture fragment.*
- *Immobilization with a below-the-knee fiberglass cast. The cast can be either weight-bearing or nonweight-bearing. Soft casting or posterior splinting/bivalve casting with some form of mild compression should be considered initially for a few days to help reduce swelling before the cast is applied. This generally works well for most calcaneal fracture types with little to no displacement, including Rowe I, II, III, IV and, at times, Rowe V fractures.*
- *Forced ambulation with soft casting (Unna boot, etc.). Combined with assistive devices and pain control, forced ambulation has been used for the treatment of calcaneal fractures with depression and collapse of the calcaneus and subtalar joint. Fat pad atrophy secondary to nonweight-bearing and cast immobilization after ORIF of a depressed fractured calcaneus can be crippling to the patient. Forced ambulation with soft casting in addition to pain control can help avoid this complication by reducing the soft tissue destruction inherent to this procedure.20,21,25,26*
- *Closed reduction is a very effective treatment for any displaced calcaneal fracture. This obviates an open reduction and the use of internal fixation devices such as plates or screws, which present a whole new set of potential complications. Omoto in 1982 discussed his bimanual reduction technique.26 Under spinal anesthesia with the patient in the prone position and the knee joint flexed, the practitioner cups the heel, applying bending and traction forces to reduce the fracture. This technique is advantageous in that it can adequately relocate displaced bone fragments as well as the subtalar joint, restores the width of the heel nicely, eliminating peroneal tendon pain and impingement, avoids iatrogenic sequelae, works for patients at any age, and is relatively simple to perform (Figure 2). Omoto did warn, however, that for this technique to work and be successful the lateral and medial ankle ligaments and the bone(s) to which these ligaments are attached must be intact. If they are not, the technique will fail to adequately reduce these fractures.*
- *Closed reduction with percutaneous fixation. This method is included with conservative treatment to distinguish it from ORIF. I consider this method a conservative approach for these fractures because it is more closely related to closed than open reduction techniques and is associated with a lower risk of complications. This technique involves placing a percutaneous pin across the calcaneal tuberosity. The knee and ankle joints are flexed and plantar-flexed, respectively, to relax the triceps surae. Distal/anterior traction is applied to reduce the dislocated fragments. These pins can then be incorporated into a cast, or subsequent pins may be inserted to fixate this portion of the fractured calcaneus into a more stable fragment such as the tuber fragment.*

Pediatric calcaneal fractures

Twenty-five percent of calcaneal fractures in children are intra-articular, as opposed to 75% percent in adults.23,27-29 There have been few accounts in the past 50 years of large-series studies dealing with the treatment of calcaneal fractures in children. There are also few reports on open treatment of calcaneal fractures in children. Interpretation of these data are often difficult since these fractures are uncommon and because apophyseal fractures are frequently included among the more serious extra-articular and intra-articular fractures. There has been as much controversy over treatment of pediatric fractures as of adult calcaneal fractures. Rigault in 1973 recommended ORIF in older children for moderate to severe fractures with thalamic depression.27 Knorr in 1992 suggested the use of closed treatment for pediatric calcaneal fractures unless there is major displacement or bilateral involvement, in which case open reduction should be attempted.28 Brunet performed one of the longest follow-up studies of conservative treatment for pediatric fractures in 2000.23 He reviewed 17 patients who had been treated for 19 calcaneal fractures as children. At the time of their injuries, 17 years earlier, these patients were 14 years or younger with a mean age of 6.2 years. Fourteen of the fractures were intra-articular and five were extra-articular. All but one was treated conservatively with casting without reduction. At follow-up, nine of the 17 patients had a sedentary-type job. The other eight patients had occupations that required standing or walking all day or worked in the construction field. Brunet utilized the American Orthopaedic Foot & Ankle Society ankle-hindfoot scale using pain, function (limitations, gait abnormalities, distance, surface, sagittal plane/rearfoot motion, ankle joint/rearfoot stability), and alignment as its parameters. An average score of 96.2 out of 100 was achieved, with the lowest score being 60. Radiographically and clinically, none of these patients required reconstruction or appeared likely to need it in the future, according to the authors. They concluded that conservative treatment for all types of calcaneal fractures in children yields good functional long-term results in almost all cases and that the severity of the fracture (joint depression, comminution) did not correlate with the functional status or vocational or leisure interests of the adult patients. Many of the patients who had had joint depression and comminution went on to become active in high-performance sports such as long-distance running. The authors went on to say that long-term functional results could be attained with conservative treatment in pediatric patients; however, open treatment may be appropriate management for adolescents with severe displacement. Thomas in 1969 suggested that children under the age of 10 have sufficient remodeling potential at the damaged articular surfaces of the calcaneus that when the immature talus grows into the defect produced by the depressed Bohler's angle, remodeling of the joint occurs with the articular surface mostly preserved, albeit with the possibility of a reduced range of motion.29 (The Bohler's angle is formed by the intersection between the line from the posterior superior pole of the calcaneus to the peak of the posterior facet and the line from the highest point of the anterior process of the calcaneus to the peak of the posterior facet as seen on a lateral view radiograph.30) The final result is one in which anatomical congruity of the subtalar joint is achieved, allowing relatively normal function of the rearfoot.29 This theory seems to be correct, considering the excellent functional outcomes seen in even the severely displaced calcaneal fractures in Brunet's study.

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Achilles insertion Type III Oblique body fracture not involving the subtalar joint Type IV Body fracture involving the subtalar joint Type V Body fracture with joint depression and comminution ---

Table 2. Essex-Lopresti Calcaneal Fracture Classification System

Tongue type (Type A)	**Components involved**
Lateral fragment	Lateral half of posterior facet and posterior body of calcaneus
Tuber fragment	Posterior extra-articular body of calcaneus
Anterolateral fragment	Anterolateral portion of calcaneus
Sustentacular or superomedial fragment	Middle facet and sustentaculum tali

Joint depression type (Type B)	**Components involved**
Lateral fragment or thalamus	Lateral posterior facet
Tuber fragment	Posterior extra-articular body of calcaneus
Anterolateral fragment	Anterolateral portion of calcaneus
Sustentacular or superomedial fragment	Anterior facet and sustentaculum tali

--- TABLE 3. Sequelae of calcaneal fractures Articular damage Widening of the foot (shoe wear problems) Compartment syndrome (10%) Neurological complications Soft tissue impingement Infection/osteomyelitis Fracture blisters Limb length discrepancy Instability of other joints/surrounding bones Deformities (e.g., Haglund's deformity) Heel pain Others (proximal injuries)
