Calcaneal fractures- the orthopaedic challenge

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Calcaneal fractures, since their description in 1843 by Malgaigne, still remain a challenge in orthopaedic surgery. They are significant from an epidemiological point of view - they represent 60% of all tarsal fractures, and of an increasing number of fractures due to traffic accidents and their outcome is unpredictable. In contrast to the disappointing results after nonoperative treatment and at the beginnings of calcaneal surgery, the outcome is promising nowadays. New imaging and fixation devices, with proper classification and indication for certain surgical procedures have led to the improved outcome. But, there are still controversies, and we emphasize the most rationale treatment for the calcaneal fractures, as well as best surgical options.

Key words: calcaneal fractures, classification, treatment

INTRODUCTION

Even though calcaneal fractures occurred in 2% of patients, they represented almost 60% of all tarsal fractures, and they are still a great challenge in terms of treatment. Calcaneal fractures are caused by a high-velocity force to the heel, mostly in vehicle accidents or fall from height. Numerous factors contribute to the fracture pattern: weight, age of the patient, type of fall. Male patients predominated (75%) and younger than 50 years of age, with incapability for the work for the period up to the 2-5 years. In most of the cases, these fractures are bilateral and conjoined with lumbar spine fractures.

HISTORY

Calcaneal fractures were first described by Norris in 1839, and then by Malgaigne in 1843 and the latter one is nowadays better known, borrowing his name to this type of fractures. The treatment of intraarticular calcaneal fractures was a source of controversy in the 20th century. Major concepts are divided into four categories of treatment: no reduction, closed reduction, open reduction, and primary subtalar arthrodesis. The historical foundations of each of these treatments are listed to make more rationale to the present and modern approaches.

In 1931, Bohler classified calcaneal fractures according to the mechanism of injury and its radiological picture. Since then, CT-scan has enabled more precise diagnostics and treatment.

Although Bohler advocated operative treatment from the beginning, most of the calcaneal fractures were treated nonoperatively due to the numerous complications (lack of antibiotics, infection, soft tissue coverage problem, lack of adequate osteosynthetic device). Thus, at that time the treatment was rather cruel such as Herman’s (variant of Bohler’s method in 1937.) use of hitting by Cotton mallet, putting the heel into "presses", with additional immobilisation in plaster cast of 4-5 weeks duration. At the time, some authors proposed triple arthrodesis in cases with persistent pain.

Until the introduction of antibiotics and new fixation devices, the results of calcaneal surgery were disappointing. Chronologically, historically, the following authors are important for nowadays quite successful treatment of calcaneal fractures:

In 1948, Kocher proposed lateral approach for the calcaneus with use of autografts.

In the 1950s, Dick advocated primary arthrodesis of the subtalar joint; but long term follow-up evaluation revealed that most of those arthrodeses were unnecessary and either nonoperative or operative treatment was preferable.

In 1953, Essex Lopresti published his famous article about percutaneous reduction of Tongue fractures. In his paper, he also described the mechanism of injury of calcaneal fractures.
Bankart also described the outcome of the operative treatment as poor. The methods varied - from traction, percutaneous fixation, internal fixation, to primary arthrodesis, but the results was similar. Thus, the knowledge of basic anatomy and biomechanics of injury was of outmost importance. Actually, the event of fracture is similar to when the heel is hit with a hammer at the medial side. Thus, throughout the entire 20th century, this issue was unsolved regardless of which method was superior: the nonoperative or the operative one, regardless of the improved fixation devices.

**RELEVANT ANATOMICAL DATA (APPLIED ANATOMY)**

Calcaneus is mostly a spongious bone and it is the largest bone of the foot. It has a complex trabecular architecture and it is the place of facets—the place of articulation with the talus. The movements of the calcaneus are integrated in the subtalar and transverse tarsal joint. Its shape is cuboid, orientated anteriorly, laterally and upward. On the superior surface, there are three facets: the anterior (articulated with the cuboid bone), the middle (on the sustentaculum tali) and the posterior one (articulated with the talus where the largest forces are transmitted). Between the posterior and middle facets, the tarsal tunnel and sinus tarsi are placed. The lateral calcaneal wall is flat, with peroneal tendons placed in the sulcus and it is better for the surgical approach; but thin soft tissue coverage makes it risky because of possible infection and wound dehiscence. The medial wall is thicker with sustentaculum tali, and fracture line is always behind it. On the medial side, there is m.quadratus plantae, the lateral plantar nerve and artery, tendons of the flexora hallucis longus muscle, making the medial approach more demanding.

The inside of the calcaneus consists of spongious bone, except beneath the posterior facet. This part of the calcaneus is harder and called the thalamic portion. The thicker cortical bone is over the sustentaculum tali (4mm thick) and under the crucial angle of Gissane. The bone which is lateral and inferior to the calcaneal thalamic part lacks trabecula and radiologically resembles a cyst and is called the neutral triangle.

The calcaneal tuberosity is positioned posteriorly and dorsally; and has the place of Achilles tendon insertion on its posterior and inferior edges. The place of Achilles tendon insertion is also thicker, what is important for the placement of the fixation screws.
**MECHANISM AND PATHOANATOMY OF CALCANEAL INJURY**

During a fall, the axial load is applied, the oblique fracture line is caused, dividing two main fragments: sustentacular - constant fragment and tuberosity fragment (Figure 1- centre). Due to its strong talocalcaneal interosseous ligament, the sustentaculum fragments is not significantly displaced and its position is stable, whereas the tuberosity fragment is displaced laterally - Figure 1 right. Further, continuous injury force develops the secondary fracture line creating the "thalamic fragment" with depressed position of the posterior subtalar facet. If the fracture line ends superiorly into the posterior facet, this is "central depression type fracture", whereas if the fracture line exits posteriorly, involving the entire posterior process, it is called the "tongue type fracture". This central fragment displaces the spongious bone widening the lateral calcaneal wall with further calcaneofibular impingement and possible peroneal tendon entrapment. This is of the clinical importance and must be taken into account during a treatment process. The lateral wall is thin and this fracture is of comminute type. The tuberosity fragment tilts into varus position, while the Achilles tendon pulls it proximally. In excessive forces, the calcaneal bone could be crushed and may collapse. Consecutively, the overlying skin shows haematoma on the plantar side, whereas the lateral side is compressed. Blisters may be present.

Pathologic changes are also seen on the X ray pictures; on lateral projection, the Bohler’s angle is decreased, whereas the Gissane’s angle is increased. Both on X-rays and CT scans, the talar declination is seen, which leads to the Achilles tendon shortening.

For classification and operative planning, CT (coronal plane) is useful. Three-dimensional CT scan is illustrative (Figure 2a,b). On the CT coronal scans it is obvious that the talus shears the calcaneal bone into two main fragments (in the line of the Gissane angle), separating the posterior facet into two parts. The secondary fracture line goes laterally, and this fragile part of the calcaneal bone enables multiple fracture lines and fragments. Thus, the lateral wall is pushed more laterally causing the "blowout fracture".

In this explanation, it is important that the talus is in connection with the superomedial fragment (SMF) and that it is stable. The calcaneal tuberosity is shifted laterally and creates 1cm gap with the SMF. Reduction is not possible if these two fragments are not conjoined and the calcaneus obtains its normal height and shape.

The natural history of the injury is of importance because it can explain when to operate or not and what is happening when the calcaneal fracture is not treated at all. After the fall onto a hard surface, the initial pain and oedema subside after 7-14 days, if the compartment syndrome is absent. After the non-weight-bearing of 2-3 months, and controlled-graduated weight-bearing after that, the pain occurs. The pain is located either at the lateral side, beneath the fibular malleoli, or at the medial side of the ankle, at the anterior part or under the plantar surface.

Most commonly, the pain at the lateral side is caused by the impingement of the peroneal tendons or by the presence of subtalar arthrosis. The pain and the limping is aggravated during day and highest in the evening. Only 17% of the patients are pain-free, while in most cases the pain subsides after 2 years.

Suspicion of the diagnosis of calcaneal fracture is a clinical one, but this fracture can be overlooked in smaller fragments or in the cases of polytrauma or in the cases when the patients did not complain of pain. Oxford sign of Bohler (1930) is presence of haematoma at the medial side after the first 24 hours after the injury. Also, 20% of patients with calcaneal fractures sustain the lumbar spine fracture.

Malunion after the calcaneal fracture could be the valgus type, elongation of the Achilles tendon, excessive dorsal flexion of the foot. The inversion and eversion of the foot are markedly restricted, and overall foot function is diminished. These fractures sometimes demand surgical treatment, internal fixation, or primary subtalar arthrodesis.

**RADIOLOGICAL EVALUATION OF THE FRACTURE CONSISTS OF THE STANDARD X RAYS AND COMPUTED TOMOGRAPHY SCANS**

Standard x rays- On the plain radiography, 4 trabecular systems of the calcaneus are described: thalamic, anterior, anterior apophyseal, anterior plantar and posterior plantar. The thalamic trabecular system is in direct contact with weight-bearing systems of the tibia and the talus and is
the most dense beneath the posterior facets. By measuring the thickness of the cortical bone, it has been found that it is thinner on the lateral and plantar sides, being the thickest (4 mm) beneath sustentaculum tali. This is of importance for the fixation, i.e., this fragment is the most stable and it must be fixed well.

When one is suspicious of the calcaneal fracture, the following views are mandatory: the lateral, anteroposterior (a-p), axial calcaneal view with the foot in dorsiflexion (to expose the sustentaculum tali), the "mortice" view (with the foot in the internal rotation of 20 degrees). On the plain lateral view, two angles described below are of importance for determining the fracture7,19,20.

The Bohler’s angle (normally 20-40°) which is formed by the two lines - one that is drawn from the tip of anterior process of the calcaneus to the tip of the posterior facet, and the second line which is drawn tangentially to the superior angle of the calcaneal tuberosity; the angle of Gissane (normally 100°) is formed by the two lines that are drawn on the lateral cortex of the posterior facet and anteriorly to the anterior process of the calcaneus4.

In the case of compressive fracture of the posterior facet, on the lateral view the Bohler’s angle is decreased (described in 1931 as tuber joint sign), while the Gissane’s angle is increased. The posterior facet length is also decreased. In case of one side facet fracture, Double Density Sign is seen.

Lateral view enable making difference between Joint depression from Tongue Type fracture6,19.

More precise diagnosis is obtained by computed tomography. So, CT scan imaging is indicated in all calcaneal fractures, especially the intraarticular ones in the coronal plane - perpendicularly to the posterior facet and in the axial plane. Some authors also suggest semicoronal slices at the angle of 30 degrees6,21,22,23.

In the sagittal plane, the dislocated tuberosity fractures can be revealed, involving the anterior processus, rotational deformities and a difference between Tongue Type and the Joint depression fractures can be determined.

In the axial plane, on the CT scans one can trace the length of the fracture up to the processus anterior and calcaneocuboid joint, as well as to the sustentaculum tali and the posterior facet.

The semi coronal plane enables the best visualisation of the fragment position in the posterior facet, the sustentaculum tali and the peroneal tendon localisation.

Fracture classification

1. Extraarticular fractures (fracture of the anterior processes, tuberosity fracture, and fracture of the sustentaculum tali), caused by the low-energy trauma, foot inversion, tendon or muscle avulsions.

2. Intraarticular fractures are caused high-energy trauma (fall from a significant height or by traffic accidents). Most commonly used classifications of intraarticular fractures, classified by native radiography or CT scans, are the following4:

   - Essex-Lopresti classification is the oldest one, based on the findings on radiographs: type A- joint depression, type B- tongue type; nowadays, this classifications are rarely used (less commonly used).
TREATMENT

There are still controversies about the optimal kind of treatment of the calcaneal fractures, but basically there are two main types of treatment: nonoperative and operative. Until the introduction of CT images in the orthopaedic practice, most fractures were treated nonoperatively, whereas the indications for surgical treatment were broader afterwards, depending on patients’ lifestyle and his expectancy. Ideally, the surgical treatment should be done inside the first three weeks, but what is important is the condition of the soft tissues. Nonoperative treatment has poorer results, but this statement could not be confirmed in the meta analysis of the more recent studies.

Generally, nonoperative treatment is suitable for nondisplaced fractures (confirmed on CT scan), in patients with peripheral vascular diseases, insulin-dependent Diabetes mellitus cases, elderly patients, whereas operative treatment is indicated in all displaced intraarticular fractures which involve the posterior facet.

Treatment of extraarticular calcaneal fractures

a) Fractures of the anterior process, avulsion or compressive types, when involving the calcaneocuboid joint, can be overlooked as the ankle sprain. Avulsion type is more common and is caused by inversion, when the bifurcate ligament pulls a part of the anterior processes. The compressive type fracture is caused by foot eversion. In differential diagnosis the following conditions are referred: ankle sprain, oss calcaneus secundarius, (accessory bone). Treatment depends on the fragment size and its displacement. Excision is not the guarantee for painlessness. Treatment of smaller and nondisplaced fractures could be nonoperative in the plaster cast for 4 weeks, and followed by orthosis for 10-12 weeks. For larger fragments and significant displacement or for cases with symptomatic pain presence and nonunion, the fixation or excision of the fragment should be done. The recovery lasts up to 6 months. When cannulate screw is used, lateral approach, according to Ollier, is indicated.

b) Fractures of the sustentaculum tali is caused by the identical mechanism as intraarticular fractures, severe inversion, but they do not involve the posterior facet. The pain is at the medial side and for precise diagnosis CT is mandatory, which also enable proper treatment. Small and nondisplaced fragments are treated nonoperatively, immobilised in orthosis, and walking without weight-bearing for the period of weeks is mandatory. Symptomatic nonunions require internal fixation or excision of the fragment.

c.) Fractures of the tuberosity are rare, mostly are of avulsion type, caused by traction by the Achilles tendon. They are seen in elderly patients, caused by fall from a small height, when the Achilles tendon pulls the tuberosity. Treatment depends on the degree of displacement and intraarticular involvement. In cases without dislocation, the plaster walking cast is worn for 4-6 weeks. When minimal dislocation is present, the plaster cast is in
the equinus position. In cases with displacement larger than 6mm or when the fracture involves the posterior facet or valgus malposition larger than 40 degrees, internal fixation is indicated. In tuberosity fracture, percutaneous-Essex Lopresti or preferably open reduction and fixation with 1-2 cannulated screws is performed to prevent the shortening of the Achilles tendon. Postoperatively, the boot is worn with full weight bearing, in the equinus position, because the fixation is rigid.2

2. Treatment of intraarticular fractures

a. In nondisplaced, in displacements less than 2mm, with preserved architecture and shape without widening (actually this is Sanders type I) fractures, the treatment is nonoperative, especially for the elderly patients. There is no need for plaster cast, due to the risk of stiffness and reflex sympathetic dystrophy. Elastic bandage is worn for 3 weeks, orthoses, followed by range of motion exercises (ROM). The patients are not allowed weight-bearing for 10-12 weeks. Nonoperative treatment is suitable also for the patients with serious peripheral vascular diseases, diabetes mellitus type 1, and severe comorbidities.2

b. Dislocated, up to the posterior facet fractures are treated by open reduction and internal fixation, but taking into consideration the age, general health condition (systemic disease or multiple trauma), and occupation of the patient. Fixation is performed from the lateral side in the period of 2-3 weeks after the injury, if there is no compartment syndrome present, when skin incision and fixation is done immediately. In case of the oedema or blister the surgery is postponed. The type of the fracture also dictates the kind of surgical treatment. The Essex-Lopresti technique is reserved for the tongue type of calcaneal fractures. Two parallel pins are inserted upward, under the fluoroscopic control, in order to obtain the realignment of the Bohler angle. Definitive fixation is achieved by cannulated screws.

In case of Sanders type III fractures, extensive lateral approach is needed. Patient is in the position of the lateral decubitus, and bloodless operative field, obtained with the tourniquet, is limited up to 120-130 minutes. Skin incision is L-shaped, 2cm below the lateral malleoli, laterally to the Achilles tendon, and then perpendicularly to the plantar side.10

Manipulation to obtain reduction is done over the pin transversely placed through the calcaneus tuber (Figure 3). Temporary fixation is obtained with K wires, the cannulated screws are placed afterward with L-H plate (Figure 4a,b). Sometimes the bone graft is needed.28,33,34,35 Case report- radiographies are presented on pre and post-operative x-rays on Figure 5a,5b and 5c. But sometimes, there is no need for grafts or bone substitutes. Postoperatively, plaster cast is worn for 2 weeks, walking with the crutches for additional 8-12 weeks is prescribed, and return to work is achieved after 6-9 months.2

Reported results depend on the fracture type: in Sanders type 2 - 86% reduction and 78% good results are obtained, whereas in type 3 60-70% excellent to good results are reported. In type 4 fractures reduction is obtained in only 27% cases, followed by 17% good clinical results.11 Thus, in type 4 primary arthrodesis is proposed.23

Primary subtalar arthrodesis in the treatment of comminuted calcaneal fractures was first described by DiDee in 1953, with excellent results. It was indicated in all comminuted fractures, Type IV Sanders, when internal fixation was not successful, and ended with unfavourable results. Triple arthrodesis is not recommended. The surgical procedure is the same as for internal fixation except that the cartilage must be removed and bone graft placed in the subtalar space.25

Whichever treatment is chosen, the surgeon has the same aim: restoration of the shape of the hind foot and the subtalar joint, with the aim of painless weight-bearing in daily activities. After the fractures and treatment of calcaneal fractures, there are numerous less or more serious complications, namely:4,7,11,27:
1. Early ones (skin necrosis, infection)
2. Compartment syndrome (in 2-10% cases)
3. calcaneofibular impigement, when resection of the part of the lateral calcaneal wall is performed or peroneal tendonitis when enlargement of sulcus is proposed
4. instability, subluxations of the peroneal tendons, due to the loss of the calcaneal height and valgus position of the calcaneus
5. subtalar arthrosis when arthrodesis is sometimes needed
6. nerve entrapment and nerve injuries
7. heel pad syndrome and exostoses
8. tarsal canal syndrome

One must be aware of these complications possibility and to made proper diagnosis and treatment modality. In conclusion we can say that calcaneal fractures is still a challenge for the treatment and one must consider both type of the fracture, patient condition and possibility-risk of complications.

SUMMARY

PRELOMI KALKANEUSA - IZAZOV U ORTOPEDIJI
Još od prvog opisa koji je 1843 dao Malgagnie, prelomi kalkaneusa i dalje predstavljaju veliki izazov za ortopedsku hirurgiju. Ovi prelomi su značajni sa epidemiološkog aspekta- predstavljaju 60% svih preloma tarzalnih kostiju, postoji povećan broj ovih povreda zbog saobraćajnog traumatizma, a rezultat lečenja je nepredvidiv. Iako su rezultati neoperativnog lečenja i početak operativnog lečenja bili razočaravajući, danas su rezultati lečenja obećavajući. Nove dijagnostičke metode i fiksacioni materijali, uz adekvatnu klasifikaciju i indikacije za određenu hiruršku proceduru, doveli su do značajnog poboljšanja ishoda lečenja. Ali i dalje postoje kontraverve i stoga prikazuju se njihov nabrojani pristup u lečenju preloma kalkaneusa, kao i najbolje hirurške tehnike.
Ključne reči: prelomi kalkaneusa, klasifikacije, lečenje
REFERENCES


