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CALCANEAL FRACTURE, EPIDEMIOLOGY, ANATOMY, MECHANISM OF INJURY, CLASSIFICATION, IMAGING PRESENTATION, CLINICAL PRESENTATION, MANAGEMENT AND COMPLICATIONS

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SUMMARY

Introduction*: Throughout time, calcaneal burst fractures have been referred to as lovers' fractures because the injury occurred when a suitor jumped off a lover's balcony to avoid detection. The calcaneus is part of the 7 tarsal bones, calcaneus, talus, cuboid, navicular, first, second and third cuneiform. Calcaneal fractures are infrequent, however, they have a high potential to weaken the limb.*

Objective*: to detail current information related to calcaneal fractures, epidemiology, anatomy, mechanism of injury, clinical evaluation, imaging evaluation, classification, treatment and complications.*

Methodology: *a total of 30 articles were analyzed in this review, including review and original articles, as well as clinical cases, of which 21 bibliographies were used because the other articles were not relevant to this study. The sources of information were PubMed, Google Scholar and Cochrane; the terms used to search for information in Spanish, Portuguese and English were: calcaneal fracture, calcaneus, calcaneal osteosynthesis, foot fractures.*

Results: *The calcaneus is the most commonly fractured tarsal bone, representing 2% of all fractures. Calcaneal fractures are bilateral in 5 to 10%, and are usually related to fractures of the lumbar spine and other fractures of the lower limb caused by high-impact trauma. About 10 % of calcaneal fractures are open.*

Conclusions: *The calcaneus is the most commonly fractured tarsal bone, accounting for 2 % of all fractures. Calcaneal fractures are bilateral in 5 to 10% and are usually related to fractures of the lumbar spine and other fractures of the lower limb caused by high impact trauma. About 10% of calcaneal fractures are open, and neurovascular injuries are infrequent in calcaneal fractures. Calcaneal fractures are more related to high energy impacts that generate axial loading of the bone, however they can occur with any injury to the foot and ankle. The main characteristics of individuals affected with a calcaneal fracture are pain, swelling, widening, deformity, ecchymosis and functional impotence. To make the radiological diagnosis of calcaneal fracture in the first instance it is recommended*

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to request an anteroposterior projection of the foot, lateral projection of the rearfoot, Harris axial projection and an ankle series; if necessary, a computed tomography can be performed. In practice, calcaneal fractures can be classified as intra-articular or thalamic and extra-articular; in addition, classification systems such as Sanders and Essex-Lopresti are used. Treatment is controversial. Even with adequate reduction and management, calcaneal fractures can become extremely disabling injuries, presenting a mutable prognosis with various types of functional limitation and pain. Currently, some factors have been found to be related to better outcomes, however, the literature comparing various methods of surgical versus conservative treatment show that surgical management has increased complication rates, however, it may lead to optimal functional outcomes in some individuals. Generally, the incidence of complications of calcaneal fractures is high and increases the worse the wound. Among the most common are calcaneal osteomyelitis, post-traumatic osteoarthritis, wound dehiscence, increased heel width, loss of subtalar mobility, chronic peroneal tendonitis, and complex regional pain syndrome.

KEY WORDS: *fracture, calcaneus, osteosynthesis, foot.*

INTRODUCTION

Over time, calcaneal burst fractures have been referred to as lovers' fractures because the injury occurred when a suitor jumped off a lover's balcony to avoid detection. The calcaneus is part of the 7 tarsal bones, calcaneus, talus, cuboid, navicular, first, second and third cuneiform. Calcaneal fractures are infrequent, however, it has a high potential to weaken the limb. The subtalar or calcaneal-talar joint is part of the dorsal flexion, plantar flexion of the ankle and foot. Calcaneal fractures that are intra-articular displaced are injuries that transform the lifestyle, the importance of the fracture and the difficulty of treatment sometimes lead to long-term discomfort, therefore, many of the affected individuals do not reach the levels of physical activity, work and other activities as prior to the pathology.

To better restore the affected lower limb to normal ambulation, surgery is suggested to reconstruct displaced intra-articular calcaneal fractures. The approach used in calcaneal fractures by means of a lateral extensor incision has presented a high rate of complications in wound healing, so currently minimally invasive and tarsal sinus incision approaches are tried in the restoration of calcaneal fractures(1-5).

METHODOLOGY

A total of 30 articles were analyzed in this review, including review and original articles, as well as cases and clinical trials, of which 21 bibliographies were used because the information collected was not important enough to be included in this study. The sources of information were Cochrane, PubMed and Google Scholar; the terms used to search for information in Spanish, Portuguese and English were: calcaneal fracture, calcaneus, calcaneal osteosynthesis, foot fractures.

The choice of bibliography exposes elements related to epidemiology, anatomy, etiology, mechanism of action, clinical evaluation, imaging evaluation, classification, treatment and complications of calcaneal fracture.

DEVELOPMENT

Epidemiology

The calcaneus is the most commonly fractured tarsal bone, accounting for 2% of all fractures. Displaced intra-articular fractures account for 60% to 75% of calcaneal fractures. About 10% of calcaneal fractures are open. Associated morbidities such as osteoporosis and diabetes may increase the risk of fracture. The majority of these calcaneal fractures occur in males between 21 and 45 years of age, accounting for approximately 90% and are very common in workers in the industrial sector. Calcaneal fractures are infrequent in infants(1,6,7).

Anatomy

The anterior half of the superior articular surface has three facets that articulate with the talus. The posterior facet is larger and forms the largest bearing area. The medial facet is located anteromedially over the sustentaculum of the talus. The anterior facet usually follows the medial facet. Between the medial and posterior facet is the interosseous sulcus, which together with the talar sulcus gives rise to the sinus of the tarsus. The sustentaculum of the talus maintains the neck of the talus in the medial part, besides being linked to the talus by means of the interosseous talocalcaneal ligament and by the deltoid ligament; it also maintains the medial articular facet in its superior zone. On the medial aspect, the tendon of the flexor hallucis longus runs under the sustentaculum of the talus. On the lateral aspect, the peroneal tendons run between the calcaneus and the lateral malleolus. The tibial nerve and artery run along the medial aspect of the body of the calcaneus; neurovascular injuries are infrequent in calcaneal fractures. The Achilles tendon reaches the posterior tuberosity of the calcaneus(1,6-8).

Etiology and Mechanism of Injury

Calcaneal fractures are more related to high energy impacts that generate axial loading of the bone, however they can occur with any injury to the foot and ankle. Falling from a height is the main origin of intra-articular fractures, since the talus impacts on the calcaneus, which is composed of a thin cortical lamina that surrounds the cancellous bone; therefore the talus generates a depression and widening of the body of the calcaneus. Other mechanisms of action presented are those given in automobile accidents, generated by impacting the plantar aspect of the foot with the accelerator or brake pedal, closed, penetrating trauma and torsion-cutting mechanisms. Most injuries lead to flattening of the bone as well as widening and shortening. Stress fractures can occur but require excessive and repetitive use. Torsional forces are related to extra-articular fractures of the calcaneus, mainly in the anterior, medial and sustentaculum processes. In

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individuals with diabetes there is a high incidence of tuberosity fractures by avulsion from the Achilles tendon(1,6,7,9-12).

Clinical Evaluation

A complete and comprehensive medical history is essential in the medical evaluation. Trauma patients should be evaluated with the ATLS algorithm to rule out any life-threatening injuries(13):
A: airway management and cervical spine stabilization.
B: Respiration
C: Circulation and hemorrhage control.
D: inability to assess neurological status.
E: Exposure
The main characteristics of individuals with a calcaneal fracture are as follows:

- ➢ Heel pain is usually moderate to severe.
- ➢ Swelling, inflammation, widening and shortening of the heel.
- ➢ Deformity of the rearfoot and functional impotence for support.
- ➢ Ecchymosis in the arch of the foot and around the heel.
- ➢ Flictenas, usually due to the massive inflammation that is generated.

Occasionally it can also occur:

- ➢ Peroneal dislocation or subluxation.
- ➢ Neurovascular compression of the posterior tibial.
- ➢ Interposition of the tendon of the flexor hallucis longus between the fragments.

The exposed fractures are not very habitual, nevertheless when they are presented they usually compromise the medial zone. A detailed evaluation of the soft tissues and neurovascular involvement is very important, in addition to assessing the existence of a compartment syndrome of the foot, which may be present in up to 10% of calcaneal fractures causing an alteration of the claw toes. Calcaneal fractures are bilateral in 5% to 10% and are generally related to fractures of the lumbar spine and other fractures of the lower limb caused by high impact trauma(6,7,11).

Imaging Evaluation.

To make the radiological diagnosis of calcaneal fracture in the first instance it is recommended to request an antero-posterior projection of the foot, lateral projection of the rearfoot, Harris axial projection and an ankle series.

In the lateral projection the angle of Böhler should be measured, which using the line that joins the highest points of the anterior and posterior processes, normally is between 25-40 degrees, a reduction of this angle suggests that the load area of the posterior facet of the calcaneus collapsed which generates a displacement of the weight of the body towards the anterior. The Gissane angle calculates the articular congruence of the posterior facet, measured between the posterior facet and the peak of the calcaneus normally 95-105 degrees and is located just below the lateral process of the talus; an increase suggests that the posterior facet collapsed(6,7,11).

In the anteroposterior projection of the foot, an extension of the fracture trace to the calcaneocuboid joint may be present.
In the Harris axial projection obtained with the foot in dorsiflexion and the X-ray beam angled 45° in the cephalic direction, it shows the articular surface, in addition to the loss of height, the increase in width and the angulation of the tuberosity fragment.

Broden projections are currently not widely used since their role has been replaced by computed tomography, however they are used intraoperatively to know the situation at the time of reduction. They are performed with the individual in supine decubitus and the chassis under the leg and ankle. The foot in neutral flexion and the leg in 15 to 20 degrees of internal rotation. The X-ray beam is centered over the lateral malleolus and four projections are made with the tube angled towards the individual's head at 40, 30, 20 and 10 degrees. The 10-degree angled projection presents the posterior portion and the 40-degree projection presents the anterior portion.

Computed tomography provides information on the global shape of the heel, the articular surface of the posterior facet, the sustentaculum, the position of the peroneal tendons and the flexor tendon of the big toe, in coronal slices. Axial slices show the anteroinferior part of the posterior facet, the calcaneocuboid joint and the sustentaculum. Sagittal reconstructions present additional information(6,7,11).

Classification

In practice, calcaneal fractures can be classified as intra-articular or thalamic and extra-articular.
Extra-articular fractures make up 1/4 of calcaneal fractures. They are usually due to avulsion of the calcaneal tuberosity of the Achilles tendon, the anterior process of the bifurcated ligament or the sustentaculum of the talus. They do not injure the posterior facet.
The fractures of the anterior process: they can result from a forced plantar flexion with inversion generating a fracture by avulsion; or by abduction of the forefoot and calcaneocuboid compression.
Fractures of the posterior tuberosity: due to avulsion by the Achilles tendon, mostly in diabetics and women with osteoporosis, although they are also generated by direct trauma.
Fractures of the medial process are vertical shear fractures caused by heel valgus loading.
Fractures of the sustentaculum of the talus generated by a load on the heel plus a forced inversion of the foot.
Fractures of the body that do not affect the subtalar joint are generated by axial loading. They can have great comminution, widening and loss of height, plus reduction of Böhler's angle and without involvement of the posterior articular facet(6,7).
Intra-articular fractures represent the missing 3/4. The talus acts as a hammer or wedge compressing the calcaneus at the angle of Gissane causing the fracture.
The Essex-Lopresti classification and the Sanders classification are also used, the latter based on the evaluation through coronal

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CT of the posterior subtalar facet and the number of fragments of this facet displaced more than 2 millimeters.

- Type I: 1 bone fragment not displaced or minimally displaced.
- Type II: 2 bone fragments involving the posterior facet. It is subdivided into types A, B and C according to the medial or lateral location of the fracture line.
- Type III: 3 bone fragments including an additional depressed medial fragment. It is subdivided into types AB, AC and BC, according to the position and location of the fracture lines.
- Type IV: 4 comminuted bone fragments(1,6,7,11).

Figure 1. Sanders classification for calcaneal fracture.

Source: Koval KJ, Zuckerman JD. Fracturas y luxaciones. 2 ed. Madrid: Marban; 2003.

Treatment

Treatment is controversial. Even with adequate reduction and management, calcaneal fractures can become extremely disabling injuries, presenting a mutable prognosis with various types of functional limitation and pain. Currently, some factors have been found to be related to better outcomes, however, the literature comparing various methods of surgical versus conservative treatment show that surgical management has increased complication rates, however, it may lead to optimal functional outcomes in some individuals. The current literature presents that the decision to operate should be based on the characteristics of the affected individual, the fracture and the talent of the surgeon. Initially, management includes excellent wound care, plus antibiotics if necessary in contamination. In addition to analgesics, the PRICE protocol "Protection, Rest, Ice, Compression, Elevation" and immobilization with splints, usually of the Bulky Jones type.

Conservative treatment is indicated on the following occasions:

- Non-displaced extra-articular fractures.
- Minimally displaced extra-articular fractures.
- Fractures of the anterior process with less than 1/4 of involvement of the calcaneocuboid joint.
- Non-displaced intra-articular fractures.
- Fractures in individuals with severe peripheral vascular disease.
- Fractures in individuals with insulin-dependent diabetes.
- Individuals with other comorbidities that contraindicate surgery.
- Fractures with long-standing phlyctenas and edema.
- Fractures with large open wounds.
- Life-threatening injuries.

The management begins with the Jones padded bandage, a support splint can be used to achieve the reabsorption of the initial hematoma, and then place a neutral flexion blocked suropedic orthosis with the purpose of not presenting equinus deformity. An elastic stocking can be used to reduce edema. Early initiation of joint mobility exercises is recommended. Unloading should be maintained for about 10 to 12 weeks, until consolidation is achieved on radiographs(6,7,14).

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Figure 2. Surgical treatment of calcaneal fracture with anatomical calcaneal plate and screws. Lateral approach.

Source: The Authors.

Surgical treatment is indicated on the following occasions:

- Fractures-dislocations of the calcaneus.
- Fractures of the anterior process of the calcaneus with involvement of more than 1/4 of the calcaneocuboid joint.
- Displaced intra-articular fractures in the posterior facet.
- Displaced fractures in the calcaneal tuberosity.
- Some open fractures of the calcaneus.

It is recommended that the affected individual receive surgical treatment in the first 3 weeks of evolution, before an early consolidation is generated. In addition, surgery should not be attempted until the swelling of the foot and ankle is lost, with reappearance of skin folds.

Specific Fractures.

Extra-articular fractures.

- *Fractures of the anterior process:* Surgical treatment is recommended when the CT scan shows a compromise of more than 1/4 of the calcaneocuboid joint.
- *Fractures of the posterior tuberosity by avulsion:* caused by sudden traction of the triceps sural, which generates the avulsion of a fragment of variable size. Surgical treatment consists of placing a compression screw with or without wire cerclage.
- *Fractures of the calcaneal body:* minimally displaced fractures of 10 mm are treated with early mobility and without weight bearing for 10 to 12 weeks. Mostly displaced fractures that result in lateral impingement, varus or valgus deformity, loss of heel height or translation of the posterior tuberosity require open reduction with internal fixation.
- *Medial process fractures:* infrequent and typically nondisplaced. Non-displaced fractures can be managed with a suropedic cast, limiting load, for 8 to 10 weeks.

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Displaced fractures can be evaluated for closed reduction(1,6,7,11).

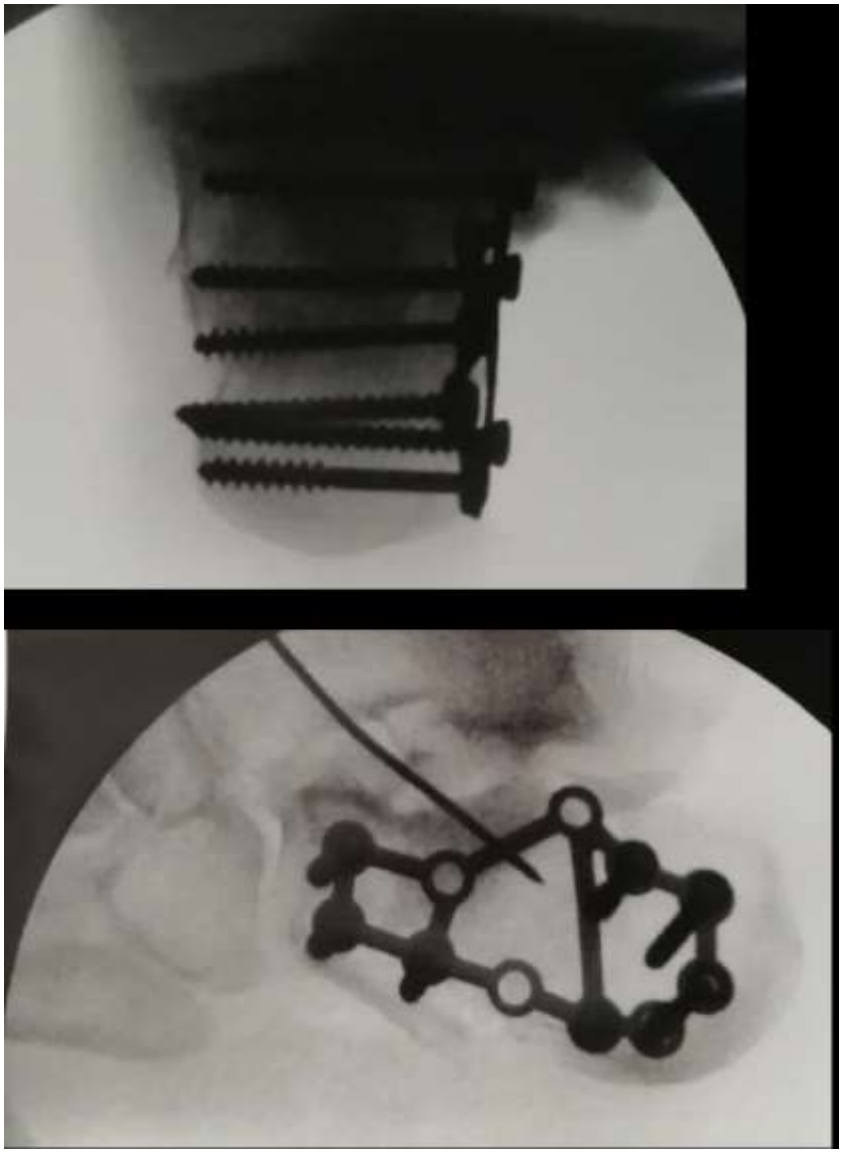
Intra-articular fractures.

Intra-articular fractures surgical treatment is significantly better with surgical treatment in female patients, young adults and individuals with a job without great physical requirements. The goals of surgery are:

- Restore congruence of the subtalar joint.
- To restore the Böhler angle.
- Restore the normal width and height of the calcaneus.
- Preserve normal calcaneocuboid joint.
- Neutralize the varus deformity of the fracture.

Open reduction with internal fixation is usually performed through a lateral L-shaped incision. The posterior facet is reduced and stabilized with compression screws in the talus sustentaculum, the calcaneocuboid joint is reduced in addition to the lateral wall, heel length is restored by neutralizing the varus, and a low-profile neutralization plate is placed on the lateral aspect to act as a strut. Bone alterations do not need to be grafted, however if they are completed, weight bearing can be established earlier. In tongue type fractures, it has good results with percutaneous reduction and fixation with compression screws. In high energy injuries, primary subtalar arthrodesis or triple arthrodesis can be used. Load deprivation is recommended for 8 to 12 weeks and full loading after 3 months(6,7).

Figure 3. Fluoroscopic Images After Immediate Postoperative Period Following Osteosynthesis With Calcaneal Plate and Screws.



Source: The Authors.

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Prognosis

The Sanders classification has been shown to have considerable prognostic value. Studies have shown that type III fractures are 4 times more likely to require a final subtalar fusion when compared to type II fractures. Some populations tend to have better outcomes such as: women, young adults, individuals not receiving institutional compensation, individuals with a lighter workload. The amount of onset displacement based on the Bohler angle of 0 degrees is related to lower functional outcomes. An onset Bohler angle greater than fifteen degrees relates to better functional outcomes(1,15-17).

Complications

Generally, the incidence of complications of calcaneal fractures is high and increases the worse the injury. There are studies that indicate that approximately 70% of individuals with calcaneal fractures present some other type of concomitant injury, due to the nature and the great force necessary to cause this type of fracture. It is important to perform a complete physical examination, mainly to rule out spinal pathology, even more so when the mechanism that produces the injury is a fall. The energy of the vigorous impact against the ground is directed upwards through the lower extremity, generating compression fractures of the spine. Infrequently, compartment syndrome may occur in the foot up to 10%(1,5,18).

Some of the complications usually related to calcaneal fractures are:

- *Calcaneal osteomyelitis:* the risk of this is reduced by allowing the soft tissue edema to self-limit prior to surgery.
- *Post-traumatic osteoarthritis:* due to articular cartilage damage, displacement and comminution of the fracture, it can be calcaneocuboid or subtalar. It can be managed by infiltrations, orthoses and in some cases with subtalar arthrodesis or triple arthrodesis. This may be present even when there is an anatomical reduction.
- *Wound dehiscence:* it is recommended to meticulously manage the soft tissues, in addition to reducing skin damage in the wound synthesis, to reduce the risk of presenting it, usually when it appears it is located in the vertex of the incision. It should be managed with dry/wet local dressings, if necessary a skin graft or a muscle flap could be performed.
- *Increased heel width:* there is usually an expected amount of heel widening, even when the patient undergoes open reduction plus internal fixation; the widening can lead to lateral entrapment of the peroneal tendons or fibula. It can be remedied by removal of the synthetic material or resection of the wall.
- *Loss of subtalar mobility:* this is common in intra-articular fractures.
- *Chronic peroneal tendinitis:* usually generated after conservative treatment for lateral entrapment.
- *Chronic pain:* some affected individuals exhibit chronic heel pain that can become disabling.
- *Complex regional pain syndrome:* it can be generated in conservative and surgical treatment(6,7,16,19,20).

Impaired wound healing and soft tissue disorders can lead to increased morbidity in calcaneal fracture patients, so reconstructive principles that preserve the injured limb well and optimize function must be maintained. As bone and soft tissue plastic reconstruction improves, better limb salvage results are also seen. A sural nerve injury can be found in 15% of surgically treated individuals; the risk of injury is minimized by a lower base L incision(4,21).

CONCLUSIONS

The calcaneus is the most commonly fractured tarsal bone, accounting for 2% of all fractures. Calcaneal fractures are bilateral in 5% to 10% and are usually related to fractures of the lumbar spine and other lower limb fractures caused by high-impact trauma. About 10% of calcaneal fractures are open, and neurovascular injuries are infrequent in calcaneal fractures. Calcaneal fractures are more related to high energy impacts that generate axial loading of the bone, however they can occur with any injury to the foot and ankle. The main characteristics of individuals affected with a calcaneal fracture are pain, swelling, widening, deformity, ecchymosis and functional impotence. To make the radiological diagnosis of calcaneal fracture in the first instance it is recommended to request an anteroposterior projection of the foot, lateral projection of the rearfoot, Harris axial projection and an ankle series; if necessary, a computed tomography can be performed. In practice, calcaneal fractures can be classified as intra-articular or thalamic and extra-articular; in addition, classification systems such as Sanders and Essex-Lopresti are used. Treatment is controversial. Even with adequate reduction and management, calcaneal fractures can become extremely disabling injuries, presenting a mutable prognosis with various types of functional limitation and pain. Currently, some factors have been found to be related to better outcomes, however, the literature comparing various methods of surgical versus conservative treatment show that surgical management has increased complication rates, however, it may lead to optimal functional outcomes in some individuals. Generally, the incidence of complications of calcaneal fractures is high and increases the worse the wound. Among the most common are calcaneal osteomyelitis, post-traumatic osteoarthritis, wound dehiscence, increased heel width, loss of subtalar mobility, chronic peroneal tendonitis and complex regional pain syndrome.

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Conflict of Interest Statement

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