Acute Fractures of the Tarsal Navicular

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Injuries of the tarsal bones result in significant long-term morbidity, adversely impacting overall outcome and long-term function in polytraumatized patients. Despite their association with high-energy trauma, injuries of the tarsal bones are often subtle and frequently only diagnosed on a delayed basis. Midfoot fractures, which are rare, are most commonly associated with motor vehicle collisions. However, these fractures are being seen with increasing frequency, a finding attributed to enhancements in automobile safety leading to improved survival of patients with significant foot injuries.

The most frequently injured lesser tarsal bone is the navicular, a vital component of the foot’s medial column and an active participant in the transverse tarsal locking mechanism. Avulsion, tuberosity, and body fractures have been described. Body fractures, although less common than avulsion and tuberosity types, are more severe and most often associated with high-energy mechanisms. In addition to acute injuries, stress fractures of the tarsal navicular have been described and can also have devastating consequences, including avascular necrosis.

Neither the adverse outcomes following fracture nor the biomechanical significance of the navicular can be refuted. However, there is little literature devoted to these injuries. This article provides an overview of acute fractures of the navicular, reviewing the relevant anatomy and biomechanics, the classification and presentation, and the indications for and outcomes following both conservative and operative interventions.

**Anatomy**

The navicular derives its name from its resemblance to a small boat, as suggested by its concave proximal articular surface. The bone articulates distally with the 3 cuneiforms, proximally with the talar head, and laterally with the cuboid (Figures 1-2). It is located in the uppermost portion of the medial longitudinal arch of the foot, acting as the keystone of the arch (Figure 3). The body of the navicular is a 6-sided, horseshoe-shaped disk. The navicular’s distal articulation with the cuneiforms is via 3 facets that share a common synovial cavity. Its medial surface slopes posteriorly, ending in the tuberosity. Plantar and dorsal ligaments reinforce each articulation, with further stability provided by the posterior tibial tendon and plantar calcaneonavicular (spring) ligament, which insert distally and medially on the tuberosity, as well as the...
antior fibers of the deltoid ligament, which enhance medial talonavicular joint stability. This robust ligamentous network can only be disrupted with significant force, which is why displaced navicular body fractures are most frequently seen in the setting of high-energy trauma.

The extensive articular cartilage surrounding the navicular limits blood vessels to dorsal and plantar entry into the bone. Branches of the dorsalis pedis artery supply the dorsum, while the medial plantar branch of the posterior tibial artery supplies the bone’s plantar surface. The navicular tuberosity receives its blood supply from an anastomosis between these vessels. This pattern renders the middle one-third of the bone largely avascular, making this area the most vulnerable to stress fractures and nonunion.

**Biomechanics**

The talonavicular and calcaneocuboid joints collectively form the transverse tarsal joint, the proper functioning of which is crucial for effective gait. The axes of the talonavicular and calcaneocuboid joints are parallel when the hindfoot is everted, allowing displacement of the fore- and midfoot, and the pattern of joint disruption.

Motion at the talonavicular joint is tightly coupled with subtalar motion. Fusion of the talonavicular joint eliminates all subtalar motion, while fusion of the subtalar joint leaves only 26% of normal talonavicular motion. Isolated fusion of the calcaneocuboid joint has less of an impact on subtalar motion and hindfoot stiffness, leaving 67% of talonavicular motion intact. This further elucidates the important biomechanical role of the navicular in hindfoot motion and gait.

**Classification**

Acute navicular fractures are broadly classified into 3 types: avulsion fractures, tuberosity fractures, and body fractures. In 1989, Sangeorzaz et al further stratified body fractures into 3 types on the basis of the direction of the fracture line, the direction of displacement of the fore- and midfoot, and the pattern of joint disruption.

A type-1 body injury is defined as having a transverse fracture line in the coronal plane, with the dorsal fragment consisting of less than 50% of the body. There is no angulation of the forefoot, and no disruption of the alignment of the foot’s medial border.

A type-2 fracture, which is the most common, has a primary fracture line extending dorsal-lateral to plantar-medial, with the major fragment and forefoot displaced medially. The naviculocuneiform joint usually remains intact, but the dorsal talonavicular ligament is often involved.

Type-3 injuries involve a comminuted fracture in the sagittal plane of the navicular body. The medial border of the foot is usually disrupted at the naviculocuneiform joint with these injuries and there is lateral displacement of the forefoot, with some involvement of the calcaneocuboid joint as well.

**Mechanism of Injury**

Approximately 50% of navicular fractures are avulsion fractures. These low-energy injuries result from disruption of the dorsal talonavicular ligament, anterior division of the deltoid ligament, or traction of the posterior tibial tendon or spring ligament complex. Avulsion of the talonavicular ligament occurs in extreme inversion and plantarflexion, while deltoid ligament failure is seen with extreme eversion. Tuberosity avulsions are the result of an acute eversion or valgus injury to the forefoot.

Tuberosity fractures can appear similar to type-2 body fractures on radiographs. However, the primary fracture fragment in true tuberosity injuries is smaller and more lateral.

Acute navicular body fractures are caused by both direct (eg, crush) and indirect (eg, axial load) forces. There are several theories regarding the indirect mechanisms. Main and Jowett describe a shearing mechanism in which longitudinal compression of the plantarflexed foot causes impaction of the cuneiforms into the navicular. Nyska et al hypothesize that the cuneiforms are compressed backward and medially, causing the navicular body to be crushed by the talar head with the ankle in plantarflexion. Both Eft-
Anteroposterior (A) and coronal computed tomographic image of the patient in Figure 4. This image was obtained to better delineate both the calcaneal and the navicular fractures.

Figure 4: Anteroposterior (A) and lateral (B) radiographs of the right foot of a 49-year-old man involved in a high-speed motor vehicle collision. A nondisplaced fracture of the navicular body is present, in addition to a Gustillo grade 1 open calcaneal fracture. The patient was taken to the operating room the day of presentation, where he underwent an irrigation and debridement of his calcaneus in association with an open reduction and percutaneous pinning. The navicular fracture was managed non-operatively. Navicular body fractures are often seen concurrently with other foot trauma. This is attributed to the significant force required to fracture the navicular body.

Rocket and Brage believe that it is a combination of plantarflexion and abduction at the midtarsus. Although these theories each have distinguishing features, they all involve fracture secondary to axial loading of a plantarflexed foot.

Figure 5: Coronal computed tomographic image of the patient in Figure 4. This image was obtained to better delineate both the calcaneal and the navicular fractures.strong dorsiflexion force in the setting of hindfoot eversion. In this position, the subtalar and transverse tarsal joints are unlocked, causing plantarflexion and adduction of the talus head. This leads to forceful contact between the head of the talus and the articular surface of the navicular body.

PRESENTATION AND DIAGNOSIS

Patients with avulsion and tuberosity fractures will usually describe a low-energy twisting injury, while those with body fractures present following a high-energy mechanism. On physical examination, swelling is most often localized to the dorsomedial midfoot, but can be present diffusely. Patients are extremely tender at the navicular and report limited weight bearing and pain with push-off during gait. When presenting in a delayed fashion, observation of the patient during weight bearing may reveal foot deformities, such as loss of the longitudinal height. As with any evaluation of the foot in the setting of trauma, a detailed neurovascular examination must also be performed. Further, compartment syndrome should be ruled out if there is significant swelling. Additional ipsilateral foot injuries may also be present, with one study identifying a 62% incidence of concurrent midfoot and hindfoot injuries (Figure 4). Anteroposterior, lateral, and oblique radiographs of the foot are mandatory and are usually sufficient to make the diagnosis. Weight-bearing radiographs are ideal, and should be obtained if the patient is able to comply. Stress views can also be obtained and can identify serious ligamentous injury. Avulsion fractures will demonstrate a fleck of cortical bone, which may be present on only one view. Tuberosity fractures must be distinguished from an accessory navicular, which appears well corticated and smooth on radiographs. Comparison radiographs of the other foot can be helpful to identify an accessory navicular, which is often bilateral. Of note, an external oblique view of the foot (opposite to the oblique view of the foot usually obtained) will provide the best visualization of the navicular tuberosity. Given the high-energy nature of body fractures, ankle radiographs should also be obtained to identify any additional injuries.

Computed tomography is not mandatory, but can be used to better delineate the geometry of the talonavicular joint and midfoot anatomy, identify more subtle injuries, assess for intra-articular fracture involvement, and assist the orthopedic surgeon in selecting the most appropriate treatment (Figure 5). Magnetic resonance imaging has a limited role in the setting of acute navicular fractures, and is obtained more often in the setting of a suspected stress fracture, in the presence of an accessory navicular, or when concern exists for injury to the posterior tibial tendon.

TREATMENT

Avulsion fractures can be managed non-operatively in a supportive shoe, cast boot, or short-leg weight-bearing cast. However, if major soft tissue
Swelling or severe pain is present, a more serious ligamentous injury may have occurred and the patient should be kept non-weight bearing with immobilization for 6 weeks. Simple, nondisplaced body fractures can also be managed conservatively with immobilization and protected weight bearing in a short-leg cast. Radiographs should be obtained at monthly intervals to assess for any displacement necessitating operative intervention (Figure 6).

Indications for surgical fixation of navicular body fractures include displacement or joint incongruity greater than 1 mm, medial column shortening greater than 2 to 3 mm, resultant subluxation or dislocation, lateral column involvement, open wounds, compartment syndrome, gross instability, skin tenting, and irreducible dislocations (Figure 7). The goals of open reduction and internal fixation (ORIF) include anatomic reduction of the talonavicular joint, restoration of medial column length, and rigid fixation allowing for early range of motion. At least 60% of the navicular’s proximal articular surface must be restored to prevent talonavicular subluxation after healing. With fracture malreduction, medial column stability is compromised, which can have devastating effects on push-off strength and hindfoot motion.

Type-1 body fractures are approached through an anteromedial incision, which proceeds between the anterior tibial and the posterior tibial tendons. Exposure of the talonavicular and naviculocuneiform joints is performed via capsulotomies. Ideal fixation of these injuries is with two 3.5-mm cortical lag screws placed in a dorsal-to-plantar trajectory.

Type-2 fractures are approached through a dorsal incision directly over the fracture. Simple fractures can be fixed with lag screws. However, most type-2 fractures are usually more complex with some comminution present. In these instances, additional incisions may be required and plate and screw constructs must be used (Figure 8). The traditional 2-incision approach uses the aforementioned anteromedial incision as well as a lateral incision. The intermuscular plane encountered during the lateral exposure is between the extensor hallucis and the extensor digitorum brevis muscles. One must be careful to protect the superficial peroneal nerve and motor branch of the deep peroneal nerve during this approach.

Type-3 fractures are not amenable to percutaneous screw fixation. Instead, plate fixation must be used to provide stable fixation. Bone graft is sometimes needed secondary to the comminution present and can help buttress the talonavicular articular reduction. The plates available for
body fractures include small washer plates, one-quarter tubular plates with 2.7-mm screws, 2.4-mm miniplates with 2.4-mm screws, and 2.0-mm miniplates and T plates with 2.0-mm screws.

When the orthopedic surgeon is faced with a severely comminuted navicular body fracture, ORIF may be a suboptimal intervention. In this setting, the surgeon has several options, including primary arthrodesis of the naviculo-cuneiform joints, spanning external fixation, delayed reconstruction, temporary medial column bridge plating, or primary medial column arthrodesis.19

OUTCOMES
Fracture pattern and quality of reduction have been shown to correlate with outcome following ORIF of navicular body fractures (Figure 9).6 Of the 21 patients reported on by Sangeorzan et al,9 satisfactory reduction was obtained in all type-1 fractures, 67% of type-2 fractures, and 50% of type-3 fractures. Radiographic evidence of healing was seen at an average of 8.5 weeks.10 In a retrospective review of 24 patients treated with miniplate fixation, Evans et al9 found no instances of nonunion, loss of reduction, or deep infection. They concluded that minifragment fixation was a good fixation option for rigid stabilization of navicular body fractures.

COMPLICATIONS
All patients who have been treated with navicular body ORIF should be counseled on the possibility of persistent stiffness, pain, and loss of hindfoot motion. The development of posttraumatic arthritis may be the cause of these symptoms, for which arthrodesis is an effective intervention. Although talonavicular fusion reliably relieves pain, it does so at the expense of hindfoot motion. Avascular necrosis can also occur and is attributed to the bone’s tenuous blood supply and soft tissue stripping performed during surgery. It leads to collapse of the navicular and joint space narrowing, which is most appropriately managed with fusion. Nonunion can also occur due to the bone’s limited blood supply. As mentioned previously, it typically occurs in the central watershed area of the bone. This complication is usually amenable to bone grafting with rigid fixation. An additional complication is the progressive and late development of hindfoot varus, which occurs secondary to progressive collapse of the lateral side of the navicular. This should be treated with deformity correction and concurrent talonavicular or triple arthrodesis.19

CONCLUSION
Acute fractures of the tarsal navicular can present as low-energy avulsion injuries, fractures of the tuberosity, or high-energy body fractures. While both direct and indirect loading of the navicular can lead to injury, it is only with tremendous force that a fracture will occur. This is attributed to the stout ligamentous network surrounding the navicular and its various articulations. Because the navicular is the keystone of the foot’s medial longitudinal arch, and intimately involved in hindfoot motion and effective locomotion, most navicular body fractures should be treated with ORIF. However, in those fractures that are nondisplaced, as well as in the setting of avulsion injuries, conservative interventions are appropriate. All patients must be advised of the risk of experiencing postoperative complications, which include pain and loss of motion, as well as the need for a future arthrodesis secondary to the development of posttraumatic arthritis or avascular necrosis.

REFERENCES
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