Helene Pavlov, M.D.
Joseph S. Torg, M.D.
Robert H. Freiberger, M.D.

Tarsal Navicular Stress Fractures: Radiographic Evaluation[1]

Tarsal navicular stress fractures are a potential source of disabling foot pain in physically active individuals. The diagnosis of tarsal navicular stress fracture requires a high index of clinical and radiographic suspicion because the fracture is only rarely evident on routine radiographs or standard tomograms. The radiographic diagnosis of a tarsal navicular stress fracture may require anatomic anteroposterior tomograms or a radionuclide bone scan with plantar views. Radiographic examinations of 23 fractures in 21 patients are evaluated.

Index terms: Foot, fracture, 46.410 • Foot, radionuclide studies, 46.1299 • Fracture, stress • (Foot, stress fracture, 46.415)

Radiology 148: 641–645, September 1983

TARSAL navicular stress fractures are an underdiagnosed source of prolonged disabling foot pain in young athletes. Eichenholtz and Levine (1), in referring to all fractures of the tarsal navicular, stated "the diagnosis is being missed with and without radiographs because this fracture is not being suspected". Towne *et al.* (2) recognized the limitations of routine radiographs and, in a report of two stress fractures of this bone, suggested the need of "special roentgen views and laminography for detection", but without further elaboration. Goergen *et al.* (3) reported two stress fractures in runners and emphasized the importance and difficulty in radiographic diagnosis. In the orthopedic literature, Torg *et al.* (4) recently described the diagnosis, fracture patterns, complications, and possible etiology of 21 tarsal navicular stress fractures in 19 patients. They emphasized the orthopedic management and stated that "the interval between the onset of symptoms and the diagnosis ranged from less than one month to thirty-eight months (mean interval 7.2 months)" because the fracture was not evident or it was overlooked on the routine foot radiographs. The radiographic observations of these 19 patients plus two others form the basis of this report.

The purposes of this paper are to bring this fracture to the attention of radiologists and describe the radiographic patterns of tarsal navicular stress fractures; to identify the characteristic features of the foot, as seen on routine radiographs, that should alert the radiologist to the possibility of this fracture; and to describe in detail the role of radionuclide bone scanning and tomography in the diagnosis and emphasize the required positioning for both examinations.

MATERIALS AND METHODS

The clinical and radiographic findings of 21 patients with 23 tarsal navicular stress fractures were reviewed. Clinical records of all patients were examined to determine their age, sex, athletic ability and interest, and presenting complaints.

The routine radiographs included anteroposterior (AP), oblique, and lateral views. Additionally, "coned AP views" were available in 13 feet and a direct magnification AP view in one foot. Radiographs were reviewed to determine whether the fracture was evident and if there were characteristic features of the involved feet.

Radionuclide bone scanning was performed 1½ hours following the injection of 15 mCi (555 MBq) Tc-99m MDP (Osteolite technetium Tc-99m medronate sodium) and using an all-purpose collimator (5–7). Scans were obtained in 14 patients (16 feet) and included the standard frontal, medial, and/or lateral views and, in 10 of these feet, plantar views. Plantar views were obtained with the soles of both feet on the face of the gamma camera (Fig. 1).

Thin (1-mm) linear or multidirectional tomograms, collimated to the navicular, were obtained in 17 patients (19 fractures). The tomography was performed in either the "anatomic AP" position (13 feet), both anatomic AP and standard AP positions (5 feet), or only the standard AP position (1 foot). Standard AP tomograms are obtained with the sole of the foot flat on the table. In this position, the dorsal surface of the navicular is slanted with respect to the table and

[1] From the Department of Radiology, Hospital for Special Surgery, affiliated with New York Hospital-Cornell University Medical College, New York, NY (H.P., R.H.F.), and the Department of Orthopaedic Surgery, University of Pennsylvania School of Medicine, Philadelphia, PA (J.S.T.). Received Nov. 4, 1982; accepted and revision requested Feb. 18, 1983; revision received March 9, 1983. ht

Figure 1

Plantar views are obtained with the soles of the patient's feet positioned on the face of the gamma camera. The patient leans posteriorly so that the isotope uptake from the body pool does not contribute to the uptake in the feet.

TABLE I: Common Foot Characteristics in Tarsal Navicular Stress Fractures

Characteristic	No.
Anteroposterior view:	
Sclerosis of the proximal articular border of the navicular	22
Short first metatarsal	19
Metatarsal adductus primus or 1st-3rd digits	17
Metatarsal hyperostosis or stress fractures of the 2nd-4th digits	17
Narrowing of medial aspect of the talonavicular joint	9
Lateral view:	
Plantarward displacement of the talus and the navicular with the cuneiforms	17
Juxta-articular ossicles	16
Os trigonus	10
Os calcaneous secondarias	2
Os supratalare	4
Os supranaviculare	5
Os tibia talare	3
Os tibiale externa	2

tomographic plane (Fig. 2a). Anatomic AP tomograms are obtained with the forefoot elevated from the table with a sponge. In this position, the dorsal surface of the navicular is horizontal to the table and tomographic plane (Fig. 2b). The foot is positioned for the anatomic AP tomograms under fluoroscopic control. The foot is supinated until the medial facet of the navicular is seen *en face* and the forefoot elevated until the talonavicular joint is tangential to the x-ray beam. On the standard AP view, the central third of the navicular is seen tangentially and the articular surface is oblique to the tomographic plane (Fig. 3a). On the anatomic AP view, the central third of the navicular is seen *en face* and the articular surface is perpendicular to the tomographic plane (Fig. 3b). Thin linear or multidirectional tomographic sections are obtained at 5-mm intervals through the entire navicular, including the plantar and the dorsal surfaces. If linear tomograms are used, the entire foot is placed at an angle to the direction of the tomographic movement so that linear streaking is not confused with a fracture. Once a lesion is detected additional tomographic sections are obtained at 1-mm intervals above and below that level as necessary.

RESULTS

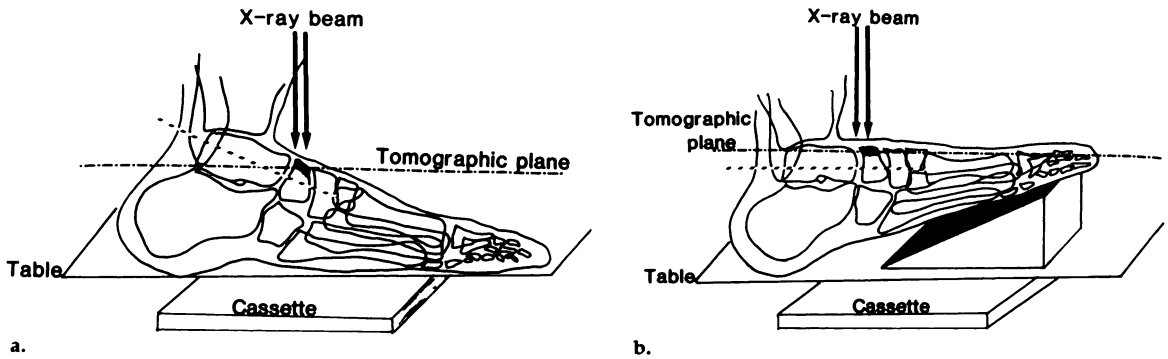
All patients complained of an ill-defined foot soreness or cramping sensation that increased during athletic activity. Clinical examination in all patients revealed deep-seated pain to palpation along the medial longitudinal arch, on the dorsum of the foot, or both. Tenderness was present over the navicular in 17 of the 23 feet and poorly localized in the remaining patients.

There was a male predominance, 19 males and two females. Both feet were represented, 10 left and 11 right; two male patients had bilateral fractures. Patients ranged in age from 15 to 44 years, with 20 of 23 fractures occurring in patients 27 years or younger. All patients participated in professional, collegiate, or recreational athletic activities with the majority participating in basketball (eight fractures) or running (seven fractures). Football (four fractures), ballet, tennis, soccer, and raquetball (each one fracture) were also represented.

Only five fractures had been diagnosed based on the radiographs that the patients brought with them. Retrospectively, the fracture could be diagnosed on the routine AP radiographs in 9 of the 23 symptomatic feet (Fig. 4). In the remaining 14 feet, the tarsal navicular appeared intact even on collimated and direct magnification views. The fracture was never evident on the oblique or lateral views.

Multiple minor foot abnormalities observed on the routine radiographs are detailed in TABLE I. To summarize, on the AP view, the major findings were sclerosis of the proximal articular border of the tarsal navicular, a short first metatarsal, metatarsus adductus of the first through fourth rays, and hyperostosis or stress fractures of the second, third, and/or fourth metatarsals (Fig. 5a). On the lateral view, especially in the standing position, there is a tarsal malalignment with the talus and navicular dorsal to the cuneiforms (Fig. 5b). Proliferative changes on the dorsum of the talus and

Figure 2



a. Standard AP tomogram position. The foot is flat on the table. The dorsal surface of the navicular (shaded area) and the long axis of the talus and the navicular are oblique to the tomographic plane.

b. Anatomic AP tomogram position. The forefoot is lifted off the table with a wedge so that the dorsal surface of the navicular (shaded area) and the long axis of the talus and the navicular are parallel to the tomographic plane.

→

a. Standard AP tomogram position. On this view, the central third of the navicular (shaded area) is seen obliquely. Also, the undersurface of the navicular is usually seen because the x-ray beam is not tangential to the talonavicular joint.
b. Anatomic AP tomogram position. On this view, the central third of the navicular (shaded area) is seen *en face* and the x-ray beam is tangential to the talonavicular joint.

navicular and juxta-articular ossicles were also frequently observed but the incidence of these findings was not compared with a control population.

On radionuclide bone scanning there was increased isotope uptake in all naviculars with stress fractures (16 of 16 feet) (Fig. 6). There was diffuse increased isotope uptake in the region of the hindfoot and tarsal area on the frontal view, and localized isotope uptake in the region of the navicular on the medial and/or lateral view. The area of increased uptake had the shape and configuration of the tarsal navicular on 9 of 10 plantar views; in the one remaining patient, the scan was obtained several months following fracture identification and treatment and there was a diffuse pattern of isotope uptake on all views consistent with the radiographic findings of disuse osteoporosis.

There were 12 partial and 11 complete fractures. A partial fracture involves only the dorsal 5 mm of the tarsal navicular; a complete fracture extends through the entire bone and involves both the dorsal and plantar surfaces (4). Of the nine fractures that could be seen initially or retrospectively on the routine AP view, all were complete fractures. Seventeen of the 23 fractures were diagnosed on anatomic AP tomograms; one fracture was diagnosed on a standard AP tomogram. In the five feet in which tomograms were obtained in both the anatomic AP and standard AP tomographic positions, the fracture was demonstrated only on the anatomic AP tomograms.

All fractures, both complete and partial, were linear, in the sagittal plane, and in the central third of the navicular. Of the 12 partial fractures, nine involved the proximal articular border, one involved the distal articular border, and two involved the entire dorsal surface extending from the proximal articular border to the distal articular border (Fig. 7). Of the 11 complete fractures, eight were nondisplaced and three were displaced. There was marginal sclerosis characteristic of nonunion in two of the dis-

Figure 3

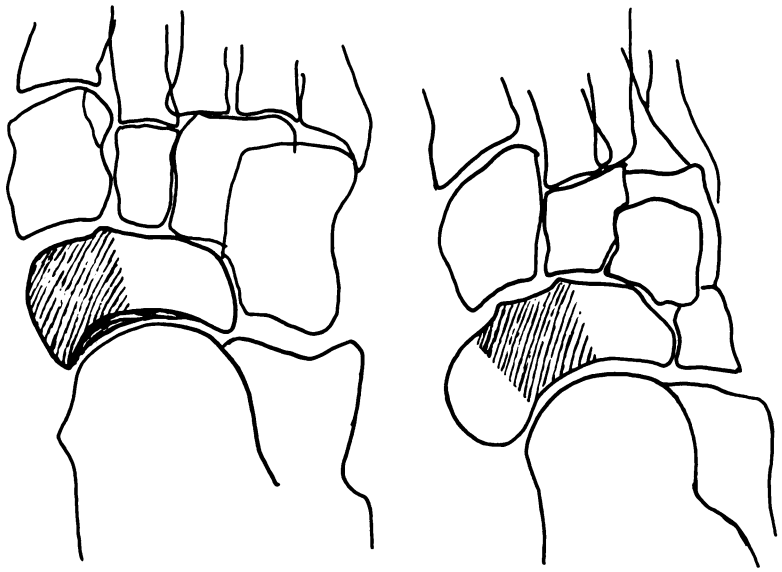


Figure 4

AP views of both feet demonstrate a complete vertical fracture in the left tarsal navicular (arrow). The fracture is linear and in the sagittal plane. The lateral fracture fragment must not be misinterpreted as a separate tarsal bone. Note that the area is underpenetrated, which is not unusual on the standard AP radiograph.

placed fractures (Fig. 8). Three of the fractures, one partial and two complete, were associated with a separate transverse fracture fragment paralleling the proximal articular border.

DISCUSSION

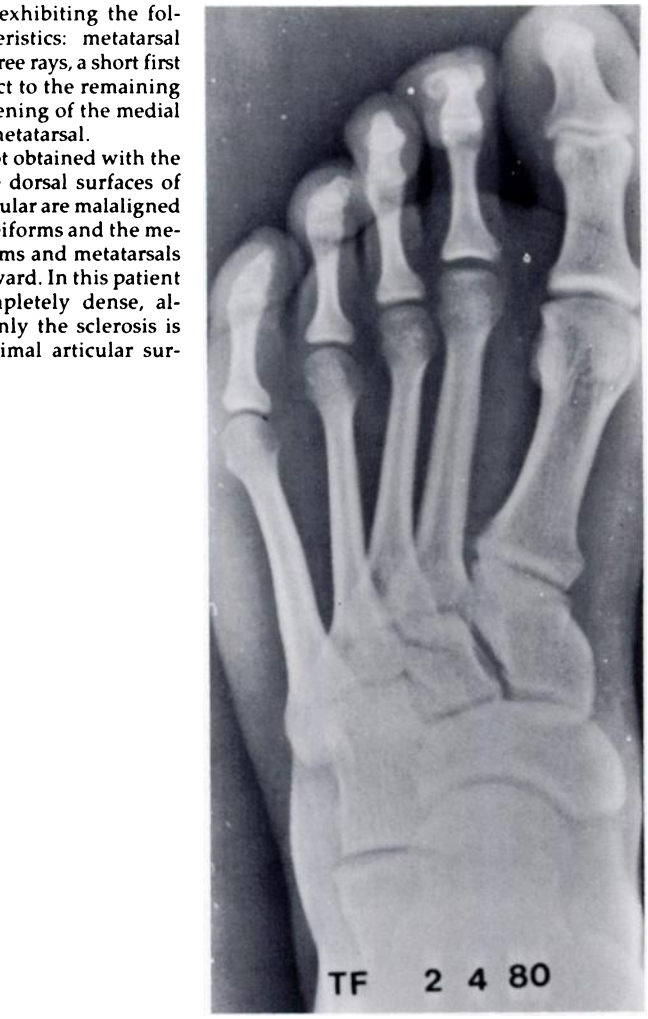
Tarsal navicular stress fractures occur in physically active individuals, especially basketball players and runners. The fractures are linear, in the sagittal plane, in the central third of the navicular, and can be complete or partial (4). Early diagnosis is difficult because they are usually not seen on the routine radiographs (4). A complete stress fracture of the tarsal navicular can occasionally be identified on the routine AP view of the foot but it is usually overlooked, either because the tarsal area is underpenetrated or because the separate lateral fragment is misinterpreted as a normal tarsal bone. A partial tarsal navicular stress fracture is confined to the dorsal 5 mm of the navicular and is not evident on the routine foot radiograph, even on views collimated to the navicular.

In a symptomatic patient, the presence of multiple foot abnormalities on the routine radiographs (TABLE I) should raise the suspicion of a stress fracture and further examinations, including bone scan and anatomic AP tomograms, are indicated.

The radionuclide bone scan consistently showed increased uptake in the fractured navicular. On the standard frontal view, the increased isotope uptake is difficult to localize but on the plantar view, the area of increased isotope conforms to the configuration of the navicular. The plantar view is a better view for evaluation of foot problems.

Anatomic AP refers to the anteroposterior position of the navicular, not the foot, and the tomography is performed with the foot supinated and the forefoot elevated. A tomogram obtained with the foot in a standard AP position is oblique to both the central third and the dorsal surface of the navicular (Figs. 2a and 3a). A tomogram obtained with the foot in the anatomic AP position demonstrates the central third of the navicular and is parallel to the dorsal surface (Figs. 2b and 3b). A typical partial tarsal navicular stress fracture is confined within the dorsal 5 mm of the central third of the bone and will not be demonstrated on the standard AP tomogram.

Figure 5



a.

b.

a. AP view of the foot exhibiting the following foot characteristics: metatarsal adductus of the first three rays, a short first metatarsal with respect to the remaining metatarsals, and thickening of the medial cortex of the second metatarsal.

b. Lateral view of the foot obtained with the patient standing. The dorsal surfaces of the talus and the navicular are malaligned with those of the cuneiforms and the metatarsals; the cuneiforms and metatarsals are displaced plantarward. In this patient the navicular is completely dense, although more commonly the sclerosis is confined to the proximal articular surface.

CONCLUSIONS

Tarsal navicular stress fractures are an underdiagnosed source of foot pain in athletically active individuals because the routine radiographic examination of the foot is usually interpreted as normal. A tarsal navicular stress fracture should be radiographically suspected in feet having the described characteristic pattern of abnormalities. A Tc-99m MDP radionuclide bone scan, including plantar views, is suggested as a screening procedure. Anatomic AP tomograms of the tarsal navicular are usually required for fracture diagnosis.

Acknowledgments: We wish to thank Patricia Boggia for her help in manuscript preparation and Dottie Page and the staff of the Department of Photography.

Department of Radiology
Hospital for Special Surgery
535 East 70th Street
New York, NY 10021

References

1. Eichenholtz SN, Levine DB. Fractures of the tarsal navicular bone. Clin Ortho Rel Res 1964; 34:142-157.
2. Towne LC, Blazina ME, Cozen LN. Fatigue fracture of the tarsal navicular. J Bone Joint Surg (Am) 1970; 52:376-378.

→

Radionuclide bone scanning was performed (starting in the upper left quadrant and moving clockwise) in the frontal, medial (right), plantar, and medial (left) positions. There is augmented isotope uptake in the left navicular and the fourth metatarsal. In the frontal view, the tarsal area is overlapped by that of the hindfoot and it is difficult to localize the isotope uptake. On the medial (left) view, the uptake is intensified in the region of the navicular, however, it is poorly localized because of other areas of augmented uptake. On the plantar view, the areas of increased isotope uptake are best demonstrated and conform to the configuration of the navicular and the fourth metatarsal respectively; stress fractures in both areas were documented.

3. Goergen TG, Venn-Watson EA, Rossman, DJ, Resnick D, Gerber, KH. Tarsal navicular stress fractures in runners. AJR 1981; 136: 201-203.
4. Torg JS, Pavlov H, Cooley LH, et al. Tarsal navicular stress fractures: review of twenty-one cases. J Bone Joint Surg (Am) 1982; 64: 700-712.
5. Geslien GE, Thrall JH, Espinosa JL, Older RA. Early detection of stress fractures using ^{99m}Tc-polyphosphate. Radiology 1976; 121:683-687.
6. Wilcox JR, Moniot AL, Green JP. Bone scanning in the evaluation of exercise-related stress injuries. Radiology 1977; 123:699-703.
7. Roub LW, Gumerman, IW, Hanley EN, Clark MW, Goodman M, Herbert DL. Bone stress: a radionuclide imaging perspective. Radiology 1979; 132:431-438.

Figure 6

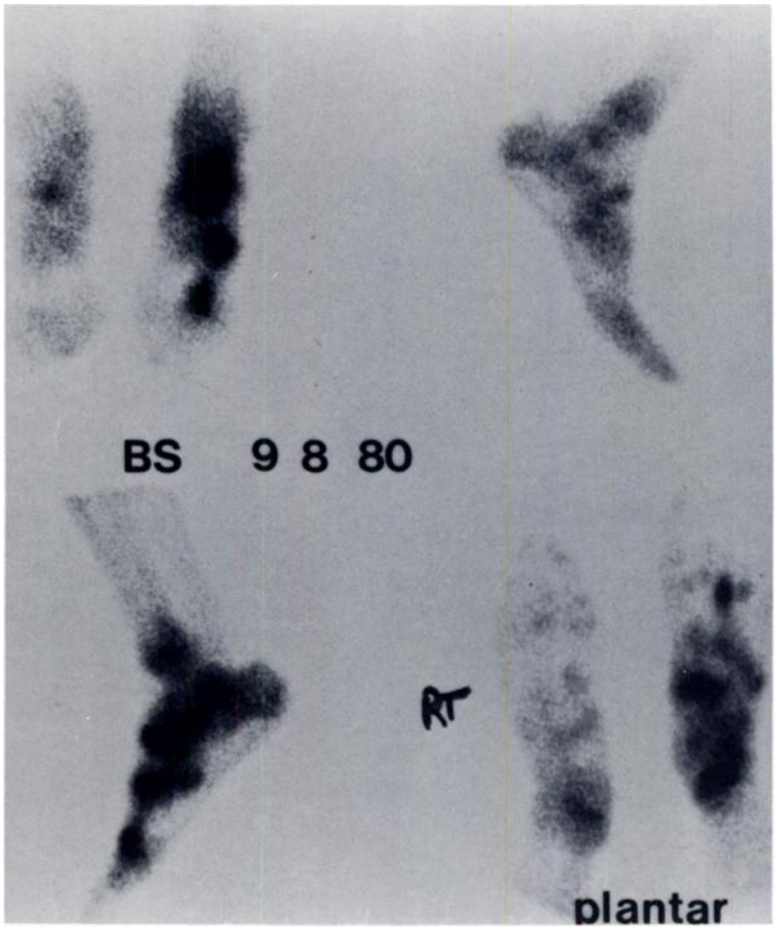
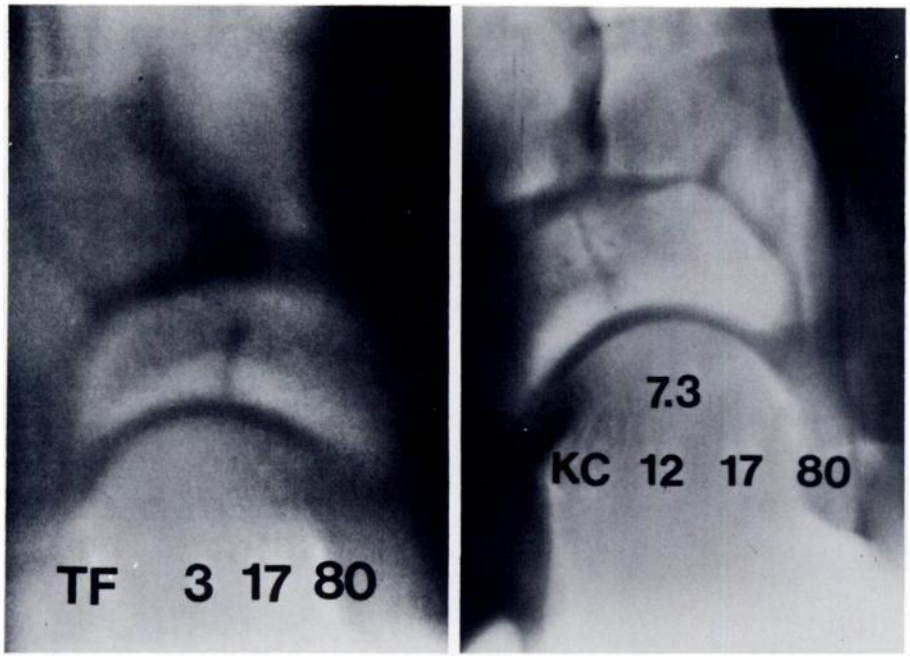


Figure 7



a. b.

a. An anatomic AP tomogram through the dorsal aspect of the navicular demonstrates a partial tarsal navicular stress fracture. The fracture is linear, sagittal, and interrupts the proximal articular border. Note the sclerosis of the proximal articular border of the navicular.

b. An anatomic AP tomogram through the dorsal aspect of the navicular demonstrates a partial stress fracture involving the entire dorsal surface and interrupting both the proximal and distal articular borders.

Figure 8

An anatomic AP tomogram demonstrating a complete fracture in which the medial fracture fragment is displaced medially. The lateral fragment is dense, indicating avascular necrosis; there is fracture nonunion. (Figure courtesy of the Journal of Bone and Joint Surgery.)