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Femoral neck stress fractures

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ABSTRACT

Fifty-four femoral neck stress fractures were studied prospectively to evaluate treatment methods. Fifty-four fractures in 49 patients were identified in a 4 year prospective study that included 1,049 stress fractures of all types. From our evaluation of treatment methods, a modification of existing classification systems was developed based on radiographic findings and treatment. Differences from earlier studies were noted in racial diversity, in nonprogression of tension-side fractures, and in return to function.

Stress fractures are a common diagnosis in this era of increased athletic activity among people of all ages. Since the classic articles of Ernst,[9] Devas,[7] and Blickenstaff and Morris,[4] added emphasis has been placed on stress fractures occurring in the femoral neck.[9] A number of recent reports describe similar findings in small numbers of joggers, runners, and soldiers.[13-16]

Although the first apparent report of a femoral neck stress fracture was made by Blecher in 1905, cited in Blickenstaff and Morris,[4] it was not until a series of reports appeared in the 1960s that the diagnosis became more clearly defined. Ernst in 1964 reported 13 cases.[9] In 1965, Devas reported on 25 patients.[7] In 1966, Blickenstaff and Morris reported on 36 military cases and proposed an expanded classification of types of femoral neck stress fractures.[4] Since then, there have been numerous publications describing the incidence, diagnosis, and treatment of small series of patients with these fractures.

Our early experience with femoral neck stress fractures suggested some differences from the mostly retrospective multicenter work of Ernst, Devas, and Blickenstaff and Morris. Prolonged disability as well as complications from a displaced fracture in the femoral neck highlighted the special nature of this type of stress fracture. To clarify the natural history of this injury, we undertook a prospective study of femoral neck stress fractures at Fort Benning, Georgia, between 1979 and 1983. The purpose of this paper is to review our results as to classification, incidence, race of patients, bone scintigraphy, and treatment of femoral neck stress fractures.

CLASSIFICATION

In 1965, Devas[7] offered a biomechanical classification of femoral neck stress fractures. He described two types, based on a review of Ernst's 1964 series and on his own 25 patients. First, he identified compression fractures. This type had radiographic changes in the compression side of the femoral neck but no apparent cortical disruption. Second, transverse fractures of the femoral neck were defined by him as follows: "the stress fracture goes transversely across the line of force in a bone whether it be a line of tension or compression." He went on to state that "if the stress is allowed to continue the fracture becomes complete and displaced." He also stated that the earliest radiographic sign of this type of fracture was a "minute, almost microscopical crack" in the superior surface of the femoral neck.[7] Ten years later, he redefined the two types as "those that are basically distracted, or being pulled open, and those that are compressed."[8]

Blickenstaff and Morris[4] noted three types of fractures and presented a descriptive classification based on the degree of fracture displacement. Type I fractures had callus without a fracture line. Type II had a fracture line in the calcar or across the neck without displacement. Type III fractures were completely displaced.

After reviewing our series of 54 fractures, it was apparent that neither Devas's nor Blickenstaff and Morris's classification alone was satisfactory. We found a combination of the biomechanical and degree of displacement classifications to be clinically useful. We therefore divided our femoral neck stress fractures into three modified categories, incorporating appropriate elements from the earlier classification systems (Table 1).

Our first category is tension-side femoral neck fractures. This is a combination of Blickenstaff and Morris's endosteal

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callus and Devas's transverse fractures. We have found it difficult to apply the transverse fracture description except when there is callus or overt tension-side cortical disruption. In our series, the transverse nature of the fracture often did not become apparent until several weeks after initial diagnosis. This made it difficult to apply Devas's classification and his recommended emergency surgical treatment at the time of diagnosis. In our series, there were eight fractures that showed a wide spectrum of tension-side femoral neck radiographic changes. At the earliest stages, tension-side fractures have normal radiographs with positive bone scintigraphy on the tension side of the neck (Fig. 1). The next stage exhibits either endosteal or periosteal callus on the tension side of the femoral neck or an overt tension-side fracture line without displacement (Fig. 2). This stage is followed by widening of the tension-side fracture line without loss of medial cortex continuity (Fig. 3). Finally, it appears that complete displacement of the femoral neck fracture is the end stage of the tension-side stress fracture (Fig. 4). Progression to complete displacement during treatment was not seen in our series.

Compression-side stress fractures are our second category of femoral neck stress fractures, and our classification shares many elements with the systems of Devas, and of Blickenstaff and Morris. A compression-side stress fracture most commonly exhibits sclerosis on the compression side of the femoral neck. The spectrum of radiographic changes starts with a negative radiograph with positive bone scintigraphy on the compression side of the femoral neck (Fig. 5). The next, and most common, stage is sclerosis without overt fracture (Fig. 6). This is followed by a compression-side cortical break (Fig. 7), and then widening of the fracture line (Fig. 8). As with tension fractures, no compression fracture in our series progressed to displacement during care. Our third category is the displaced fracture. There is no doubt that a category for displaced fractures must exist, although in our series no displacements occurred in patients under orthopaedic care. However, all patients who presented as acute displacements were without preinjury radiographs that would allow other classification.

MATERIALS

During the period July 1979 to July 1983, 54 femoral neck stress fractures were diagnosed at Fort Benning, Georgia, and are listed in order of presentation in Table 2. The average age of the patients was 22 years (range, 16 to 33). The patients were all part of the military and civilian population that was eligible for care at Martin Army Community Hospital at Fort Benning. A screening and referral program identified, documented, and followed all patients with suspected stress fractures of any bone during this period. The majority of the population was soldiers involved in Infantry Basic Training (a 14 week course). There were also, however, other highly motivated groups such as Officers Candidate School students and Airborne training soldiers. (Initial Airborne training for all branches of the Armed Services is done exclusively at Fort Benning.)

Except for one jogger and one cross-country runner, all of the patients were participating in vigorous supervised training programs at the time of injury. This training was supervised and enforced according to standard military protocol.

DIAGNOSIS

The earliest and most frequent symptom was anterior groin (inguinal) pain in 87% of patients. Night pain in the anterior

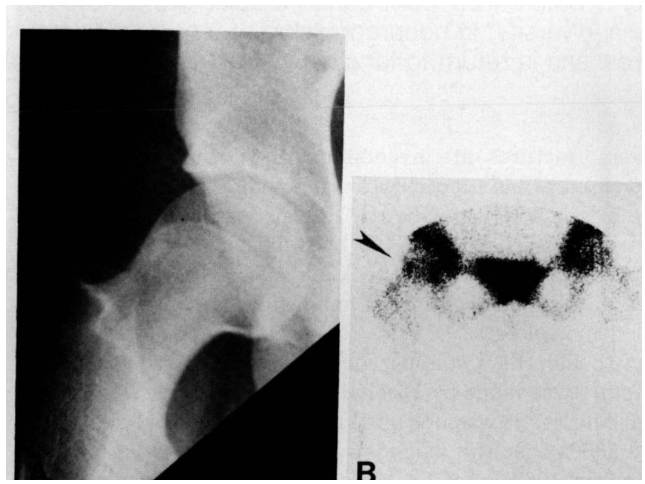


Figure 1. A, normal radiograph in patient with tension-side femoral neck stress fracture. B, positive tension-side stress fracture on bone scintigraphy.

TABLE 1
Comparison of classification systems

Devas (1965, 1975)	Blickenstaff/Morris (1966)	Fullerton/Snowdy (1983)
Compression	Type I Includes: endosteal and periosteal callus without fracture line	Compression
Transverse or distracted	Type II Fractures without displacement—includes: fracture in calcar, fracture across neck	Tension
	Type III Displaced	Displaced

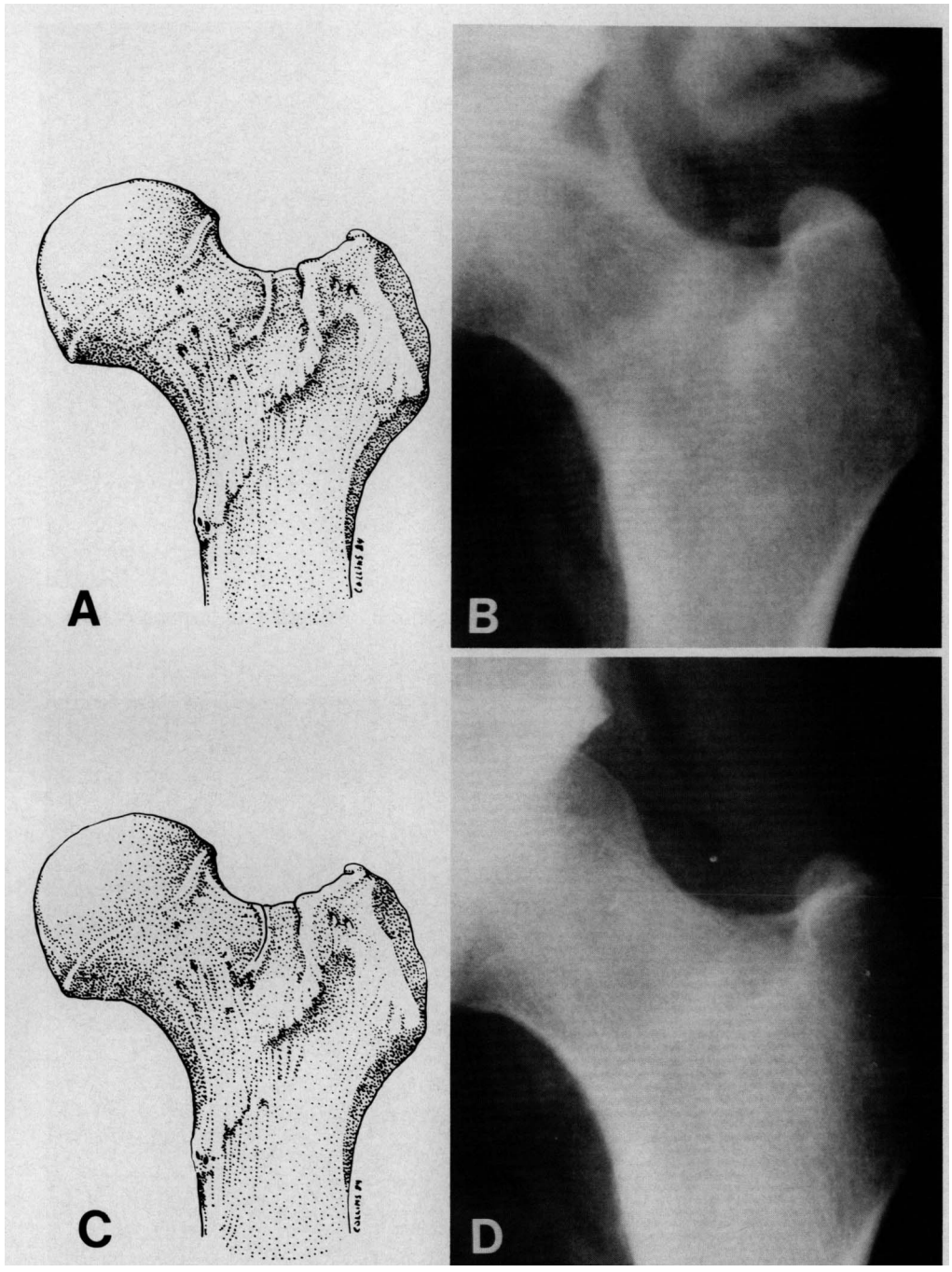


Figure 2. A, location of tension-side stress fracture sclerosis. B, tension-side stress fracture manifested by sclerosis on the radiograph. C, tension-side stress fracture demonstrated by a cortical crack. D, radiograph of undisplaced crack in the tension side of a femoral neck.

groin area was reported in 19% of the patients (not recorded in 7 patients). The onset of symptoms occurred in 40% after a long run or march between the 6th and 8th weeks of training.

On examination, pain at the extremes of hip range of motion was the most frequent and constant finding (in 79% of patients with no record in 10 patients). Tenderness to palpation of the inguinal area overlying the hip joint was reported in 62%. Heel percussion reproduced the hip area symptoms in only three patients. Laboratory evaluation of alkaline phosphatase, calcium phosphorus, and sedimentation rate was not routinely performed, because earlier femoral neck stress fracture studies had demonstrated no significant abnormalities.[4,9,16]

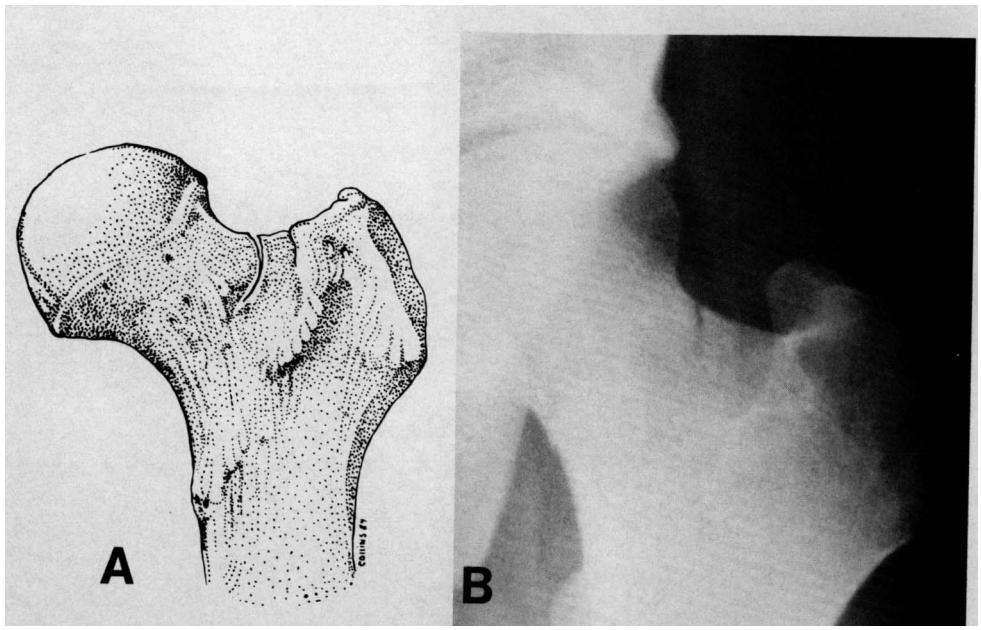


Figure 3. A, tension-side stress fracture with widening of the fracture line. B, radiograph of opening of tension-side femoral neck stress fracture.

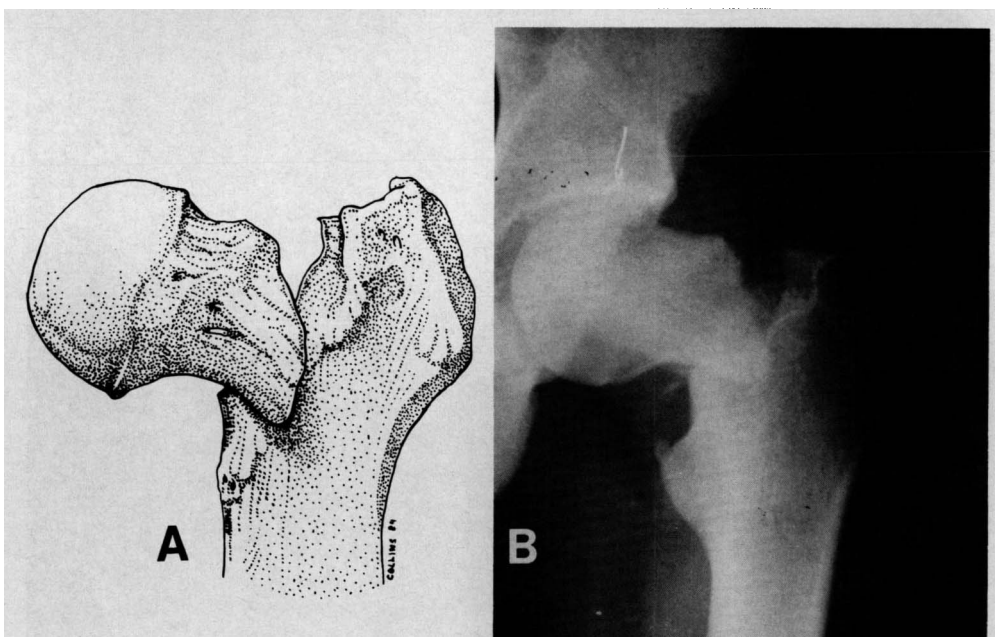


Figure 4. A, displaced femoral neck stress fracture. B, initial radiographic presentation of a displaced femoral neck stress fracture.

RADIOGRAPHY

Anteroposterior and true lateral radiographs were taken as part of the first evaluation of inguinal or hip pain in 20 of 46 patients (three displaced fractures omitted). The initial radiograph, no matter when it was taken, was diagnostic in 10 of 54 hips. In eight of the patients in our study, the radiographs never became positive. All eight, however, had positive bone scintigraphies and signs and symptoms of a femoral neck stress fracture.[12,17,22,25] All of these eight were treated by bed rest.

Bone scintigraphy is the ultimate diagnostic test for femoral neck stress fracture in the presence of negative radiographs. Twenty-five scintigraphies were performed in 35 patients who had normal radiographs but had signs and symptoms of femoral neck stress fracture. Radiographs

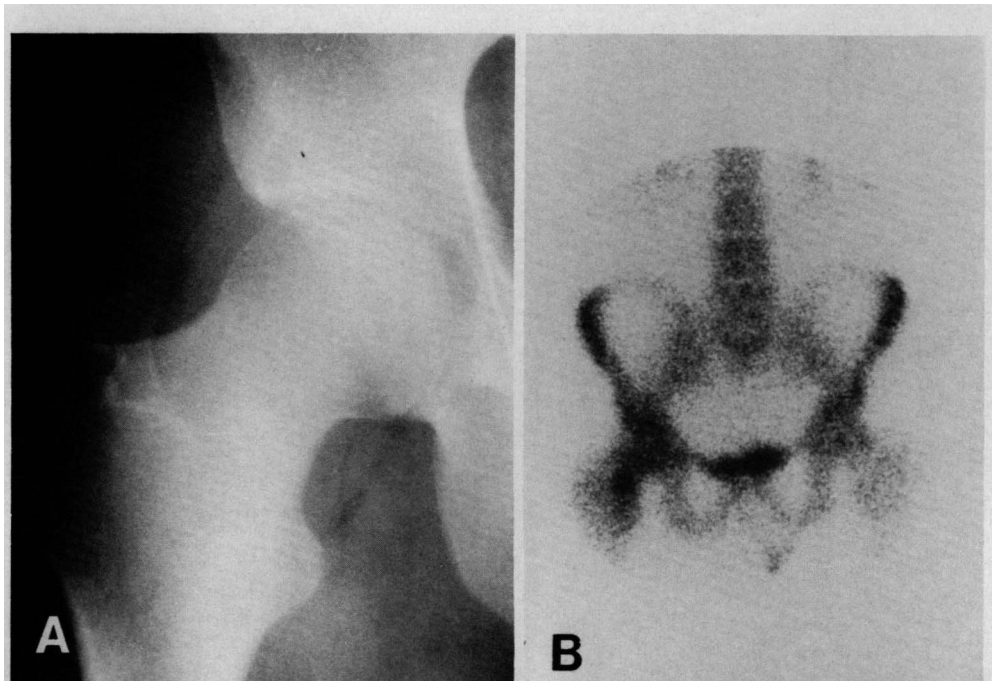


Figure 5. A, compression-side femoral neck stress fracture but a normal radiograph. B, same patient with positive compression-side stress fracture bone scintigraph.

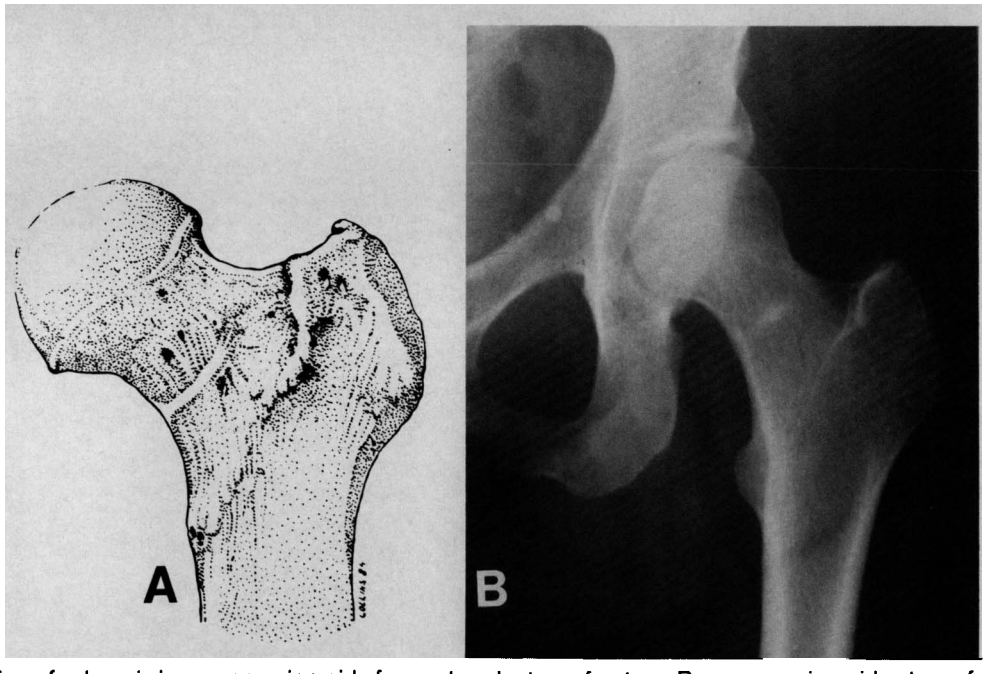


Figure 6. A, location of sclerosis in compression-side femoral neck stress fracture. B, compression-side stress fracture manifested by sclerosis.

eventually became positive in 17 patients who had positive scintigraphies. No patient with negative scintigraphy subsequently developed radiographic evidence of a stress fracture. The eight positive scintigraphy patients who did not develop radiographic changes were not considered false positives. The history, examination scintigraphy, and response to treatment were felt to be confirmatory.[12,17,22,25] False positive bone scintigraphy findings apparently do not exist. They have been described only in patients who have had disorders other than stress fractures, e.g., sickle cell disease

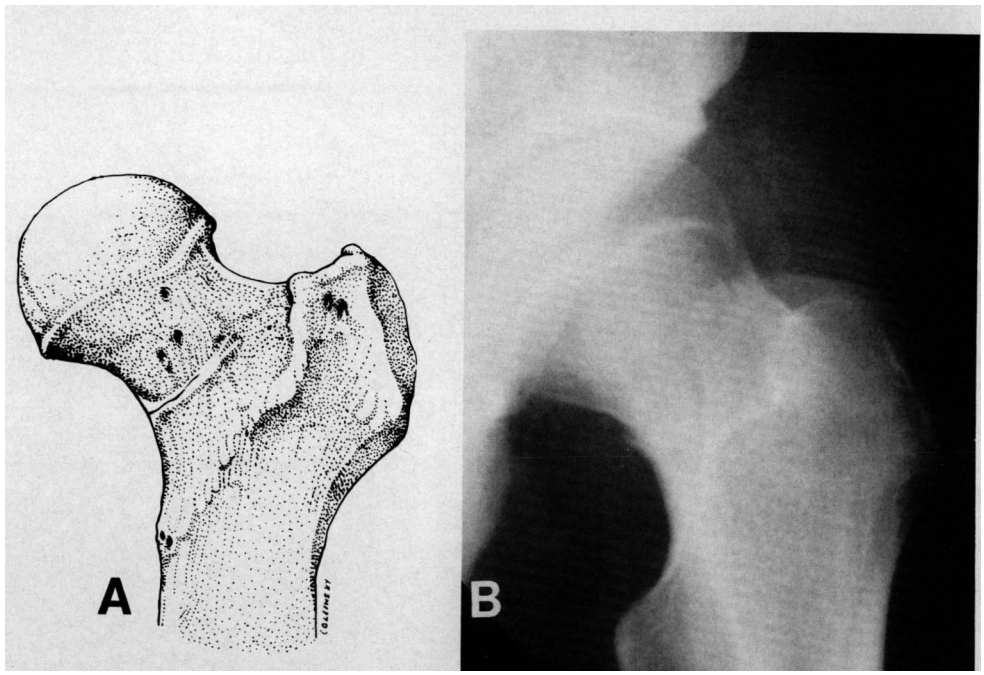


Figure 7. A, cortical crack in a compression-side femoral neck stress fracture. B, radiograph showing a compression-side stress fracture with an undisplaced cortical crack.

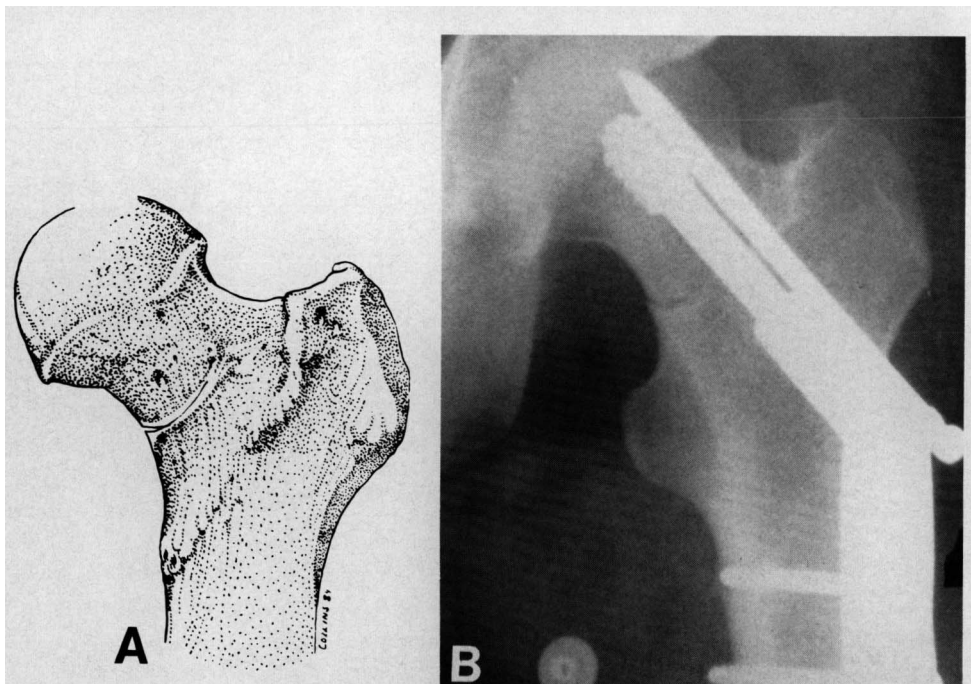


Figure 8. A, area of widening of compression-side stress fracture. B, widening of a compression-side femoral neck stress fracture.

and infections.[22] Early false negative scintigraphies have, however, recently been reported in tibial stress fractures.[19] Repeat scintigraphies were not done in this series.

The need for total-body scintigraphy has been mentioned in the past.[20] In our study, 14 total-body scintigraphies, positive for femoral neck stress fractures, were available at final review. Twelve showed multiple areas of involvement in addition to the femoral neck. None of these areas was

TABLE 2
Patient data[a]

No.	Age	Sex	Race	Side	Fracture type	Initial radiographic result	Bone scintigraphy	Treatment	Complications	Followup	
										(6 weeks)	(2 years min)
1	19	M	B	L	Compression w/ sclerosis	Neg	Subsequent radiograph Pos	Bed rest	None	Limited	Pain after walking several blocks (Q)
2	23	M	W	R	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Limited duty	Full activity (Q, P)
3	18	M	W	R	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	Full activity (Q)
4	29	M	W	B	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	Full activity (Q)
5	18	M	W	R	Compression crack w/o opening	Neg	Pos	Bed rest	None	Temporary med discharge	Pain only after long run (Q)
6	19	F	W	L	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Limited duty	Full activity (Q)
7	18	M	W	R	Compression w/ sclerosis	Neg	Subsequent radiograph Pos	Bed rest	None	Limited duty	
8	30	M	B	B	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	Full activity (Q)
9	23	M	W	L	Displaced	None	N/A	Internal fixation	None	Temporary med discharge	Pain after walking several blocks (Q)
10	23	M	W	L	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	Full activity (Q)
11	23	M	W	R	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	
12	20	M	W	L	Compression	Neg	Pos	Crutches	None	Temporary med discharge	
13	18	M	W	L	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Limited duty	Pain after walking several blocks (Q)
14	18	M	W	L	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Temporary med discharge	
15	20	M	W	L	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Full duty	Full activity but pain when running and at end of workday (Q)
16	25	M	W	R	Compression crack w/o displacement	Neg	Subsequent radiograph Pos	Bed rest	None	Full duty	Full activity, completed Airborne and Ranger School, 30 parachute jumps
17	32	M	W	R	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Full duty	Full activity (Q)
18	18	M	W	B	Compression w/ sclerosis	Neg	Subsequent radiograph Pos	Bed rest	None	Full duty	Full activity completed Airborne and Ranger School (Q)
19	18	M	W	L	Displaced	None	N/A	Internal fixation	Delayed union	Temporary med discharge	Full civilian activity, avoids running (E, Q, P)
20	25	M	W	L	Tension, crack w/o displacement	Pos	N/A	Internal fixation	None	Temporary med discharge	Hardware removed, full activity (Q, P)
21	16	F	W	R	Tension w/sclerosis	Neg	Pos	Crutches	None	Full activity	
22	20	M	W	R	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Full duty	
23	20	M	W	L	Compression w/ sclerosis	Pos	Pos	Bed rest	None	Limited duty	
24	17	M	W	L	Tension, crack w/ displacement	Pos	N/A	Internal fixation	None	Temporary med discharge	Full civilian activity (P)
25	23	M	W	L	Compression	Neg	Pos	Bed rest	None	Limited duty	
26	20	M	W	L	Tension, crack w/ displacement	Pos	N/A	Internal fixation	None	Temporary med discharge	
27	19	M	W	L	Compression w/ sclerosis	Neg	Subsequent radiograph Pos	Bed rest	None	Full duty	
28	28	M	W	R	Tension, crack w/o displacement	Pos	N/A	Bed rest	None	Limited duty	Pain after running or biking, occasional disabling pain (Q)

TABLE 2

No.	Age	Sex	Race	Side	Fracture type	Initial radiographic result	Bone scintigraphy	Treatment	Complications	Followup	
										(6 weeks)	(2 years min)
29	28	M	H	R	Compression w/ sclerosis	Pos	Pos	Bed rest	None	Full duty	
30	24	M	H	L	Compression	Pos	N/A	Bed rest	None	Limited duty	
31	18	M	H	L	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Limited duty	Pain after running (Q)
32	33	M	H	B	Tension	Neg	Pos	Bed rest	None	Temporary med discharge	Pain after walking or running more than 10 minutes (Q)
33	25	M	W	L	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Temporary med discharge	No limitations (Q)
34	26	M	W	L	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Limited duty	Pain after heavy work or running (Q)
35	26	M	W	R	Compression w/ sclerosis	Pos	Pos	Bed rest	None	Limited duty	
36	24	F	W	L	Compression	Neg	Pos	Bed rest	None	Limited duty	
37	24	M	W	R	Compression w/ sclerosis	Pos	N/A	Bed rest	None	Limited duty	
38	27	M	W	R	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Full duty	
39	29	M	W	L	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	
40	20	M	B	R	Compression crack w/o displacement	Pos	Pos	Bed rest	None	Limited duty	
41	18	M	W	L	Compression crack w/o displacement	Pos	N/A	Internal fixation	None	Temporary med discharge	Hardware removed, full civilian activity (Q, P)
42	19	M	W	R	Tension crack w/ displacement	Pos	N/A	Internal fixation	None	Temporary med discharge	Hardware removed, full activity (P)
43	18	M	W	R	Compression	Neg	Pos	Bed rest	None	Limited duty	
44	18	M	W	L	Displaced	N/A	N/A	Internal fixation	None	Temporary med discharge	Hardware removed, psychiatric discharge, disabled
45	19	M	W	R	Compression crack w/o displacement	Neg	Pos	Bed rest	None	Limited duty	
46	26	M	W	L	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	
47	18	M	W	B	Compression w/ sclerosis	Neg	Pos	Bed rest	None	Limited duty	
48	22	M	W	L	Compression crack w/o displacement	Neg	Pos	Bed rest	None	Limited duty	Full activity
49	21	M	W	R	Compression crack w/displacement	Pos	N/A	Internal fixation	None	Temporary med discharge	Hardware removed at 6 months

[a] Two year followup was attempted in all cases. Twenty-four of 49 patients responded by questionnaire (Q), phone interview (P), or examination (E). Limited duty indicates return to military duty with restrictions against jumping, running, and marching. Temporary medical discharge (Temporary Disability Retired List) indicates Disability Board felt improvement was possible.

noted to be painful by review of the history, and none required any treatment other than that given for the femoral neck. Thus, from a practical point of view, treatment is not altered by multiple positive scintigraphic findings in the patient with a femoral neck stress fracture, who has no symptoms or signs of injury elsewhere.

The major importance of bone scintigraphy is that this test gives early confirmation of clinically suspected femoral neck stress fractures. Previous reports have documented positive bone scintigraphy as early as 6 days after the onset of symptoms.[22] In the present series, scintigraphy was positive as early as 10 days after the onset of symptoms (serial radiographs confirmed this diagnosis).

Although bone scintigraphy is a relatively expensive test, it is not as costly as a displaced femoral neck fracture would be in terms of money or disability. Examples of potential problems are documented by Kaltsas[15] in his paper that described several complications in femoral neck fracture patients. In the present study, when plain radiographs were normal, bone scintigraphy was done early when diagnosis

was important in terms of job, environment, or athletic participation. Because most of the patients had a strong desire to continue their activity, and because most lived in a barracks environment, early scintigraphy was performed routinely.

TREATMENT OF UNDISPLACED FEMORAL NECK STRESS FRACTURES

The general plan of treatment followed in this study is summarized in Table 3. A more detailed description of that treatment is now given.

COMPRESSION-SIDE SCLEROSIS OR POSITIVE COMPRESSION-SIDE SCINTIGRAPHY WITHOUT OVERT FRACTURE LINE

Once the diagnosis of a fracture has been made, the patient can be placed on bed rest until there is no hip pain at rest. He then advances, as symptoms decrease, from partial to full weightbearing on crutches. Once he is free of pain with full weightbearing on crutches, he progresses to a cane and then to walking without support. During the period of cane use, the patient may resume cardiovascular conditioning by swimming or bike riding.

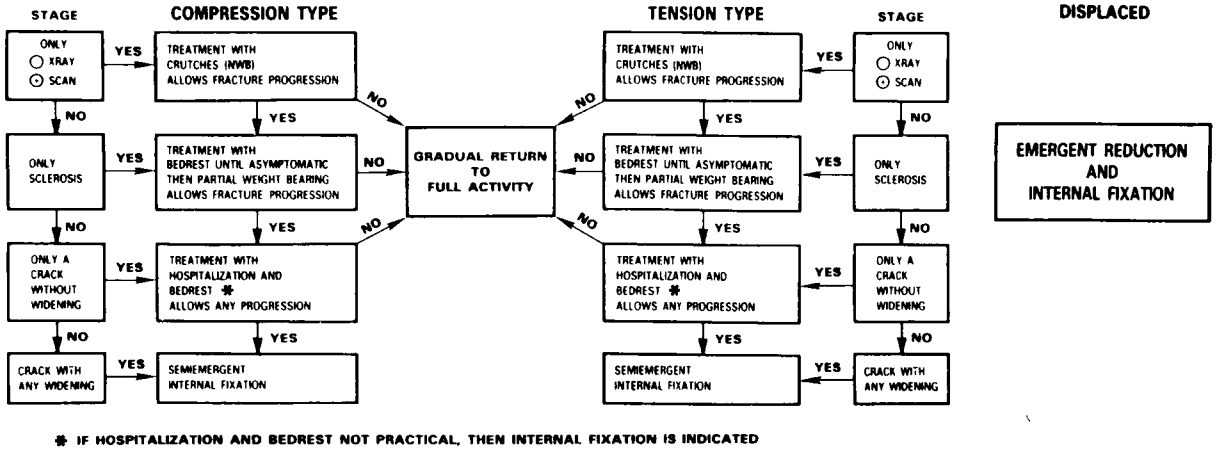
Serial radiographs are taken at weekly intervals until the patient advances to a cane. When the patient is asymptomatic while walking without support during daily activities, he is instructed to increase walking in ¼ mile increments. Once able to walk each increment without limp or pain, he is allowed to add another ¼ of a mile. After walking at least 1 mile without limp or pain, the patient advances to running. Again, the patient begins with a short run, usually starting with one block or ¼ of a mile, depending on the patient. He advances by increasing the distance run as described above for the walking program. If at any stage the patient has pain or develops a limp, he is instructed to rest for 2 days and to begin again at the distance he was able to walk or run without problems. After running 1 mile without hip pain, a final radiograph is taken. If it shows a healed fracture, the asymptomatic patient is allowed to return to his previous level of activity.

OVERT COMPRESSION FRACTURE LINE

The fractures in this category may be either a crack through one cortex or sclerosis through the entire femoral neck, as shown previously in Figures 6 and 7. The patient is immediately placed on complete bed rest. Serial radiographs are taken every 2 to 3 days for the 1st week. If there is any evidence of disruption of both cortices, of any fracture widening, or if bed rest is not feasible, the hip is stabilized with multiple Knowles pins on a semiemergency basis. If there is no displacement of the fracture, the patient is kept on bed rest until the hip is free of pain through an active range of motion. At this point, the patient is allowed partial weightbearing on crutches. He advances through the walking program described above for compression fractures without cortical disruption.

If a patient requires Knowles pin fixation, then he begins an early rehabilitation program. The 1st postoperative day, the patient is allowed up, nonweightbearing, on crutches. He progresses as described above. After 6 months, the fixation pins are removed. The patient is restricted for 3 months after pin removal; that is, during this interval, he is allowed to run but not to participate in contact sports. In addition, during this time no activities in which the patient cannot control his own environment, such as parachuting, intensive athletic or military training, or military basic training, are permitted.

TABLE 3
Femoral neck stress fracture treatment algorithm



* IF HOSPITALIZATION AND BEDREST NOT PRACTICAL, THEN INTERNAL FIXATION IS INDICATED

TENSION-SIDE SCLEROSIS OR POSITIVE TENSION-SIDE SCINTIGRAPHY WITHOUT OVERT FRACTURE

The patient is placed on crutches or bed rest depending on the severity of symptoms. Serial radiographs are taken. If there is any evidence of a fracture line developing in the cortex during treatment, the patient is treated by internal fixation as described below. If there is no evidence of cortical disruption, then once the patient has pain-free active hip range of motion, he is rehabilitated as previously described.

TENSION-SIDE CORTICAL BREAK WITHOUT DISPLACEMENT

Most authorities report that a stress fracture on the tension side of the femoral neck is of great concern. Many reports state that this type of fracture may rapidly progress to a complete, displaced femoral neck fracture.[11] None of the major studies, however, document this progression in a patient diagnosed with a tension-side stress fracture and placed on bed rest.[4,7,9] Likewise, a review of the literature has not shown a documented progression to displacement in a treatment setting such as we have developed. However, the biomechanical forces on the tension side of the femoral neck are conducive to progression and displacement of a fracture in this area.[3] Consequently, a patient is treated with great caution. Once the diagnosis has been made, the patient is taken to the ward by litter and kept on complete bed rest. Daily radiographs are taken until the patient has no hip pain on active range of motion. He is then allowed up with partial weightbearing on crutches. Weightbearing activity progresses as in the treatment of compression fractures. *If there is any widening of the cortical break at all while the patient is on bed rest, if bed rest is not practical, or if compliance is questionable, then internal fixation on a semiemergency basis with multiple Knowles pins is performed.*

TENSION-SIDE STRESS FRACTURES WITH ANY OPENING OF THE FRACTURE

Any opening or displacement of a tension-side fracture is felt to be of great significance, as demonstrated by Figure 3. This fracture is considered an emergency because of the biomechanical forces on the area. Reduction is not usually required. Fixation surgery is performed on the fracture table for control of the limb and to facilitate use of the image intensifier. Because of the forces on this fracture and because some of the younger athletic patients in our study were found to be unreliable in following the limited progressive weightbearing plan, a more substantial fixation than multiple Knowles pins evolved. Two Knowles pins are inserted into the superior half of the femoral neck and head. A compression screw is then inserted parallel to these pins in the standard manner (Fig. 9). Postoperatively, once the patient has full, pain-free active range of motion, he begins partial weightbearing on crutches. The standard progression

Figure 9. Technique of fixing a displaced femoral neck stress fracture using a compression screw and Knowles type pins.

to full activity is followed. The fixation devices are removed after 1 year. (We have removed the devices as early as 6 months if the fracture was nondisplaced, if the patient was asymptomatic, and if healing was confirmed by radiographs.) Following another progressive rehabilitation period, the patient is allowed to return to full activity.

DISPLACED FEMORAL NECK STRESS FRACTURES

This is an orthopaedic emergency. Early, accurate reduction and internal fixation are essential. The technique of combining two Knowles pins and a compression screw in the superior half of the femoral neck is used to prevent rotation and to increase fixation. Postoperatively, a patient is kept on bed rest until he has no pain on active hip range of motion. He is kept nonweightbearing for the first 6 weeks. Progressive weightbearing on crutches is permitted over the next 6 weeks. At this point, the standard progressive activity program previously described is followed. The fixation devices are removed between 12 and 18 months postopera-

tively. After radiographic and scintigraphic confirmation of healing without the complications of avascular necrosis or other femoral head-neck deformity, return to full activity is allowed.

RESULTS

During the period from July 1979 through July 1983, a total of 54 femoral neck stress fractures were diagnosed and treated. Femoral neck stress fractures comprised 5% (54/1,049) of the total number of stress fractures of all bones diagnosed during this period (Fig. 10).The population during the study consisted of approximately 330,000 young adults. Most of the group were soldiers ranging in age from 17 to 55. All of the patients were within the Army criteria for weight and height standards. The average infantry soldier marched 207 miles and ran 211 miles during the study. As part of organized training during this 4 year period, this group collectively marched over 36 million miles and ran over 40 million miles.

Forty percent of the femoral neck fracture symptoms began between the 6th and 8th weeks of a more vigorous program than had been followed or after a change in type of training. (Exact week of onset was not documented in seven patients.) The range was from 2 days to 14 weeks after an identifiable increase in distance or pattern of running or marching.

Three women in our study sustained this type of fracture. No conclusion about incidence of femoral neck stress fractures among women can be drawn from this, however, because of the small number in our study. The only women involved in training at Fort Benning were those in Airborne training (approximately 600 per year) and those in Officers Candidate School (approximately 150 per year).

The pattern of diagnosis of femoral neck stress fractures ranged from negative radiographs with positive bone scintigraphy to displacement. Of the nine fractures treated operatively, three were displaced and six met the criteria for internal fixation.

In contrast to other series, there was greater racial diversity in our patients. Forty-two (85.7%) were white. There were also, however, three black (6.1%) and four Hispanic (8.2%) patients.

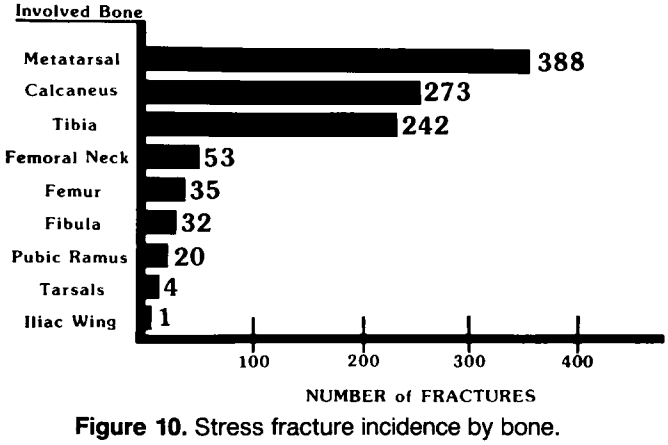


Figure 10. Stress fracture incidence by bone.

There were 43 (80%) compression fractures, 8 (15%) tension fractures, and 3 (5%) completely displaced fractures. All three completely displaced fractures were treated surgically. In the group without complete displacement, 2 of the 43 compression and 4 of the 8 tension fractures were internally fixed following the treatment guidelines described previously.

Because of varying reports on the treatment of femoral neck stress fractures that present without displacement, particular attention was directed to those fractures in this series.[2,15] Of the 44 hips that had sclerosis or an undisplaced unicortical crack at the time of initial diagnosis and at the start of orthopaedic treatment, none subsequently required surgery. No tension or compression femoral neck stress fractures widened or displaced during nonoperative treatment. None of these patients required narcotic analgesics, skeletal traction, or internal fixation for pain relief.

One of the displaced fractures occurred during a march, one during a run, and one when the patient slipped and fell while walking. No one displaced while on bed rest or on protected ambulation.

There were no patients with open capital femoral epiphyses. Four of five bilateral femoral neck stress fractures were symptomatic on both sides. Thirty-two patients were admitted for suspected femoral neck stress fractures that were subsequently proven by serial radiographs and bone scintigraphy not to be such fractures. Five of the 32 patients had subsequent diagnoses of stress fractures of other bones (2 tibial and 3 femoral shaft locations).

COMPLICATIONS

There were no complications in terms of severe or prolonged pain or displacement in those patients treated nonoperatively.

One patient with a tension stress fracture had approximately 2 mm of widening of his fracture during surgery. This occurred after the first Knowles pin had been inserted. Intraoperative lateral radiographs revealed that the pin had exited the back of the femoral neck. The anteroposterior view showed the widening of the preoperative 1 mm opening. No reduction was felt to be indicated. The first pin was removed, and three Knowles pins were then inserted in satisfactory positions. (This was the first tension fracture internally fixed in this series. The compression screw was added in all other tension fracture fixations. It was added because, if a patient became free of pain while on crutches and walked without them, the three pins would not hold.) Postoperatively, this patient healed and returned to normal activity.

Finally, one patient sustained a displaced fracture after 2 miles of an Airborne training run and had symptomatic delayed union at 5 months after the initial surgery. A Meyers' muscle pedicle graft was performed at the second surgery.[18] The fracture healed, the Knowles pins inserted ini-

tially were removed, and the patient returned to normal activity at 39 months postinjury. There were no cases of avascular necrosis or malunion among our patients.

DISCUSSION

The authors who have reported on large series of femoral neck stress fractures differentiate between those fractures occurring in the presence of disuse osteoporosis and those in the active athletic patient. The active young adults in this series all fit into the category of patients injured in the face of significant physical activity.

Throughout diagnosis and treatment, the serious potential consequences of a displaced fracture of the femoral neck in the young adult must be remembered. The incidence of avascular necrosis, nonunion, and varus deformity is high should displacement occur.[6] Prevention of these problems is the goal of early diagnosis and careful management as described in this series. Where problems of noncompliance are involved, consideration for early surgical management has been recommended.[21] Clearly, the treatment scheme chosen is based on the dependability of the patient and his ability to control his environment. Where patient compliance or other considerations make bed rest unreasonable, then the more conservative treatment is internal fixation. All of the patients in this study were initially hospitalized. Initial inpatient care was felt to be important in this setting because of the potential problems of displacement, the need to protect the patients from the demands of military training, and the desire to observe the effectiveness of treatment. A treatment algorithm was developed that indicates stages of treatment (Table 3).

There is a common set of theories that explain why and how the femoral neck (as well as other bones) develops this stress-induced injury.[1,5,11,23,24] Loss of the normal shock absorber effect of muscles when they become fatigued is a logical factor.[4] The increased incidence of stress fractures in highly motivated soldiers and in long-distance runners supports this theory.[14,16] Moreover, in this study, the overall incidence of stress fractures in those runners who cannot control their environment, e.g., training soldiers, makes muscle fatigue a significant associated finding. A second common factor in femoral neck stress fractures is high stress repetition.[10,11] However, the reasons for 54 femoral neck stress fractures compared to 903 stress fractures of the metatarsals, calcanei, and tibiae, and 92 to other bones, documented during the period of our study at Fort Benning, are not clear.

Laboratory studies lend some information about the causes of femoral neck stress fractures. At the same time, these studies post new problems. Belding[2] noted in a study at the Campbell Clinic that in skeletized cadaver femurs, experimenters were unable to reproduce a compression-side stress fracture solely by the application of force to the femoral head. They were, however, able to produce transverse fractures that failed on the tension side with cyclic loading. Static loading in that study caused fractures that were described as starting in tension but progressing to acute fracture in shear.

In another clinical and biomechanical study, the sequence of muscle fatigue, compensatory altered gait, abnormal gait patterns, and, finally, changes in stress application, was felt to be a common causative pattern.[1] The authors concluded that this pattern, repeated over time, could result in "human wreckage" comparable to that in cars and planes caused by metal fatigue. If overuse leads only to microdamage (compression loading and shear fatigue), it can provide the stimulus to new bone growth that will increase bone strength. If, however, overuse leads to extreme muscle fatigue, the result is high tension loading, transverse fracture, and displacement.

Because of the potential for disastrous consequences of displaced femoral neck fractures, a complete evaluation, often including bone scintigraphy, is indicated in the running patient. This is particularly important in those patients who are highly motivated by training goals or coaches, or who are in situations such as a military training course. It is also important to realize that susceptibility to femoral neck stress fractures is not limited to whites. Although only one previous report of a nonwhite femoral neck stress fracture was found, seven were diagnosed in black and Hispanic patients in our series.

In addition, the prospective analysis of four undisplaced tension fractures showed that none displaced with strict inpatient nonoperative treatment. This is an important observation, because previous major series have indicated that tension or transverse fractures have a tendency to displace and should be internally fixed even if there is no displacement at diagnosis. Although such suggestions concerning the tendency to displace are supported by Koch's classic free body analysis (discussed in Black[3]) of the normal femur that shows maximum tensile stress near the midpoint of the tension side of the femoral neck, no documented case of progression of this type of fracture while under orthopaedic care on bed rest could be found.[3] Thus, a patient with a tension femoral neck stress fracture without displacement may reasonably be treated initially by bed rest as an alternative to immediate surgery. Operative intervention in an athletic patient would be indicated if serial radiographs showed any displacement of if bed rest was not practical. The decision of how to treat those patients who present with an undisplaced cortical crack on the compression or tension side is most difficult. In our series, if the patient's symptoms had already begun to subside by the time the diagnosis was made (four of nine patients), then bed rest was used. If the symptoms were of acute onset (five of nine patients), then surgery was performed (one compression and four tension fractures).

As a final point, the applicability of these findings to the general population is of interest. It would seem that similar results could be expected in any individual who participated in intensive athletic training. The factors that should alert the physician to the diagnosis are hip or groin pain in a patient who is subjected to repetitive loading of the femoral

neck in a situation were exercise to the point of muscle fatigue is common.

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