DIABETIC AND DIABETIC CHARCOT FOOT RECONSTRUCTION

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In the past five years our thoughts regarding the diabetic foot have changed more than those on any other aspect of foot care. Many misconceptions have been dispelled and the overall understanding of the various facets of neuropathy have improved. We feel that the members of the Institute are prepared to make a genuine impact in the preservation of diabetic limbs. The purpose of this paper is to present the latest in the efforts of reconstructive surgery for the diabetic and diabetic charcot foot. Reconstruction is a viable form of limb salvage in these individuals. Indeed, many of the patients who have undertaken such surgery have been advised elsewhere as to the benefits of below knee amputation.

Rationale for Reconstruction

As mentioned above, the choice that we face is most often amputate or reconstruct. In others cases where collapse is not as advanced, the future is equally bleak if left as is. Statistics have shown that once a diabetic loses a limb that the outlook for the other leg, and the overall condition of the patient is not optimistic (1-3). Surgery in the neuropathic foot is not a new concept. Over 20 years ago both Johnson, Harris and Brand mentioned the need for surgical intervention in such limbs to arrest further breakdown and deformity (4,5).

One might argue that these doctors worked with nondiabetic populations: Brand's early experience appears to have been primarily involved with Hansen's disease, while Johnson was more frequently working with diabetics. In fact Johnson went so far as to suggest that such surgery probably could not be performed on diabetics based on vascular considerations. Unfortunately, diabetes has become synonymous in many circles with vascular disease. Many physicians fall into the trap of this inaccurate summation: diabetics are predisposed to develop certain forms of vascular disease, therefore, all diabetics have poor circulation. The truth is far removed from this philosophy.

Vascular Supply

The fact that diabetes is a risk factor for large and medium vessel disease is known and accepted. However, the assumption that diabetics suffer from peripheral microangiopathy has yet to be objectively demonstrated. LoGerfo and Coffman state that there is no evidence that diabetic patients are more predisposed to occlusive microvascular disease compared to nondiabetics (6). They indicate that the theory of microvascular disease of the lower extremity in diabetics has been propagated and ingrained in many health care practitioners and that many diabetics may be subjected to inadequate foot care due to this misconception. Practically stated, diabetics may not be given appropriate opportunity to heal lesions or injuries because they are not expected to be able to heal.

Although the work of LoGerfo and Coffman was published in 1984, it apparently has been largely ignored in many areas. The current authors wholeheartedly concur with LoGerfo and Coffman and the experience of those at the Institute confirms that position. Although a small number of patients have lost limbs to amputation due to non-bypassable large vessel occlusion, those patients without proximal blockage have all healed. Additionally, if small vessel disease were prevalent, bypass surgery would fail to perfuse the most distal segments of the limb. Once again, this has not been our experience.

The Charcot foot is an example wherein the theory of microvascular compromise is grossly errant. In fact, we have found that the Charcot foot only develops in the presence of good circulation. While sensory neuropathy is typically quite apparent in these patients, many have overlooked the importance of autonomic neuropathy in the diabetic lower extremity. It has been estimated that in diabetic patients with symmetrical peripheral neuropathy that 70% suffer from a mixed involvement of sensory, motor, and autonomic fibers (7).

Autonomic (sympathetic) nerves supply the small blood vessels, sweat glands, and arrector pilaris muscles of the lower extremity. Once this autosympathectomy is established a warm, well perfused foot is present. One should not be misled by the dry skin or the potential lack of digital hair, as such is representative of neuropathy. Clinical and experimental studies have shown that the presence of this type neuropathy results in an

enhanced perfusion of the lower limb. A complete discussion of this topic has been provided in another paper within this text. The basic point is that any patient who possesses autonomic neuropathy will present with more than adequate circulation to undergo surgery and heal (provided substantial proximal disease is absent).

Healing Considerations

In addition to concerns over blood supply many have questions with regard to the healing capacity of diabetics. Two papers have been published which note that diabetics take 1 1/2 times longer than nondiabetics to heal similar fractures (8,9). Harris and Brand recommended immobilizing neuropathic limbs postoperatively 1 1/2 times the usual interval following arthrodesis.

It has been the authors' experience, as well as others at the Institute, that the Charcot patients who have undergone reconstruction heal in 2/3—3/4 the time needed for nondiabetics undergoing similar procedures. Incision lines coapt in a rapid manner and edema is neither as extensive nor persistent.

The authors herein provide several cases which are representative of the types of pathology seen at the Institute.

NIDDM Male With Iatrogenic Forefoot Derangement

R.S.C. is a 58 year old non-insulin dependent diabetic male. He was referred to the Podiatry Institute (Drs. Andy Peterson and William Kennedy, Sarasota, FL) after having undergone earlier surgery by another local physician. He complained of multiple forefoot deformities and that "the feet have collapsed since the earlier surgery"

By history the earlier surgery had involved:

hallux valgus repair, bilaterally
base wedge osteotomy first metatarsal, bilaterally
opening first cuneiform osteotomy right
arthrodesis of proximal interphalangeal joints
second, third, fourth toes, bilaterally

Clinical Findings

Clinical and radiographic examination confirmed extensive forefoot deformities with all previous procedures having failed (Fig. 1 A & B) . Findings included:

dislocated left first metatarsophalangeal joint
with staked metatarsal

A

Fig. 1A. Dorsoplantar radiograph of left foot showing iatrogenic forefoot deformities including marked narrowing of lesser metatarsophalangeal joint spaces.

B

Fig. 1B. Radiograph showing iatrogenic deformities of right foot. Cuneometatarsal joint collapsed after attempt at opening wedge osteotomy of cuneiform.

C

Fig. 1C. Incisional planning provides long incision access to first and fifth rays. Notice that intervening incisions are largely on toes and extend only to level of metatarsal necks. This avoids long peninsulas of tissue which can easily compromise blood supply.

D

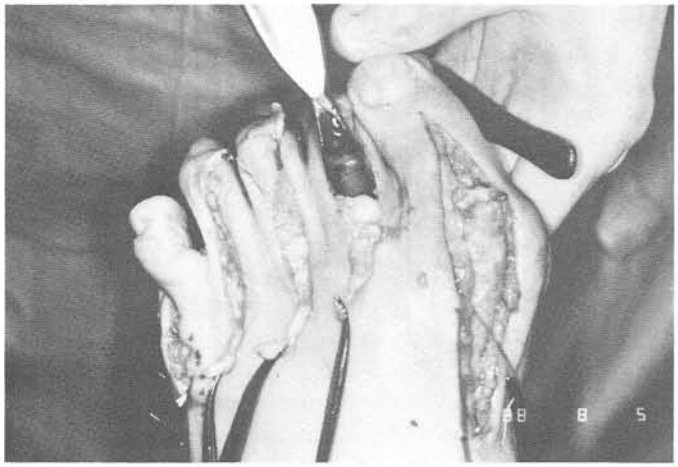


Fig. 1D. All five rays are exposed at same time. This provides for more accurate judgement in resecting correct amount of bone from each metatarsal.

metatarsus primus adductus/elevatus left
rigid hammertoes 2-5, left
severe metatarsophalangeal joint limitus 2-4 left
plantar protrusion metatarsals 2-4 left
angular deformity first metatarsal with elevatus, right
collapsed first cuneiform osteotomy, right
rigid hammertoes 2-5, right, with severe contractures
unstable first cuneiform-metatarsal joint, right
lesser metatarsophalangeal joint limitus, right

Further medical findings included the presence of mixed neuropathy involving both feet. Sensory neuropathy was mild as was motor neuropathy. Autonomic neuropathy was moderate.

Circulatory evaluation demonstrated four plus dorsalis pedis and posterior tibial pulses bilaterally. Capillary rebound was instantaneous. The skin was quite warm to touch; though rather dry as is most often true with the presence of autonomic neuropathy.

A mild equinus was identified bilaterally; though not so severe as to require surgical attention.

Surgical Plan

Because of the extensive nature of the reconstructive surgery planned it was judged necessary to have the patient non weightbearing during convalescence. And since the left foot was the more painful of the two, surgery was performed on that foot first. Surgical procedures included:

pan metatarsal head resection
hinge implant arthroplasty first metatarsophalangeal joint
plantarflexory/abductory osteotomy first metatarsal base
digital stabilization arthrodesis 2-4 toes (peg-in-hole) with Kirschner wire fixation
arthroplasty and Kirschner wire fixation fifth toe

Surgery was carried out through five parallel longitudinal incisions (Fig 1C). The first incision is the full length of the first ray, providing access to the first metatarsophalangeal joint as well as the base of the metatarsal (Fig. 1D). The digital incisions are placed midline between the medial and lateral blood supply to the toe. These extend just far enough proximally to provide access to the metatarsal heads. By limiting the proximal extent of the four lateral incisions one avoids long peninsulas of tissue which could be subject to compromised blood supply.

Since the first metatarsal head had been previously staked this sets the pattern for the amount of resection required. The first metatarsal head and base of the proximal phalanx are resected initially (Fig. 1E). The other metatarsal heads are then resected at appropriate lengths relative to the first. In agreement with the recommendations of Gerbert and Dobbs the second metatarsal remains the longest (10). The first metatarsal is the second longest and the third, fourth, and fifth in descending lengths. This is done to insure that all five metatarsals will bear approximately equal weight.

The closing base wedge osteotomy is oriented so as to result in both abduction and plantarflexion of the first ray (Fig. 1F). A Dow Corning flexible hinge implant is then seated in the first metatarsophalangeal joint (Fig. 1G). Arthrodesis of the second, third, and fourth toes is performed to provide a stable lever arm on which the flexors can

E

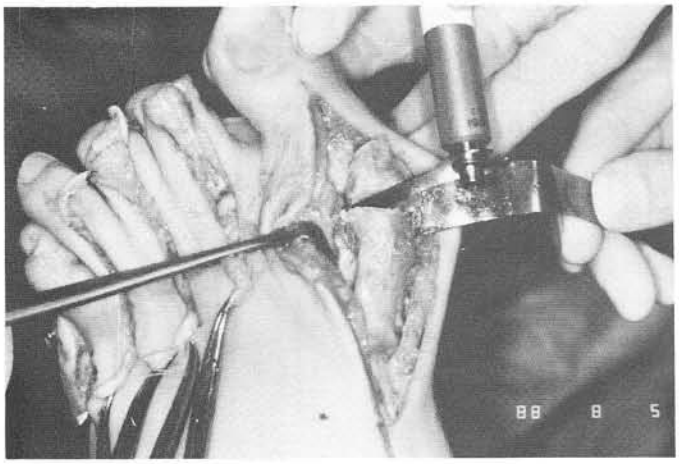


Fig. 1E. The first metatarsal head has been previously staked. Amount of bone resection necessary at first head will set pattern of resection for each of the other four heads.

F

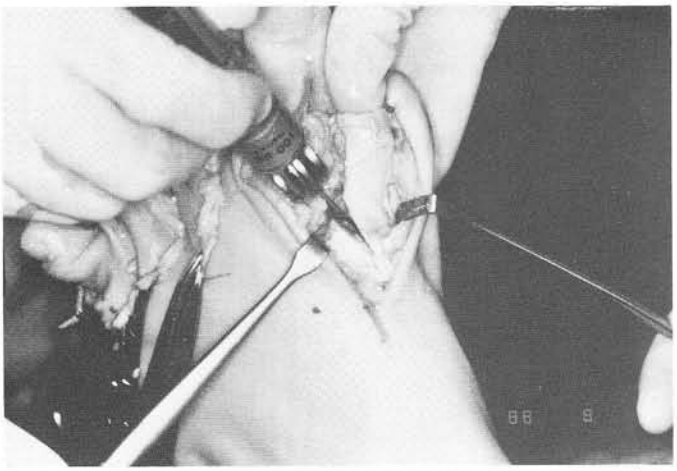


Fig. 1F. A closing base wedge osteotomy is placed so as to result in abduction and plantarflexion of first metatarsal bone.

G

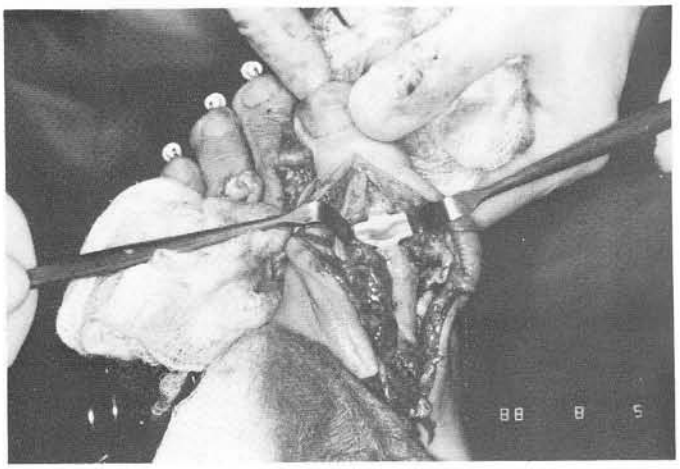


Fig. 1G. A total first metatarsophalangeal joint hinge implant sizer is used to check alignment and range of motion of joint.

H

Fig. 1H. Kirschner wires extend across metatarsophalangeal joints, but an attempt is made to maintain space at joint. The space fills with fibrous tissue providing a suitable hinge for metatarsophalangeal joints.

function to assist in maintaining metatarsophalangeal joint stability. The Kirschner wires that fixate the peg-in-hole arthrodeses of the toes extend across the metatarsophalangeal joints (Fig. 1H). An attempt is made to maintain some space at the metatarsophalangeal joint which fills with fibrous tissue and serves as an excellent hinge. If no space is maintained then limitation of motion may result.

Post Operative Care

rest and elevation 3 days
redressed post operative day 3
bivalved cast applied/ instructed in multiple daily removal of cast and ankle exercise
Kirschner wire removal at 8 weeks
fitted with new orthotic device 8 weeks
elastic support of foot and return to shoe and weightbearing 8 weeks
range of motion exercises of metatarsophalangeal joints for two additional months
orthodigital retainer for two months after removal of Kirschner wires.

Discussion

The patient's postoperative course was unremarkable. He is most cooperative and has done well throughout his surgery and convalescence. He is currently awaiting surgery on the opposite foot.

Examination of the foot at the three day redressing demonstrates the speed with which healing occurs (Fig. 1I). Minimal edema and no erythema is seen and the skin incisions show the strength that might be expected at 7-10 days. This finding is characteristic of diabetic patients in whom autonomic neuropathy has caused loss of

vasomotor tone. This same autonomic dysfunction usually produces very dry skin which may require special attention to prevent fissures or bandage irritation.

At four weeks following surgery radiographs demonstrate excellent progress of bony healing (Fig. 1J). The twelve week view shows solid union with very satisfactory functional alignment (Fig. 1K).

NIDDM 40 Year Old Male Charcot Collapse Hallux I-P Joint

D.R. a 40 year old male was referred to the Podiatry Institute in December 1986 after having been repeatedly hospitalized for presumed osteomyelitis and ulceration at plantar aspect of the hallux interphalangeal joint (Fig. 2 A & B). The patient had undergone multiple deep debridements of the area under anesthesia. He had also completed 6 weeks of I.V. antibiotics. The wound though refusing to heal cultured no organisms and showed no clinical evidence of infection. Furthermore, pathology reports failed to confirm the presence of osteomyelitis.

By history the patient had:

- plantar ulceration with infection at interphalangeal joint
- developed osteomyelitis (clinical diagnosis only)
- was hospitalized for I.V. antibiotics and multiple debridements of bone and soft tissue
- was allowed to bear weight throughout hospitalization
- ulcer failed to heal

Clinical Findings

Clinical examination demonstrated a deep 1 cm diameter ulceration beneath the interphalangeal joint of the hallux. Range of motion examination showed a completely unstable interphalangeal joint. On weightbearing the distal phalanx cocked up and the proximal phalanx plantarflexed compressing the ulcer area with its end. Mild mixed neuropathy was present and both feet were quite warm to touch. Capillary rebound was instantaneous and pulses were bilaterally excellent and equal.

The patient was placed on total non weightbearing for 10 days and the ulcer healed completely.

Surgical Plan

It was believed that the instability of the hallux interphalangeal joint allowed the flexor hallucis brevis an unreasonable mechanical advantage in flexing the hallux.

I

Fig. 1I. Examination of foot at three days postoperatively illustrates relatively mild swelling and absence of erythema. This is quite a usual observation in patients with autonomic neuropathy.

J

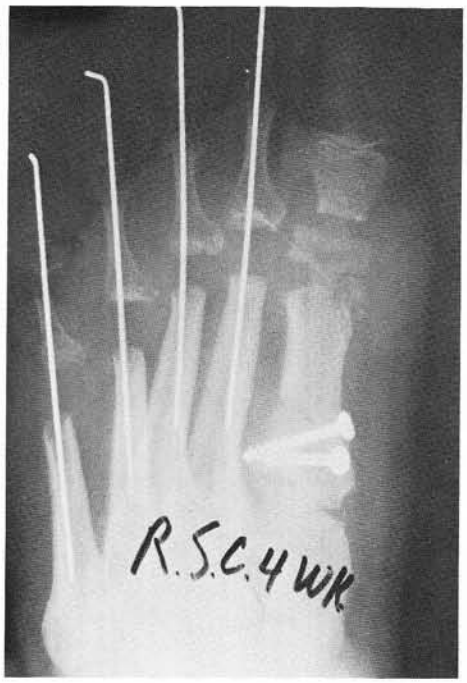


Fig. 1J. Four week follow-up x-ray illustrates excellent progress of bony healing with good maintenance of lesser metatarsophalangeal joint space.

The surgical plan, therefore, involved:

- arthrodesis of the hallux with rigid internal fixation
- external splinting and bandaging for 6 weeks
- appropriate shoe prescription at 6 weeks
- accommodative orthotic device at 6 weeks

It was felt that with stabilization of the hallux interphalangeal joint the inordinate pressure at the distal end of the proximal phalanx would be eliminated. The metatarsophalangeal joint motion was fully adequate, rul-

Fig. 1K. Twelve week view shows solid bony union and very satisfactory functional alignment.

Fig. 2A. Dorsoplantar radiograph of diabetic Charcot joint at left hallux interphalangeal joint. This is a fairly common Charcot joint collapse in diabetic with autonomic neuropathy. It is difficult to distinguish from osteomyelitis and often becomes complicated with bony infection.

ing out hallux limitus as a cause of the excessive plantar pressure.

Discussion

The surgical wound healed quite rapidly and without complication (Fig. 2C). Return to an accommodative orthotic device and appropriate shoes provided excellent weight distribution. At 9 months post surgery the patient was without complaint and without plantar excrescence (Fig. 2D). After a year and a half he continues doing well.

Fig. 2B. Oblique view of joint. Appearance is no longer characteristic in appearance because of previous surgical debridement.

Forefoot Derangement and Charcot Foot

M.B. a 43 year old insulin dependent diabetic female for 27 years was referred to the Podiatry Institute (by Dr. David Buchan, Columbus, Ohio) for management of a deranged left foot.

The patient complained of multiple painful foot deformities primarily involving the left foot of many years duration. The symptoms had become especially severe in the past 2-3 years. She also indicated that her shoes had started to run over badly in the past 4-6 weeks.

Prior treatment of the left foot included amputation of the second toe as a result of recurring dorsal ulceration secondary to shoe irritation.

C

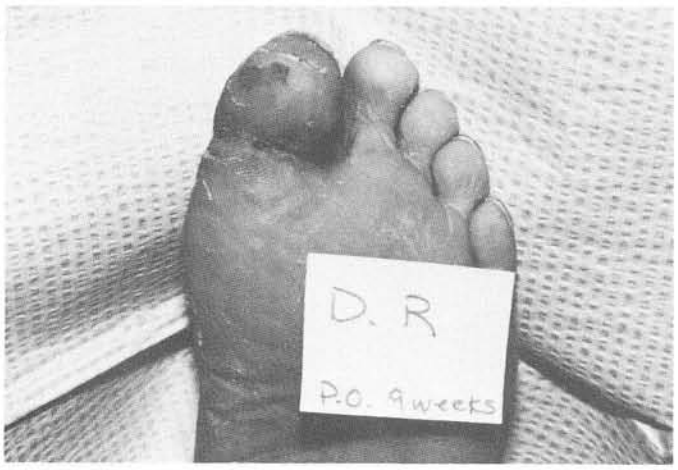


Fig. 2C. Appearance of toe with healed plantar lesion nine weeks after arthrodesis of joint.

Clinical Findings

Clinical examination showed the presence of a severely deranged left forefoot and midfoot (Fig. 3 A-C). The right foot showed only deformity of the hallux and hammertoe deformity of the fourth and fifth toes (Fig. 3D). Clinical and radiographic findings on the left foot included the following:

- severe hallux abducto valgus, left
- metatatarsus primus adductus/elevatus, left
- Charcot joint left second cuneometatarsal joint
- instability first ray, left
- status post amputation left second toe
- Charcot third and fourth metatarsophalangeal joints, left
- hammertoes 3-5, left
- pes valgus deformity, left foot only

Neurovascular examination demonstrated excellent circulation with both the dorsalis pedis and posterior tibial pulses being patent and with instantaneous capillary rebound. The skin was dry and scaly. Moderate sensory neuropathy was present bilaterally, and some evidence of motor neuropathy could be detected. Definite evidence of autonomic neuropathy was present and equal in the two feet.

The clinical impression was that of a left foot which undoubtedly had previous forefoot deformity and with advancing neuropathy underwent partial Charcot collapse of the first and second ray. Our recommendation was for surgical reconstruction of the left foot. The patient was made aware of particular vulnerability of the contralateral foot to collapse during convalescence from surgery and was advised as to appropriate protective mechanisms during convalescence from the planned corrections.

D

Fig. 2D. Radiograph at nine months after surgery shows solid bony union.

Surgical Plan

It was obvious that stability of the left foot would be dependent on return of integrity to LisFranc's joint as well as restoration of even weightbearing to the five metatarsals. The surgical plan therefore included:

- forefoot reconstruction approached through five longitudinally placed incisions arranged so as to minimize long peninsulas of tissue (Fig. 3E)
- stabilization arthrodesis first and second cuneometatarsal joints
- pan metatarsal head resections left foot (Fig. 3 F & G)
- hinge implant arthroplasty first metatarsophalangeal joint
- stabilization arthrodesis 3-4 toes, left, with Kirschner wire fixation
- arthroplasty fifth toe, left, with Kirschner wire fixation

The intent of the foregoing procedures was to return relative stability to the foot regardless of whether additional motor neuropathy might occur.

Post Operative Care

Post operative plans were designed to allow for thorough consolidation of the arthrodeses before allowing weightbearing. Additionally, the other foot required special protection during the period of non weightbearing on the left foot. Aftercare plans included:

Fig. 3A, B, C. Clinical and radiographic demonstration of deranged left forefoot from which second toe has been previously removed. Note Charcot metatarsophalangeal joints left third and fourth. Also left first and second cuneometatarsal joints demonstrate evidence of Charcot joint changes along with clinical instability.

Fig. 3D. Right foot shows Charcot joint deformity of right hallux interphalangeal joint and hammertoe deformity of fourth and fifth toes.

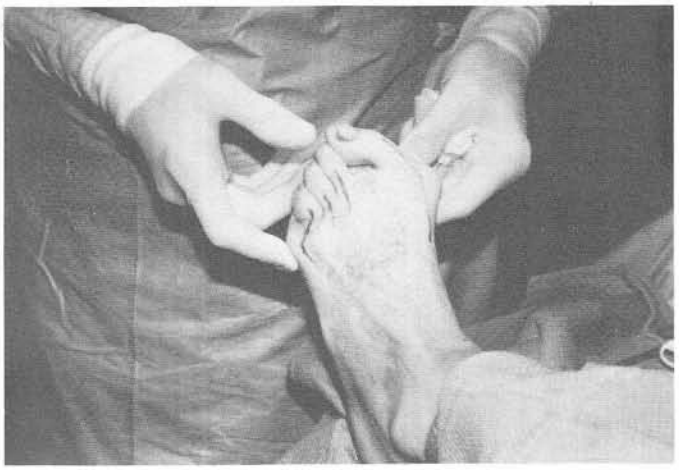
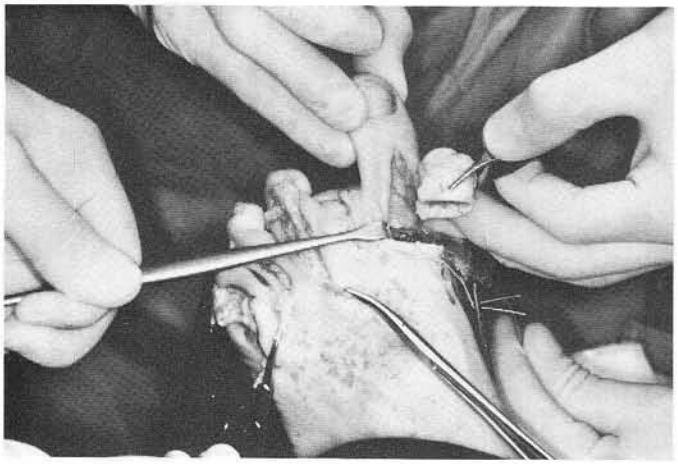


Fig. 3E. Except for incisions over first and fifth rays, longitudinal incisions were kept as much distal as possible to avoid long peninsulas of tissue which could compromise circulation.

three months of non weightbearing
Kirschner wires to remain for 6-8 weeks
ankle range of motion exercise against no resistance multiple times daily
sterile bandage till Kirschner wires removed
soaking and increased range of motion exercise of ankle and metatarsophalangeal joints after Kirschner wire removal, exercise against no resistance
elastic bandage to replace sterile bandage once Kirschner wires removed
prescription shoe with accommodative full length orthotic device on return to weightbearing

F



G

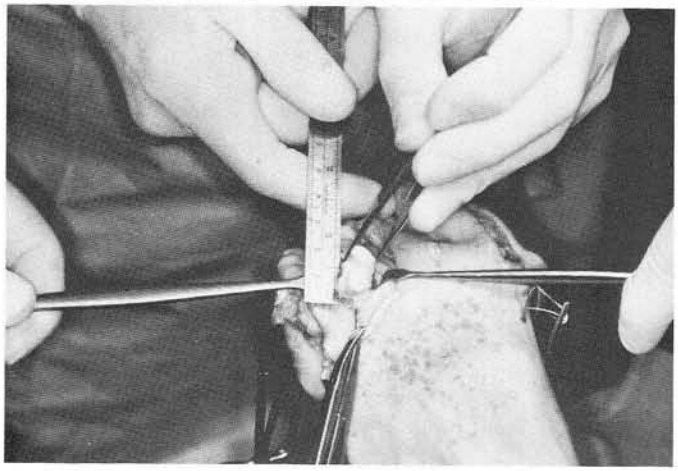
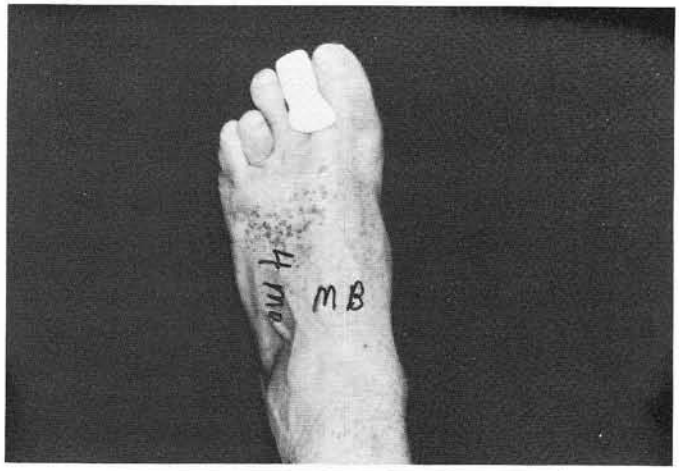


Fig. 3F.& G. Measured amounts of bone are resected from five metatarsal heads. The planned length pattern leaves second longest followed by first, third, fourth, and then fifth. This normally provides most even weight distribution.

H

Fig. 3H. Four days following surgery little edema and no erythema is evident despite rather extensive surgery to forefoot.

I



J

Fig. 3I & J. Clinical and radiographic views of left foot at four months following surgery.

cane or single crutch for first two weeks resumption of weightbearing
prosthetic silicone toe spacer to replace missing second toe, left
full length orthotic accommodation of contralateral foot during convalescence

The patient's postoperative convalescence was uncomplicated. A view of the foot at four days following surgery shows the rather minimal amount of post surgical swelling and inflammation so characteristic in patients with autonomic neuropathy (Fig. 3H). Reexamination at 4 months post surgery showed all surgical sites well healed and alignment and stability satisfactory (Fig. 3 I & J). The left fourth toe showed mild floating toe syndrome indicating probability of weak flexor plate function. This later condition could lead to a progressive dorsal contraction of the toe and further surgery may be required to halt the dorsal float of the fourth toe.

Discussion

Considering the rather extensive forefoot and midfoot surgery involved the rather limited amount of edema and the absence of erythema present at four days post surgery is again impressive. Incisional strength could very well be judged as equal to that normally seen at 7-10 days.

While bone and soft tissue healing tends to occur more rapidly in patients with autonomic neuropathy than in the normal patient one should be aware of the vulnerability that the neuropathy provides. The increased circulation which provides for rapid healing also washes out bone mineral and provides for weakening of the osseous structures that exposes the patient to risk for other fractures or fracture-dislocations. Appropriate care, therefore, provides for gradual return to function with due protection of both feet. Indeed, the most common complication we have seen is collapse of the opposite foot while convalescing from surgery on the one. This secondary collapse has occurred in just over 10% of the patients treated.

Progressive Charcot Collapse in 51 Year Old Female with NIDDM

I.S. a 51 year old undiagnosed diabetic female was first seen at the Podiatry Institute with an acute cellulitis following a puncture wound to the left foot. Radiographs at that time failed to show any evidence of osteomyelitis (Fig. 4A). The patient was found to have a deep infection beneath a mal perforans ulcer at the fifth metatarsal head. A profound mixed neuropathy was present.

Surgical incision and drainage was performed followed by appropriate antibiotic therapy and institution of diabetic control. A prolonged hospital course included serial incision, drainage and debridement with subsequent identification of infection involving the proximal phalanx and the fifth metatarsal.

Several weeks later with a deteriorating wound the patient was returned to surgery for deep debridement and excision of osteomyelitic bone. Bone resection included the distal one-third to one-half of the fifth metatarsal (Fig. 4B). Antibiotic therapy was continued and the wound appeared to heal without complication. Non weightbearing was stressed, and the patient discharged from the hospital on crutches.

The patient failed to comply with use of crutches and returned slightly over a month later with edema and erythema over the second, third, fourth metatar-

A

Fig. 4A. Patient first seen with deep mal perforans ulcer beneath fifth metatarsal head following puncture wound. No evidence of osteomyelitis is seen at this time. Note evidence of old Charcot joint at hallux interphalangeal joint.

B

Fig. 4B. Two months later severe osteomyelitis necessitated resection of diseased bone including fifth metatarsal head and neck. Note increased concentration of weight now shifted to intermediate metatarsal heads.

C

Fig. 4C. Twelve days later patient is seen with severe edema and erythema of forefoot. Radiograph demonstrates Charcot joint changes of lesser metatarsophalangeal joints.

D

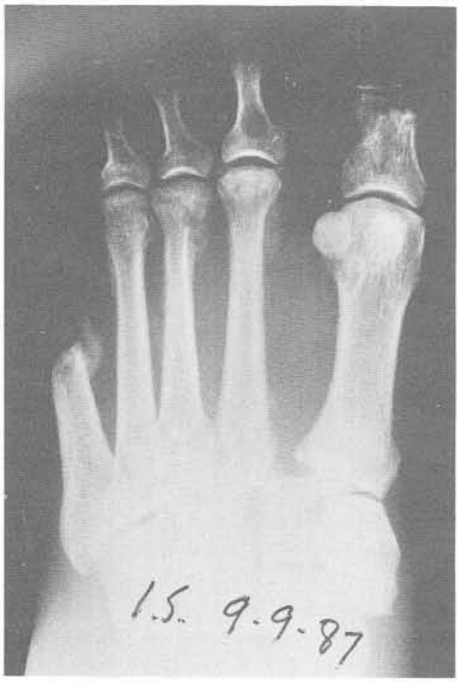


Fig. 4D. Radiographic changes just over two weeks later show collapse of first and second cuneometatarsal joints with avulsion of first ray. This change was predictable after collapse of lesser metatarsal heads in patient who persisted in full weightbearing against instructions.

sophalangeal joints. X-ray examination demonstrated Charcot fractures of all three intermediate metatarsal heads (not at all difficult to understand with the increased loading of these heads which predictably followed resection of the fifth metatarsal head) (Fig. 4C).

The patient was again treated with protected weightbearing with the use of a walker and with a surgical shoe with an accommodative orthotic device. She was to do no full weightbearing.

Just under three weeks later patient was seen with severe edema of the left midfoot and with angulational deformity present. Radiographic examination demonstrated a classic Charcot fracture dislocation of Lis Franc's joint (Figs. D -G). With fracture of the three middle metatarsal heads weight had shifted to the first ray. And with failure of the patient to restrict weightbearing the increased load on the weakened bone sheared off the first ray followed by collapse of the second, third, and fourth tarsometatarsal joints. Since the fifth ray had been previously shortened and was thus relieved of stress the fifth metatarso cuboid joint was largely spared.

Following such an extensive history of non compliance the patient was treated with several months of non weightbearing casting and was subsequently managed with molded shoe therapy and then lost to follow-up.

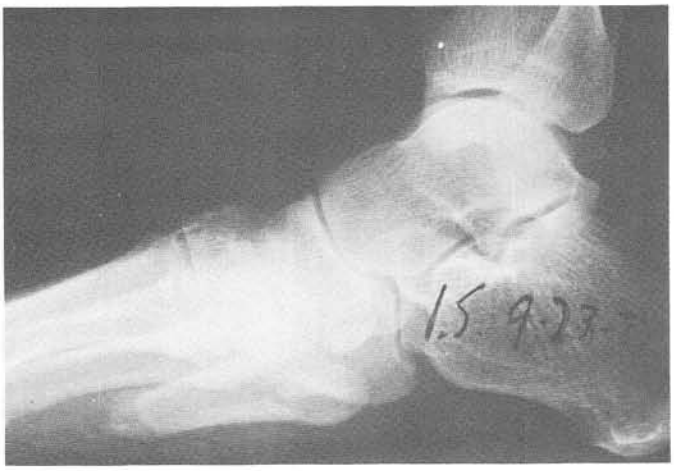
Discussion

This case illustrates the predictable nature of Charcot joint collapse. Autonomic neuropathy and the resultant osteopenia weakens bone so that it is vulnerable to breakdown at predictable points of stress. The loss of early warning normally provided through the sensory nerves allows a painless progression of destruction. One only needs to understand the biomechanics of the particular foot in order to predict where the next collapse will occur.

As in this case a non compliant patient invites continuing collapse of the foot and ankle until little remains to treat.

The More Typical Charcot Foot Collapse

W.F. is a 44 year old insulin dependent diabetic. She was 42 years old when first examined at a staff medical conference (11). The patient was presented by her diabetologist who explained that she was scheduled for below knee amputation of the right limb some three weeks hence. He asked for ideas as to whether there were any alternatives to the scheduled amputation. It was explained that the patient had been under treatment for



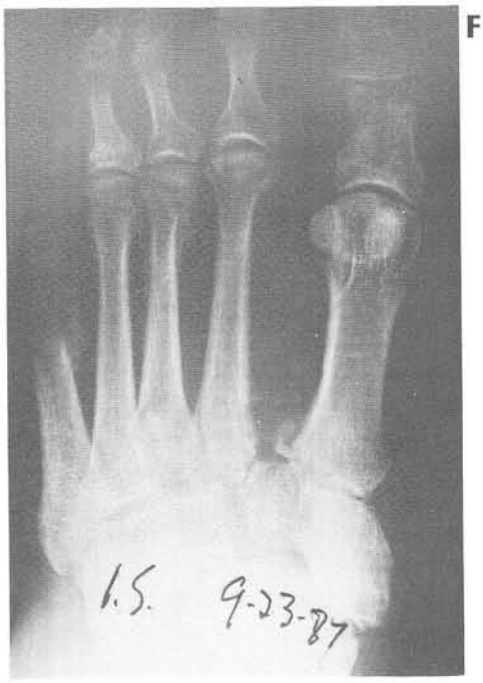


Fig. 4E., F., G. Radiographs show continuing collapse of LisFranc's Joint and collapse of first cuneiform.

some thirteen months with contact casting in an attempt to heal a large mal perforans ulcer beneath the first cuneiform. The ulcer had shown no sign of healing and in fact appeared to be enlarging. It had been concluded that the patient simply did not have sufficient circulation to heal the ulcer.

Clinical Findings

When first examined the patient presented a large mal perforans ulcer beneath the right first cuneiform. The ulcer was deep and showed peripheral erythema and swelling. The foot was severely abducted and everted and a rocker-bottom arch deformity was present. The apex of the rocker-bottom and of the forefoot abduction was at LisFranc's joint. The foot was generally swollen below the ankle but the erythema was limited to the area immediately surrounding the ulcer. The foot was quite warm to touch from above the ankle distally. The skin of both feet was exceptionally dry with fissuring of the heels and callous accumulating in the nail grooves and beneath the nails.

The opposite foot was quite warm to touch but showed no evidence of edema.

Range of motion examination demonstrated significant equinus bilaterally with the right foot much more severe than the left.

Clinical Findings One Week Later

One week later we were asked to see the patient as an emergency. She was septic. The edema was greatly increased and the erythema now included the entire plantar arch area and extended proximally almost to the ankle (Fig. 5A). The erythema seemed most severe surrounding the ulcer but was continuous from the ulcer throughout the arch of the foot. The patient's diabetes was completely out of control. She was unable to feel sharpe stimulation or vibratory testing of the involved foot up to mid leg. Profound mixed neuropathy was obviously present. Severe skin dryness, uncontrollable diarrhea, and a significant cardiac problem correlated well with widespread autonomic neuropathy. The inability to feel sharpe or vibratory stimulation up to mid leg confirmed sensory neuropathy. Anterior leg muscle weakness as well as intrinsic muscle atrophy confirmed motor neuropathy.

A diagnosis of deep central compartment abscess was made and arrangements made to take the patient im-

A

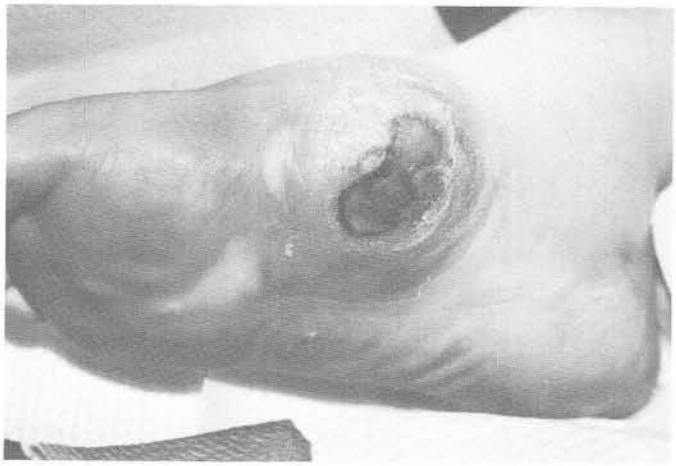


Fig. 5A. Large mal perforans ulcer now complicated by deep central compartment abscess. This is a true surgical emergency.

mediately for emergency incision and drainage followed by irrigation and packing.

Surgical Plan, Stage I

Because of the emergency nature of the infection it was planned to address only the emergency first. The patient was told that an assessment of the entire problem would be made after the wound and the diabetes had been stabilized.

The patient was taken to surgery and was deemed to need no anesthesia. Repeated testing suggested the absence of pain and temperature sensation as well as that of position and vibration in the entire foot and ankle. Surgery included:

deep central compartment incision and drainage from the second metatarsal head proximally and curving to connect with the mal perforans ulcer
wound was flushed thoroughly and curetted free of all devitalized tissue
wound packed with iodoform gauze

All of the above was accomplished with only mild sedation. Within thirty minutes of the surgery the patient's temperature had returned to normal. The erythema in the foot and ankle had almost totally disappeared. The patient's diabetes was then easily returned to satisfactory control within twelve hours.

The wound was repacked daily while continuing intravenous antibiotics. In two weeks the wound had totally healed, and interestingly the mal perforans ulcer had likewise healed.

Radiographic evaluation indicated a complete collapse of LisFranc's joint. The midtarsal joint appeared unstable though there was no evidence of Charcot fractures at that level. This raised the prospect of possible rupture of the tibialis posterior tendon.

In view of the ease with which the patient healed and the obviously excellent circulation a long range surgical plan was recommended to the patient. There appeared to be an excellent chance of satisfactory bony healing which would enable the patient to avoid the scheduled below knee amputation.

Surgery recommended included:

resection of all Charcot fracture surfaces
arthrodesis of all five tarsometatarsal joints
arthrodesis of intercuneiform joints
possibility of later stabilization arthrodesis of other rearfoot joints

The patient was cautioned that she would have to remain in a wheel chair and await soft tissue and bony equilibration with the opposite foot while convalescing. She was also made aware of the fact that the most common complication in treating the Charcot foot is breakdown of the opposite foot while convalescing with the foot which has undergone surgery.

It was five additional weeks before soft tissue texture, edema, and color matched that of the opposite extremity (Figs. 5 B-D). The patient was then scheduled for stage II, the first reconstructive procedures.

Surgery, Stage II

As with the first surgery the second surgery was accomplished without anesthesia. Mild intravenous sedation was employed. The surgery which lasted nearly five hours included:

tendo Achillis lengthening
resection of all five of LisFranc's Joints
resection of all joint surfaces between the cuneiforms and the cuboid
fixation of the intercuneiform joints
temporary fixation of first and fifth metatarsal to establish a transverse plane
fitting and temporary fixation of other three metatarsals to the same plane of weightbearing as established by the first and fifth
rigid fixation
fiberglass bivalved cast

Post surgical recovery was rapid and at two weeks the patient lacked edema or erythema. The incision lines were well healed and normal skin character lines had returned (Figs. 5E & F). Nine weeks following surgery solid bony union was evident (Fig. 5G). Patient was placed in a depth oxford with an accommodative full

B

Fig. 5B. Five weeks after incision and drainage foot shows full equilibration with opposite foot. Patient has been totally non weightbearing during this period.

C

Fig. 5C. Dorsoplantar radiograph after five weeks of non weightbearing shows subsiding of bony activity.

D

Fig. 5D. Lateral radiograph shows degree of dislocation present at LisFranc's Joint.

E

Fig. 5E. Dorsal view of foot two weeks after reconstructive surgery shows minimal edema and no evidence of erythema. Incision lines have fully healed.

F

Fig. 5F. Plantar view at two weeks shows return of normal skin character lines.

G

Fig. 5G. Lateral radiograph at nine weeks shows excellent consolidation of bone, well ahead of normal expectations.

length orthotic device. It was evident from first weight-bearing that the lack of stability of the midtarsal joint would constitute a source of potential further collapse (Fig. 5H). The patient was returned to the hospital just over three months following the LisFranc's reconstruction. This time the surgery was for talonavicular arthrodesis. This was done with the full knowledge that further tarsal arthrodeses might be necessary.

Surgery, Stage III

Surgery was again scheduled under mild sedation without the benefit of anesthesia. Surgery this time would be quite short since it involved arthrodesis of the talonavicular joint only (Figs. 5 I & J).

Surgery included:

resection of the talonavicular joint
fitting of the joint surfaces
rigid internal fixation
sterile dressing and bandaging
fiberglass bivalved cast to facilitate
range of motion exercises

The patient's healing was quite rapid, fully a third quicker than would have been expected for a non diabetic. She was continuously cautioned to protect the opposite foot since collapse of the "good foot" while convalescing with the operated foot may become a complication.

At eight weeks following surgery patient had returned to the depth oxford with a new accommodative orthotic device (Fig. 5K). Questions still remained as to the stability of the naviculocuneiform joints. Three months post operatively x-rays confirmed diastasis of the naviculocuneiform joints and the patient advised to return to surgery (Fig. 5L).

Surgery, Stage IV

At this surgery the plan was to arthrodese the naviculocuneiform joints as well as remove some of the considerable hardware that was accumulating in the patient's foot. As with surgery in Stage III this was a rather short procedure and was accomplished under intravenous sedation. Surgery included only arthrodesis and rigid internal fixation of the involved joints and removal or redundant hardware.

The patient's convalescence was uncomplicated and quite rapid. At seven weeks the joints appeared clinically and radiographically solid and the patient was returned to the depth oxford with accommodative orthoses (Figs. 5 M, N,O). Re x-ray at four months after surgery

H

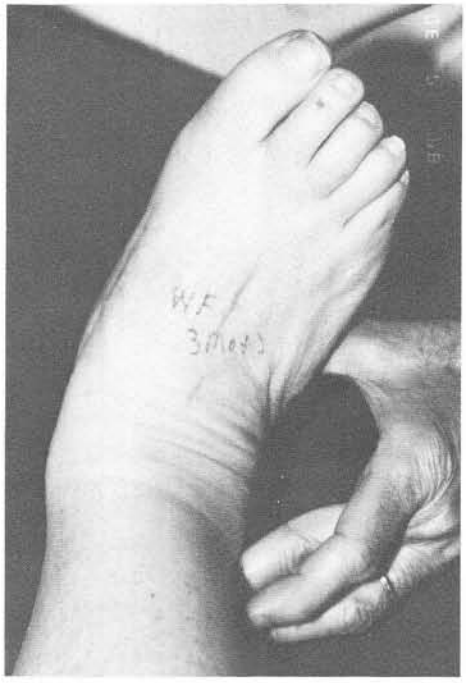


Fig. 5H. Loading of forefoot demonstrates midtarsal instability associated with ruptured tibialis posterior tendon.

I

Fig. 5I. Resection of talonavicular joint in preparation for arthrodesis.

J

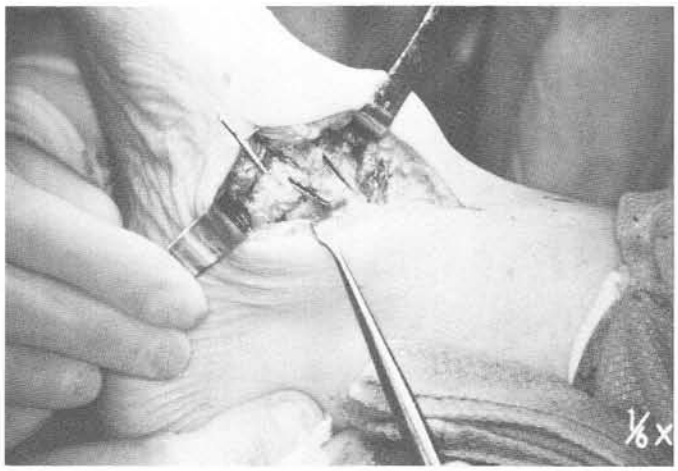


Fig. 5J. Double staple fixation is combined with resident Steinmann pin for fixation.

K

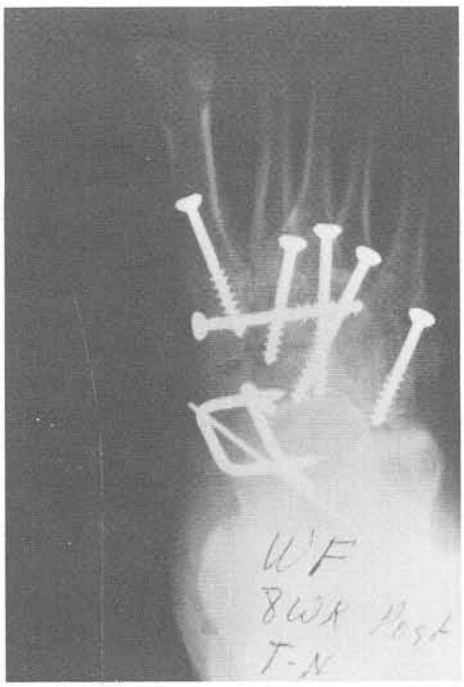


Fig. 5K. Radiograph eight weeks after talonavicular arthrodesis.

L

Fig. 5L. Three months after talonavicular arthrodesis naviculocuneiform diastasis is evident.

confirmed continued consolidation of all arthrodesis sites (Figs. 5 P & Q).

Post Operative Care

Post-operative care must consider the patient as a whole and not become overly focused on simply healing the surgical site. The patients aftercare included:

M

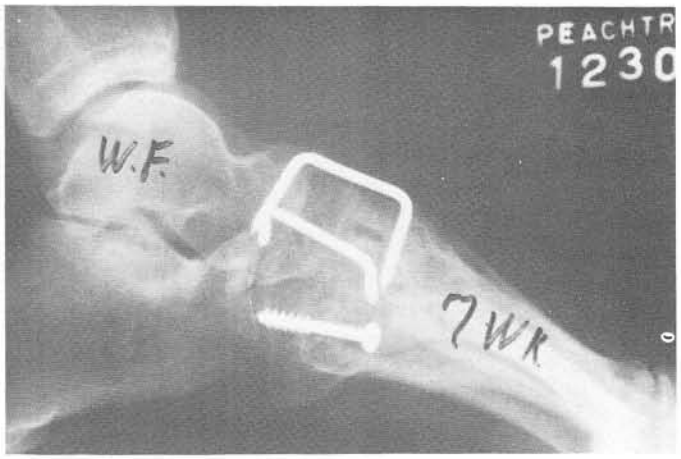


Fig. 5M. Seven weeks after naviculocuneiform arthrodesis and removal of excess hardware.

N

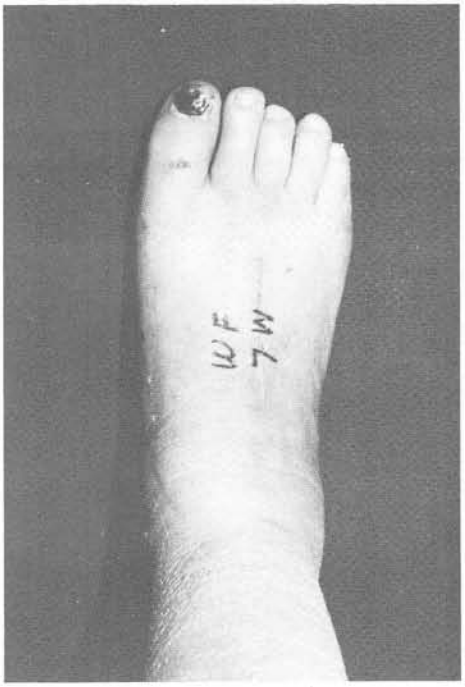


Fig. 5N. Clinical appearance at seven weeks.

bivalved cast after each surgery
early range of motion exercises (after 3 1/2 week delay) in the first surgery which had included tendo Achillis lengthening
full length accommodative orthotic device for both the operated foot and the contralateral side
upright brace or ankle foot orthosis until or unless triceps strength is adequate
crutch or walker assistance until muscle tone and bone strength have adequately recovered from disuse
physical therapy to encourage muscle strengthening of weak and stretching of tight muscles
gradual return to full activity over a period of several months from time of cast removal

O

Fig. 5O. Patient returned to inlay depth oxford with full length accommodative orthotic device.

P

Fig. 5P. Lateral radiograph four months following naviculocuneiform arthrodesis.

Q

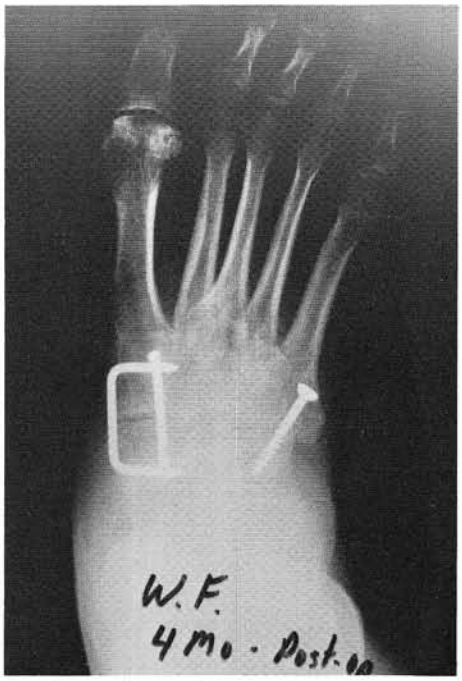


Fig. 5Q. Dorsoplantar view at four months.

R

Fig. 5R. Mid-shaft pathologic fracture of second metatarsal left foot occurred as patient began resuming full weightbearing on both feet.

constant monitoring of opposite foot during convalescence

heel raise to accommodate equinus in opposite extremity and decrease bending force in foot where equinus is present

education of patient at every visit as to the nature of mixed neuropathy and the vulnerability that it inflicts

positive reinforcement of patient and family in how to live within the limits of neuropathy in particular and diabetes in general

At two months post surgery radiographs showed rather solid union. But with significant osteopenia present patient was maintained non weightbearing while beginning strengthening exercises. Not until three months post surgery was the patient fully weightbearing with the use of a walker. She was likewise continuing on a twice weekly session with a physical therapist to further strengthen remaining muscle function.

S

Fig. 5S. Dorsoplantar view just over five weeks later shows first ray collapse despite casting and limiting weightbearing.

T

Fig. 5T. Dorsoplantar view three months following stabilization arthrodesis of first and second rays.

U

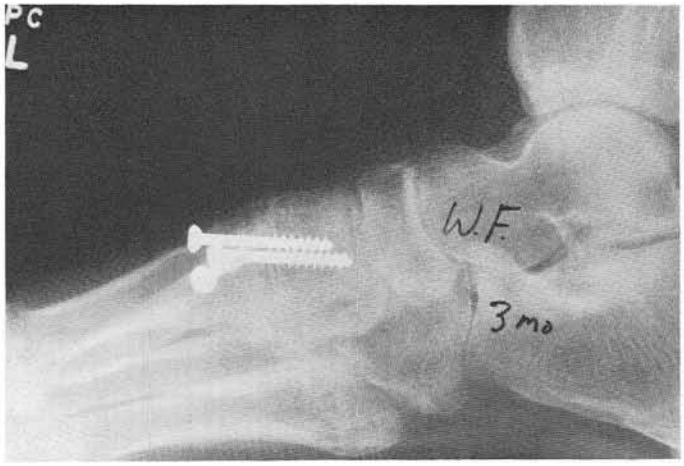


Fig. 5U. Lateral view at three months.

V

Fig. 5V. One year and eight months after initial incision and drainage patient is fully weightbearing.

Discussion

This patient's problems illustrate all too well the complexity and the chronic nature of the diabetic charcot foot. Indeed, just as the patient began functioning well on the right foot following Stage IV surgery disaster struck the left foot. First a midshaft fatigue fracture of the second metatarsal developed (Fig. 5R). That, of course, increased the load on the first and third metatarsals. Not surprisingly, then, diabetic Charcot collapse of the first ray followed (Fig. 5S).

With collapse of the first ray on the left foot the patient was placed in a wheel chair until soft tissue equilibration with the opposite foot could occur. She was then taken to surgery for stabilization arthrodesis of the left first and second cuneometatarsal, intercuneiform, and intermetatarsal base joints (Figs. 5 T & U). Since an equinus of the left ankle appeared to be a major contributing factor to the foot breakdown a tendo Achillis lengthening was performed concomitantly.

Of interest, Achilles tendon lengthening in patients with diabetic neuropathy may yield quite unpredictable results. In many they appear to regain virtually full strength. In others an upright brace or ankle foot orthosis (AFO) may be necessary for life. A great deal is dependent on the degree of motor neuropathy, but much also rests upon the motivation of the patient. Even in the worst possible scenario where the patient may require an upright brace they are so much less at risk for breakdown with elimination of the restriction in ankle joint dorsiflexion. Indeed, if the equinus were not corrected the foot would simply break at the next weakest link. On the other hand, one must be aware that over lengthening can result in excess pressure under the calcaneal tuberosity and ulceration at that point.

We have followed many patients who developed a Charcot foot collapse while wearing a well molded thick plastizote accommodative appliance. Very simply, any time there is substantial restriction of ankle dorsiflexion it must be compensated by some means. In many instances this will occur by breakdown at LisFranc's joint or at the midtarsal and subtalar joints. The collapse will occur at the biomechanically weakest level.

One year and eight months after the initial incision and drainage, and four additional surgeries later, the patient was fully weightbearing on both extremities (Fig. 5V). One may ask was it worth while? When we consider the fact that we definitely prevented one amputation and in all probability prevented amputation of both extremities it is obviously worth it. The patient is still an insulin dependent diabetic with profound mixed neuropathy and will continue to be at high risk for complications. Yet, through the extensive surgery she has learned to recognize the hazard signs and more importantly to prevent most of them. The patient definitely concurs that it was worth the effort.

Multiple Rearfoot and Forefoot Charcot Joint Collapse

E.B. was a 54 year old insulin dependent diabetic caucasian female when first seen. She was referred to the Podiatry Institute by Dr. Paul Smaha of Macon, Georgia.

When first seen 11-5-87 she complained of a very swollen, hot, but non-painful left foot. She stated that the foot had "given way" while walking for her daily exercise six weeks earlier. She had first seen an orthopedist who had casted the foot but allowed continued weightbearing. She had been subsequently referred to Dr. Smaha who in turn referred her to the Podiatry institute. The patient indicated that she had been made aware that below knee amputation was the only definitive treatment for the condition involving the left foot.

She had been a known diabetic for twenty years and insulin dependent for fifteen years.

Clinical Findings

Initial examination presented an extremely swollen, hot, indurated left foot (Figs. 6 A & B). An ulcer was present on the left fifth toe due to cast irritation.

Range of motion examination revealed a foot without stability in either the sagittal or transverse plane. The ankle also showed very questionable stability. Severe ankle equinus was present, though with the instability of the ankle and midtarsal joints it was impossible to measure accurately.

Circulatory evaluation demonstrated a marked increase in blood supply to the foot. All pulses were patent. The foot showed a degree of inflammatory response that is only possible in the foot with excellent perfusion.

Neurological examination produced evidence of significant mixed neuropathy below the knee. Sensory and motor neuropathy were present, but autonomic neuropathy was even more advanced. The skin was very dry with scaling of the entire foot and leg and with fissuring of the heels and around the nail grooves.

A diagnosis of severe diabetic Charcot foot was made. The patient was placed at total non weightbearing to await equilibration with the opposite extremity. Surgery was planned following return of soft tissues to a normal state and allowing adequate time for bone to return to a firmer consistency.

Surgery

Patient was maintained non weightbearing for over two months before adequate equilibration was felt to be present (Figs. 6 C-E). She was made aware of the extensive nature of the destruction in the left foot and was told that surgery might well involve two or three stages. She was also aware that while we would try to salvage the ankle joint there was no certainty that we could avoid arthrodesis.

Surgery was scheduled and performed which included:

tendo Achillis lengthening, left
removal of dislocated navicular, temporarily
removal of dislocated cuneiforms, temporarily
removal of dislocated cuboid, temporarily
arthrodesis of subtalar joint
resection of Charcot Joint surfaces
and replacement of cuboid with temporary fixation
resection of Charcot Joint surfaces and replacement of
navicular bone and temporary fixation

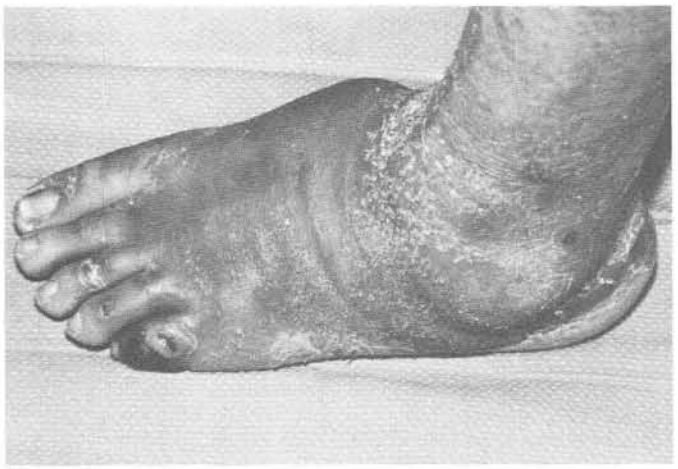


Fig. 6. A, B. Severely inflamed and swollen left foot several weeks after Charcot joint collapse while walking. Patient has been in cast for several weeks but was allowed to continue walking. Consequently, inflammatory process has continued.

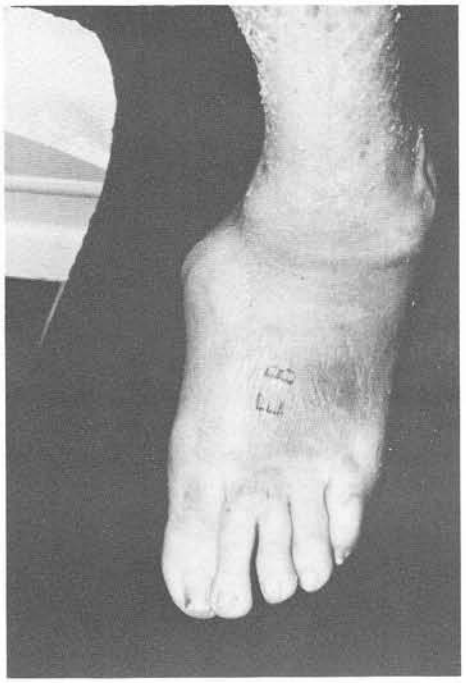


Fig. 6C. Appearance of foot after two months of non weightbearing.

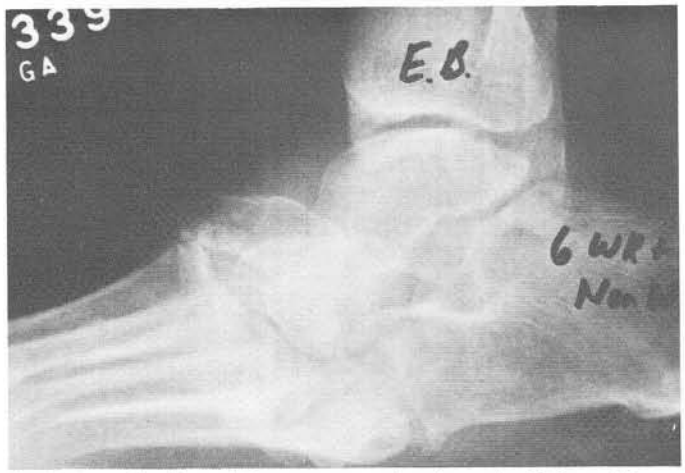


Fig. 6E. Lateral radiographic appearance after six weeks. Collapsed bony surfaces are now consolidating.

Fig. 6D. Dorsoplantar radiographic appearance after two months of non weightbearing.

resection of Charcot Joint surfaces and replacement of cuneiform bones and temporary fixation
resection of LisFranc's joints 1-5 and temporary fixation
resection of intermetatarsal base articulations at the first, second, third, and fourth intermetatarsal bases

Intraoperative x-rays confirmed satisfactory alignment and permanent fixation was installed. Because of rather soft bone screws purchased poorly and mixed fixation

was used. A combination of screws, pins, and staples was found desirable. The surgery slightly exceeded five hours.

Postoperative Care

In view of the extensive reconstruction, particularly removal and replacement of multiple tarsal bones, it was anticipated that up to six months of non weightbearing would be required. As with most diabetic Charcot feet, there was little postoperative edema and no erythema.

Postoperative care included:

four months total non weightbearing on left foot
bivalved cast for entire period
removal of cast with range of motion exercise of ankle from six weeks post surgery
isometric exercises of ankle and metatarsophalangeal joints from six weeks postoperatively
full length molded accommodative orthotic device from initial weightbearing (bilaterally)
walker for first month after return to weightbearing
physical therapy twice weekly for two months on resumption of weightbearing
extensive patient education as to the nature of diabetic neuropathy and how to cope with it
depth oxford with orthotic device or molded shoe for life

Discussion

This case illustrates the extreme complexity that can be present in the diabetic Charcot foot. At surgery it was impossible to use the usual routine of internal fixation. Instead it was necessary to have a back up system. The inflammatory soup that represents the post collapse period may require several months for bone to return to a reasonably firm consistency. Consequently one should always be prepared with an alternative system of fixation.

Since the navicular, the cuboid, and the cuneiforms were dislocated they were removed from the foot and placed in sterile saline while aligning and arthrodesing the subtalar joint (Fig. 6F). Once that was stable the bones were replaced one at a time from proximal to distal and temporarily fixated with Kirschner wires. Once all tarsal bones were in place the joints of LisFranc's articulation were resected and realigned (Fig. 6G).

The first and fifth tarsometatarsal joints were aligned first. Once temporarily fixated this afforded a transverse plane against which to align the other metatarsals. It is extremely critical to align all five metatarsal heads on the same transverse plane to avoid pressure ulceration.

F

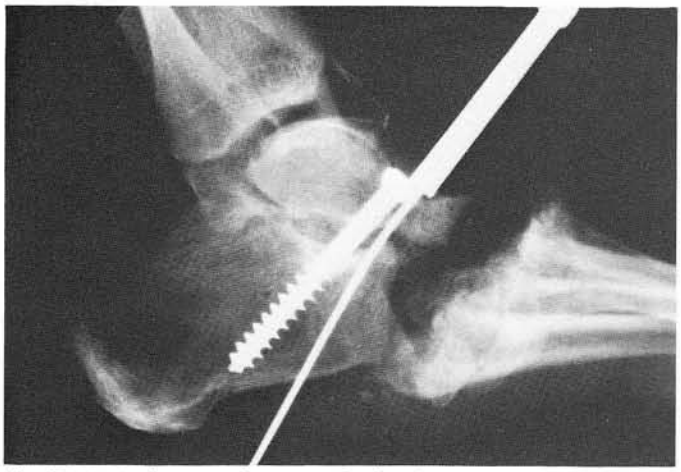


Fig. 6F. Navicular, cuneiforms, and cuboid were removed from foot to allow realignment of talocalcaneal joint.

G

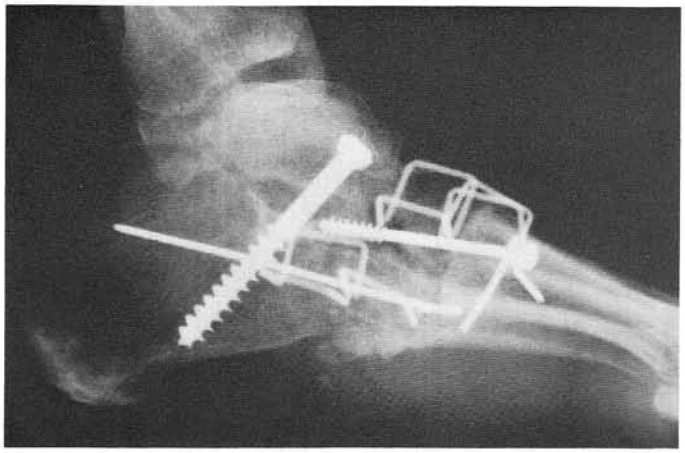


Fig. 6G. Cuboid, navicular, and remaining cuneiform bones were trimmed of cartilage, replaced and temporarily fixated as were all five tarsometatarsal joints.

H

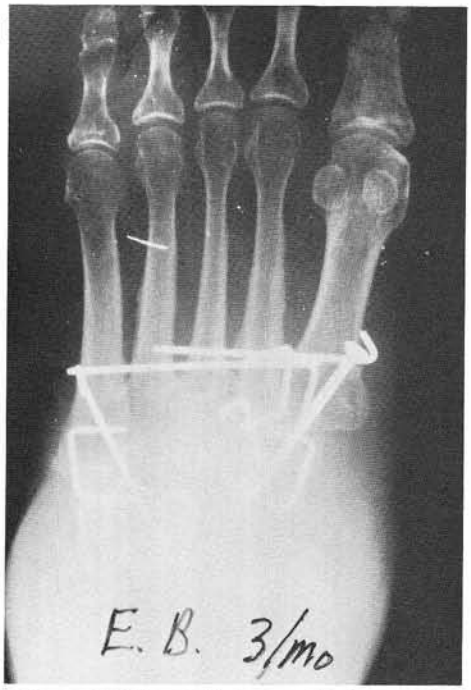


Fig. 6H. At three months post surgery joints are showing good consolidation.

I

Fig. 6I. At six months temporary hardware has been removed, and dorsoplantar view shows good consolidation of arthrodeses.

J

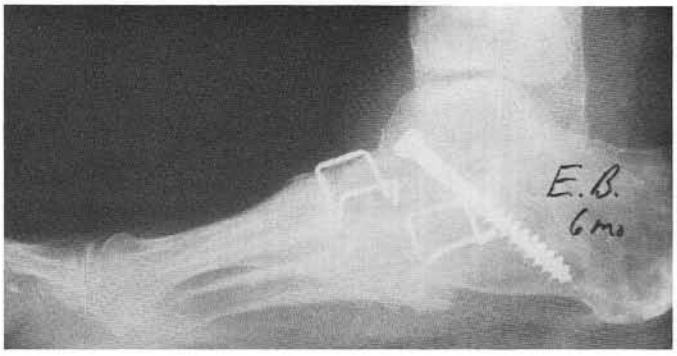


Fig. 6J. Lateral radiograph at six months.

K

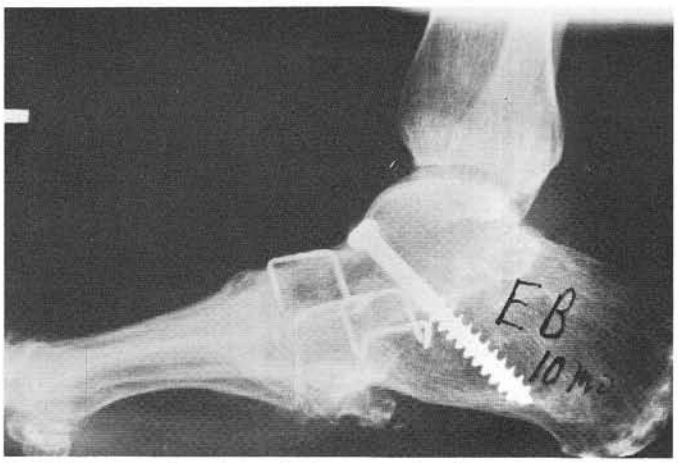


Fig. 6K. Ten month radiograph shows excellent bony consolidation of arthrodeses.

The rate of healing and the relative absence of erythema or edema is most impressive in feet such as this despite the rather extensive dissection required for exposure. The key element to recognize is the vastly increased circulation in most diabetic Charcot feet. That same increased circulation which contributes to rapid healing likewise causes the osteopenia which makes the patient vulnerable to breakdown at other sites either in the same or in the contralateral foot. For this reason it is imperative that severe bending force such as that imposed in the presence of equinus be corrected as a part of the surgical plan even if the patient never regains full strength in the triceps group. To neglect such deforming force will assure breakdown at some other joint in the foot.

In this instance with the stabilization of the rearfoot it appears thus far that the ankle will present no problem. The ankle continues to be less than fully stable, but should be adequate in a patient who is unlikely to redevelop a full heel toe gait.

In this case three different systems of internal fixation were combined to achieve stability of the involved joints. This is seen at the three month postoperative x-ray when the temporary Kirschner wires were scheduled for removal (Fig. 6H). At six months after surgery the consolidation of bone is apparent and only the talocalcaneal screw and four of the staples remain (Figs. 6 I & J). These are creating no pressure points and are likely to be retained. At ten months excellent bony consolidation is evident (6K).

At eleven months the patient was reevaluated and found to possess a mild calcaneus gait. This was felt to be due in part to arthrodesis of the talus in a plantarflexed position and in part to weakness of the triceps following lengthening. The patient was encouraged to continue strengthening exercises and was made aware of the possible need for upright bracing unless triceps strength increased.

Recurring Ulceration Arch of Right Foot

G.K. was a fifty-eight year old insulin dependent male when first seen at the Podiatry Institute (11). He had experienced ulcerations beneath the medial arch. The ulcerations healed with protection from weightbearing. Despite proper shoes and full length molded orthoses the problem continued to worsen with the foot showing increasing collapse of the arch and abduction deformity of the forefoot during the previous two years. The patient was referred for surgical reconstruction by Dr. Gerald Falke of Hagerstown, Maryland.

Clinical Findings

Clinical examination showed a moderately advanced mixed neuropathy. The patient indicated that there had been a noticeable increase in the neuropathy over the past two years. Findings included:

rockerbottom foot deformity
abduction deformity of forefoot
severe ankle equinus, bilaterally
well preserved posterior muscle strength
decreased anterior muscle strength
vastly increased circulation, bilaterally
pronounced dryness of skin and nails
moderately severe mixed neuropathy, bilaterally

Weightbearing examination demonstrated a rockerbottom right foot with total collapse of LisFranc's joints. The opposite foot showed severe pronation and equinus, but still possessed structural integrity.

Radiographic examination confirmed complete collapse of LisFranc's joints with near total destruction of the first cuneiform bone (Fig. 7A).

A diagnosis of diabetic Charcot foot was confirmed as directly related to autonomic, sensory, and motor neuropathy. Non invasive vascular tests confirmed the presence of a vastly increased peripheral circulation which was presumed related to the loss of vasomotor control.

Surgical Plan

The patient was scheduled for stabilization arthrodesis of all five tarsometatarsal joints as well as the intercuneiform and cuneocuboid joints. Arrangements were made to have iliac crest autograft available to replace the compromised first cuneiform. Surgery ultimately included:

iliac crest bone graft to replace first cuneiform
arthrodesis tarsometatarsal joints 1-5 with rigid internal fixation
arthrodesis of intercuneiform and cuneocuboid joints
tendo Achillis lengthening

The surgery for reconstruction of the arch was carried out through three longitudinal incisions, a medial, a midline, and a lateral (Figs. 7 B & C). All the Charcot surfaces were resected and the joints temporarily fixated with Kirschner wires (Figs. 7 D & E). The void created by the missing first cuneiform was filled with autograft from the iliac crest of the same side. Reciprocal planing was utilized to place all five metatarsal heads on the same transverse plane. With x-ray confirmation of satisfactory alignment permanent fixation was achieved with screws and a T-plate (Figs. 7 F-I).

A

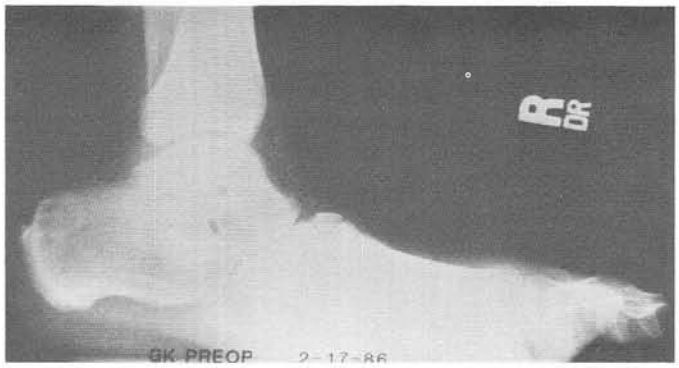


Fig. 7A. Lateral radiograph showing rockerbottom collapse of LisFranc's joint in spite of attempts at orthotic control.

B

Fig. 7B. Medial view at surgery shows severe rockerbottom deformity. Planned incisional approach is drawn on skin.

C

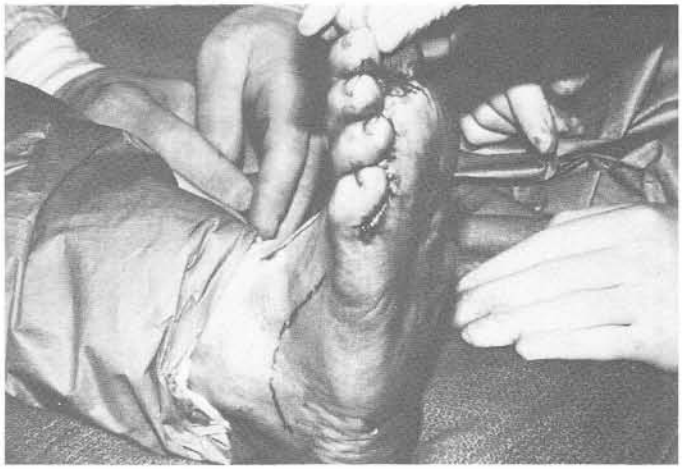


Fig. 7C. Lateral and midline incisions are outlined.

D

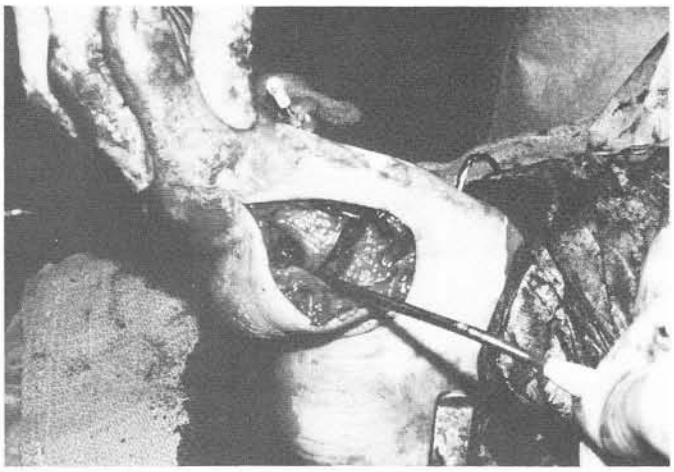


Fig. 7D. Charcot Joint surfaces are resected back to normal bone.

E

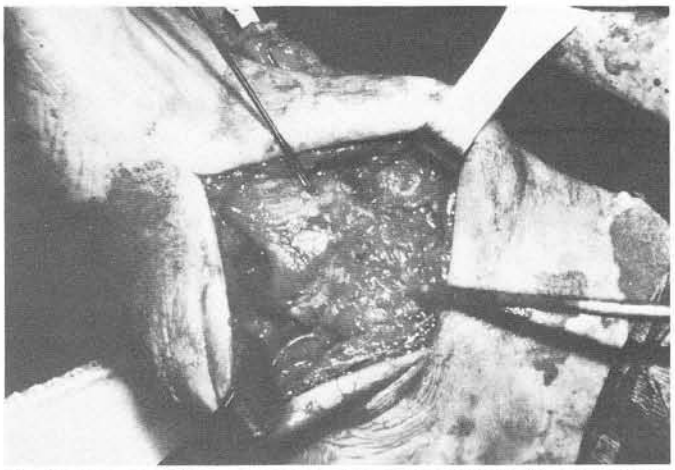


Fig. 7E. Bone graft is used as needed to replace missing first cuneiform, and joints are temporarily fixated with .062 Kirschner wires.

F

Fig. 7F. Five hole T-plate is necessary to stabilize first ray and bone graft.

G

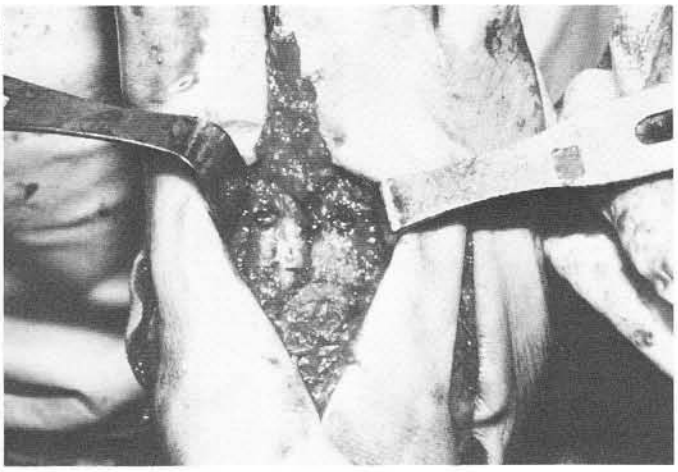


Fig. 7G. Screws successfully fixate tarsometatarsal joints. Good compression is evident.

H

Fig. 7H. Intraoperative radiograph before application of cast.

I

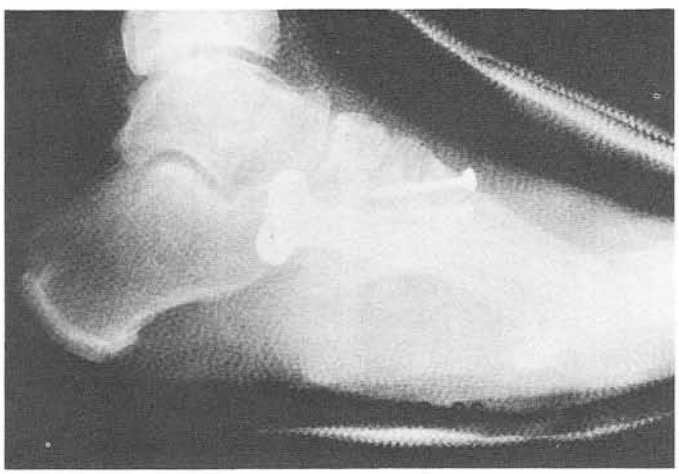


Fig. 7I. Lateral radiograph intraoperatively after application of synthetic cast.

J

Fig. 7J. Clinical appearance of foot at one year after surgery.

K

Fig. 7K. Dorsoplantar radiograph at two years one month.

L

Fig. 7L. Lateral radiograph at two years one month.

Postoperative Care

Because of the rather large graft utilized it was anticipated that convalescence would be correspondingly lengthened. Aftercare was planned with this in mind and included:

five months of non weightbearing on the involved foot
bivalved cast for first three months
range of motion exercises of ankle against no resistance from six weeks post operative
full length molded orthosis in hightop shoe from fifth to eighth month
cane assisted weightbearing from fifth to seventh month
orthotic accommodation and heel raise to compensate equinus of opposite extremity

The patient's postoperative convalescence was satisfactory and at one year postoperatively he was found walking well with an accommodative orthotic device in the shoe (Fig. 7J). At two years Dr. Falke reported the patient to be continuing to coach little league baseball and to have had no further complication (Figs. 7 K & L).

Discussion

With the degree of equinus presented it was obvious that a tendo Achillis lengthening would be required on the involved foot. As always there was concern as to how much triceps strength would be recaptured. In this instance that appears not to have been a problem. Excellent function was recovered.

The presence of equinus on the opposite side raised concern for possible breakdown while recovering from surgery on the involved foot. Exercises for that side to stretch the triceps and to strengthen the anterior muscle group along with a full length accommodative orthotic device and heel raise may well have been responsible for its preservation.

As with all cases involving neuropathic arthropathy the patient requires detailed instruction as to the nature of the problem and how to live with it. It is not enough to repair the foot. Unless potential deforming forces are neutralized or controlled one can expect a new area of bone collapse, either as a pathologic fracture or as a Charcot foot.

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