MIDFOOT AND HINDFOOT ARTHRODESES IN DIABETIC CHARCOT ARTHROPATHY

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OBJECTIVES: To review the clinical outcome of arthrodesis of the foot in patients with diabetic Charcot arthropathy and to review the pathophysiology, clinical and radiographic features of Charcot arthropathy.

DESIGN: A retrospective review and clinical follow-up of a series of patients.

SETTING: St. Michael's Hospital, Toronto, a tertiary care teaching hospital.

PATIENTS: Ten diabetic patients treated between 1996 and 1998 who required an arthrodesis of the midfoot or hindfoot secondary to deformity of diabetic neuropathic joints.

INTERVENTIONS: Three midfoot (Lisfranc) and 7 hindfoot arthrodeses with autogenous iliac-crest bone grafting and internal fixation.

OUTCOME MEASURES: Patient satisfaction, maintenance of the correction of the deformity and avoidance of amputation. Western Ontario / McMaster University score and midfoot / hindfoot American Orthopaedic Foot and Ankle Society foot ratios. Clinical examination including E-MED pedographic examination. Correction and evidence of bony or fibrous union assessed radiologically.

RESULTS: The postoperative correction was maintained, no further skin ulceration occurred and amputation was avoided in 9 of 10 patients. Because this is a salvage procedure and there was often significant concomitant illness, the results of clinical rating systems were poor. Five of 9 patients had clinical and radiographic evidence of a solid bony arthrodesis; 4 had a stable fibrous union.

CONCLUSIONS: With careful surgical technique, a reasonable number of feet can be salvaged by an arthrodesis of a diabetic neuropathic joint when nonoperative measures fail. Patient selection is important because there is a significant complication rate.

OBJECTIFS : Examiner le résultat clinique d'une arthrodèse du pied chez des patients atteints d'arthropathie diabétique de Charcot et examiner la pathophysiologie et les caractéristiques cliniques et radiographiques de l'arthropathie de Charcot.

CONCEPTION : Examen rétrospectif et suivi clinique d'une série de patients.

CONTEXTE : Hôpital St. Michael's de Toronto, hôpital universitaire de soins tertiaires.

PATIENTS : Dix patients diabétiques traités entre 1996 et 1998 qui ont eu besoin d'une arthrodèse de la partie moyenne du pied ou de l'arrière-pied à la suite d'une déformation articulative causée par une neuropathie diabétique.

INTERVENTIONS : Trois arthrodèses de la partie moyenne du pied (Lisfranc) et 7 arthrodèses de l'arrière-pied avec greffe autogène d'os provenant de la crête iliaque et fixation interne.

MESURES DE RÉSULTATS : Satisfaction des patients, maintien de la correction de la difformité et amputation évitée. Score de l'Université Western Ontario et de l'Université McMaster et ratio partie médiane du pied / de l'arrière-pied de l'American Orthopaedic Foot and Ankle Society. Examen clinique, y compris examen pédographique E-MED. Correction et indication de fusion osseuse ou fibreuse évaluée par radiographie.

RÉSULTATS : La correction postopératoire a été maintenue, il n'y a pas eu d'autre ulcération cutanée et l'on a évité l'amputation chez 9 des 10 patients. Comme il s'agit d'une intervention de sauvegarde et comme il y avait souvent une importante maladie concomitante, les résultats des systèmes d'évaluation clinique ont

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été médiocres. Cinq des 9 patients montraient des indications cliniques et radiographiques d'une arthrodèse osseuse solide et 4 présentaient une fusion fibreuse stable.

CONCLUSIONS : Avec une technique chirurgicale minutieuse, il est possible de préserver un nombre raisonnable de pieds au moyen de l'arthrodèse d'une articulation atteinte de neuropathie diabétique lorsque des mesures non chirurgicales échouent. La sélection des patients est importante parce que le taux de complications est élevé.

The increased prevalence of diabetes combined with advances in treatment that prolong life expectancy have resulted in a growing number of patients afflicted by the complications of this disease. The Canadian Diabetes Association estimates that 15% of Canada's 1.5 million diabetic patients will suffer from foot ulcers. Foot ulcers precede 85% of amputations and account for 1 in 5 diabetes-related hospitalizations as well as a greater number of days spent in hospital than all other diabetic complications combined. A small but significant number of these ulcers are caused by foot deformities created by diabetic Charcot arthropathy (also known as diabetic neuropathic foot).

This condition was first described by Jordan in 1936. The disease process is characterized by a collapse of the bony architecture of the foot. It commonly occurs at the level of the joints and is characterized by disintegration of the articular surface with subluxation and dislocation of the joints involved. This process leads to structural deformity with a bony prominence. Not uncommonly, the skin over the prominence breaks down and a pressure ulcer results. The classic deformity is that of a rocker bottom foot with a chronic plantar midfoot ulcer (Fig. 1). A deformity can also occur at the level of the ankle joint creating an axial malalignment in the varus (medial) direction and ulceration over the tip of the fibula (Fig. 2). Historically, a foot in this condition has been removed at the level of the ankle (Symes amputation) or below the knee (below-knee amputation). Over the past decade several clinical series whose focus was on salvaging the neuropathic foot have reported encouraging results.[1–7] Correction of the deformity and an arthrodesis with rigid internal fixation have provided most patients with a stable, plantigrade foot that has remained free from ulceration for many years.[1–7] The concept of salvaging these feet is attractive to both the patient and the health professionals involved with their care.

PATIENTS AND METHODS

We reviewed the charts and radiographs of 10 patients with diabetic Charcot arthropathy who were treated surgically between 1996 and 1998 after failing a trial of nonoperative management. In all patients, the Western Ontario / McMaster University (WOMAC) scores and midfoot:hindfoot American Orthopaedic Foot and Ankle Society (AOFAS) foot ratios were obtained.[8] Patients who were able to return (5 of 10) were examined

FIG. 1. Anteroposterior (left) and lateral (right) radiographs of a collapsing midfoot through neuropathic joints in the Lisfranc complex.

clinically, and an E-MED (Novel GMBH Electronics, Munich, Germany) pedographic examination was performed. It is important for the reader to realize that 10 patients represent a small percentage of the total number of those having diabetic ulcers managed over the allotted time period.

Most patients were initially treated for a minimum period of 3 months with protected weight bearing in a total contact cast. If the swelling and erythema did not settle or if the deformity progressed, operative treatment was considered. Those patients with a severe axial malalignment (Fig. 2) were not offered a period of total contact casting; this option was impractical considering the severity of the deformity. All patients had palpable pulses. (It is the practice of the senior author that if pulses are not palpable, vascularity is assessed by measuring transcutaneous oxygen levels or consultating with a vascular surgeon, or both.) Patients had either a tibiotalocalcaneal arthrodesis with an intramedullary reconstruction nail or a midfoot arthrodesis. The midfoot arthrodesis was performed under general anesthesia with a thigh tourniquet applied and inflated. Three longitudinal incisions were used — the first on the medial border of the first metatarsal, the second in the midline dorsally between the second and third metatarsals and the third dorsal–lateral between the fourth and fifth metatarsals. Fibrous tissue and fragments of bone were excised to identify the joints of the Lisfranc complex. Bony resection and release of ligamentous structures, particularly on the plantar aspect, were then carried out to correct the midfoot collapse and the forefoot abduction. This was achieved by plantar flexing the first metatarsal and adducting the first through fifth metatarsals such that they were appropriately aligned with their corresponding midtarsal bones. Bleeding cancellous bone was exposed over all joint surfaces and multiple cannulated screws used across all joints for fixation. Low profile plates were used on both the medial and lateral sides if required. Autogenous iliac crest bone graft was used to fill gaps and to enhance union (Fig. 3).

FIG. 2. Clinical and radiographic views of a neuropathic ankle. Note the severe varus deformity with impending ulceration of the skin overlying the tip of the fibula. The talus has undergone complete resorption indicating an atrophic Charcot response.

Patients with an axial malalignment through the ankle or hindfoot were managed with a tibiotalocalcaneal arthrodesis. This was done through a lateral incision over the anterior border of the distal fibula and a medial incision over the medial malleolus. The subtalar joint could be debrided through the lateral incision. If the talus was found to be necrotic from avascular necrosis

it was removed and a tibiocalcaneal arthrodesis was done. No attempt was made to interpose tri-cortical graft to maintain length. Prepared cancellous surfaces were compressed together and rigidly fixed with a reconstruction nail inserted in a retrograde fashion through the calcaneus, remaining talus and into the medullary canal of the distal tibia. Autogenous bone graft was used to fill any defects (Fig. 4).

All patients were kept non-weight bearing in a cast for 6 to 12 weeks; weight bearing was increased on the basis of radiographic and clinical assessment of union. After cast removal, all patients were fitted with and instructed to wear a rigid total contact ankle foot orthosis whenever weight bearing on the affected extremity.

RESULTS

Three of the 10 patients in the series had fusion of the midfoot joint complex and 7 had tibiotalocalcaneal arthrodesis with a Richard's reconstruction nail. All had palpable dorsalis pedis and posterior tibial pulses preoperatively (Table I). The mean age of the patients was 63 years (range from 51 to 69 years), and they had a history of diabetes mellitus for mean period of 14 years (range from 6 to 30 years). Follow-up ranged from 12 to 37 months (mean 24 months). Nine patients were located for follow-up. All were satisfied with their result and would have the procedure again as an alternative to amputation. These patients had no episodes of reulceration. Five of 9 had clinical and radiographic evidence of a solid bony arthrodesis. Radiologically, 4 had a fibrous union, but clinically the arthrodesis was stable and all hardware remained intact. None of the 9 patients contacted experienced pain. One patient with a tibiotalocalcaneal arthrodesis had some breakdown of the distal aspect of the lateral wound; it healed with dressing changes and antibiotics taken orally and there was no deep infection. Six patients used walking aids and 1 with bilateral Charcot arthropathy used a motorized wheelchair outside her home. All of these patients had required ambulatory aids preoperatively.

The mean WOMAC score (0% excellent, 100% poor) was 33% (range from 11% to 63%). The AOFAS midfoot:hindfoot ratio (0 poor, 100 excellent) averaged 52 (range from 43 to 66).

Four of the 9 patients had an E-MED pedographic examination, which gave significantly abnormal results in all. The most striking abnormality in patients with hindfoot arthrodesis was the loss of hindfoot to forefoot weight transfer. The patients with midfoot fusion showed increased weight bearing at the midfoot region. Not all of the midfoot collapse could be corrected at the time of the arthrodesis and the increased plantar forces at the midfoot were evident on the E-MED examination.

Our 1 failure had a tibiotalocalcaneal arthrodesis. There was nonunion, progressive deformity and reulceration. A below-knee amputation was recommended; however, the patient never returned for follow-up and could not be located at the time of our review.

DISCUSSION

Diabetes mellitus affects the neurologic, vascular and immunologic systems. Abnormalities in these systems combine to produce a neuropathic joint. Long-standing high glucose levels result in a sensory and autonomic neuropathy. The sympathetic neu-

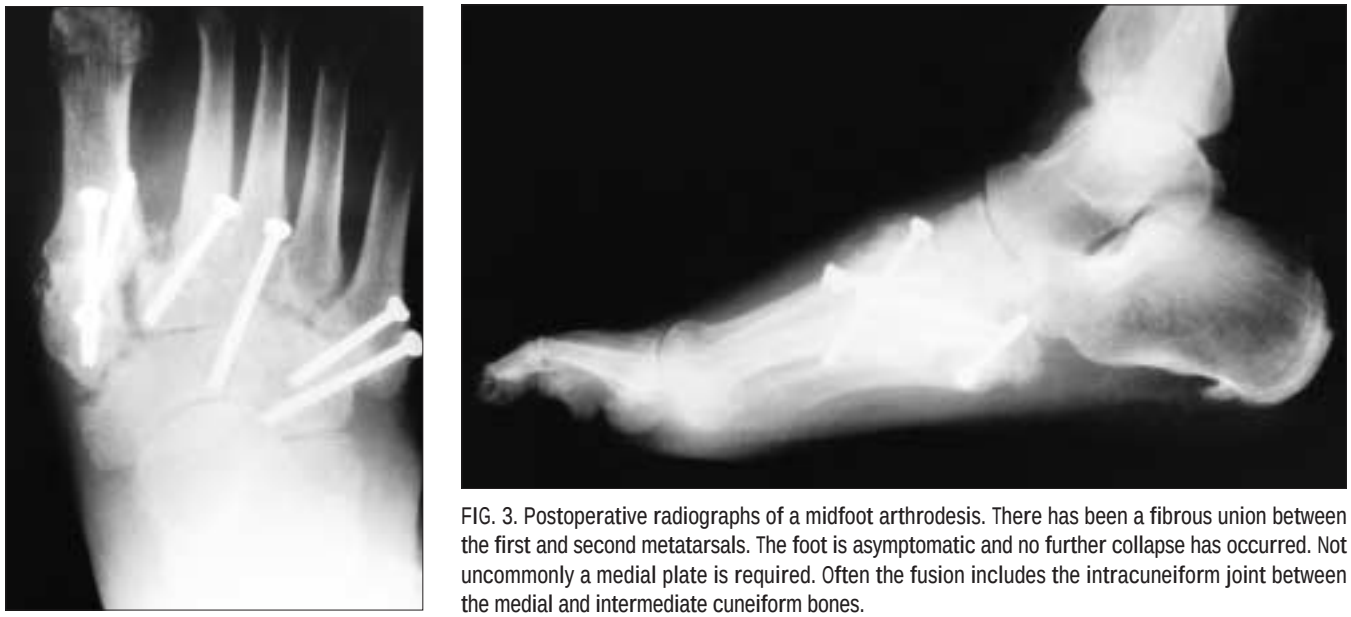

FIG. 3. Postoperative radiographs of a midfoot arthrodesis. There has been a fibrous union between the first and second metatarsals. The foot is asymptomatic and no further collapse has occurred. Not uncommonly a medial plate is required. Often the fusion includes the intracuneiform joint between the medial and intermediate cuneiform bones.

ropathy results in a widely dilated vascular bed and an increase in peripheral blood flow. The increased blood flow stimulates active bone resorption which, in turn, weakens the supportive capabilities of the bone, thereby making it susceptible to fracture.[9] The hyperemic response to the injured bone further augments the bone loss and a vicious cycle of resorption, destruction and resorption develops.[10] The presence of a sensory neuropathy decreases the pain associated with this Charcot process, and the patient continues to bear weight. The clinical consequence is a very warm, erythematous, collapsing foot.

The best treatment is early identification of the "foot at risk." The diabetic patient with an impending Charcot process presents with a warm, swollen foot. This may have been precipitated by a minor injury, and pain may be present, although usually it is not of significant concern. Often, the patient has been treated for a suspected infective process and may have undergone investigations such as bone and gallium scanning or aspiration of the swollen area. Aspiration is not recommended since this can introduce bacteria into an area that is already susceptible to infection. Increased skin temperature is a good screening tool and helpful in assessing the response to treatment; the latter can be done subjectively by comparing the skin temperature between the affected and unaffected sides or objectively with an infrared thermistor. Archer and associates[9] found a mean skin temperature of 33.5 °C in neuropathic feet compared with 25.8 °C in control subjects. Total contact casting at this point can allow the acute Charcot process to settle down and prevent further collapse of the foot.

The areas of the foot and ankle most commonly involved are the midtarsal and tarsal metatarsal joints. The metatarsal phalangeal joints run a tight second, followed by the subtalar and ankle joints. The midfoot is most commonly involved because it is subjected

FIG. 4. A successful tibiocalcaneal arthrodesis with a reconstruction nail.

to much higher than normal shear forces in the mid-stance phase of the gait cycle. It is beyond the scope of this paper to provide a complete description of the gait abnormalities. It is sufficient to say that the primary causative factor is an equinus contracture at the ankle. The equinus contracture is the result of the peripheral motor neuropathy where the strong plantar flexors win over the weaker dorsiflexors. During the gait cycle the equinus contracture lifts the heel off the ground at an earlier point during the stance phase. This places the full body weight through the midtarsal joints while they are still horizontal to the ground; as a result, increased shear or tangential forces pass through these articulations. The process of nonenzymatic glycosylization of type 1 collagen has already weakened the ligaments supporting these joints, bony fragmentation occurs and the joint collapses.

The radiographic findings in neuropathic arthropathy can be subtle or gross. The 2 patterns most commonly seen are an atrophic or hypertrophic response. The atrophic Charcot event is uncommon: the involved neuropathic joints and associated bones seem to "melt away." The hypertrophic Charcot response is most common: it is characterized by massive destruction of the joint with bony fragmentation and osteophyte or new bone formation. The osteophytes attain a size out of proportion to the joint space and form huge, haphazard, widely based hypertrophic shelves of bone. The foot takes on a "bag of bones" appearance. More subtle radiographic signs that can aid in early detection of a diabetic, Charcot "foot at risk" are diffuse osteopenia (often juxta-articular), vague disorganization of the joint (its appearance is similar to that of a slightly-out-of-focus x-ray film) and soft-tissue calcification.

There are 2 surgical principles important to treatment of the neuropathic joint in the foot. First, avoid surgery during the stage of acute inflammation. Wait until the edema and inflammation have subsided. In the interim, protect the extremity with a cast and elevate it. Second, when an arthrodesis is warranted, adhere strictly to proper technique; a half-hearted attempt at fusion will only further destabilize the area and result in persistent deformity and ulceration. The key to a successful outcome is complete correction of the deformity, rigid internal stabilization and autogenous bone grafting followed by prolonged immobilization and limited weight bearing. If it is technically impossible to achieve rigid fixation, if the patient is unable or unwilling to tolerate an extended period of inactivity or if low transcutaneous oxygen levels in

Table I

Data on 10 Diabetic Patients Who Underwent Arthrodesis for Charcot Arthropathy

Patient no.	Treatment	Sex	Age, yr	Side	Diabetes mellitus			Other diagnoses	Follow-up, mo	Outcome
					Type	Duration, yr	Treatment			
1	TTC, supracondylar nail	F	64	L	II	6	Insulin	Retinopathy, HTN, obesity	11	Fibrous union, well aligned, pain free
2	TTC, supracondylar nail	F	55	L	II	10	Insulin	HTN, IHD, obesity	12	Fibrous union, well aligned, pain free
3	Lisfranc fusion	M	69	R	II	25	OH	HTN	12	Solid arthrodesis
4	Lisfranc fusion	M	63	R	II	12	OH	HTN, IHD	13	Solid arthrodesis
5	TTC, supracondylar nail	F	51	L	II	6	OH	Obesity	24	Solid arthrodesis
6	TTC, supracondylar nail	F	63	L	II	15	Insulin		30	Fibrous union, well aligned, pain free, uses cane
7	TTC, supracondylar nail	F	65	R	II	30	OH	Schizophrenia	30	Solid arthrodesis
8	TTC, supracondylar nail	M	68	L	II	15	Insulin	HTN, gout, retinopathy	30	Pain, nonunion, below-knee amputation booked
9	Lisfranc fusion	M	68	L	II	20	OH	Retinopathy, HTN	34	Solid arthrodesis
10	TTC, supracondylar nail	M	66	R	II	30	Insulin	IHD, HTN	37	Fibrous union, well aligned, pain free

TTC = tibiotalocalcaneal arthrodesis, L = left, R = right, OH = oral hypoglycemic drugs, HTN = hypertension, IHD = ischemic heart disease.

the foot may prevent wound healing,[11] amputation may be indicated.

With an aging population and improved screening methods, diabetes and the long-term sequelae of this disease are becoming an area of increased focus and demand on the health care system. Proper care of the diabetic foot attracts immense interest at major diabetic clinics throughout the country, mainly owing to the growing number of patients suffering from complications of diabetic foot. Preventing a Charcot collapse of the foot by early recognition is the ideal method of management. Proper patient and physician education, improved clinical evaluation and early intervention are gradually achieving this goal. However, once a Charcot collapse and ulceration are present, saving the affected extremity may be better for the patient both physically and psychologically. This study confirms the findings of other published clinical series that most of the diabetic patients have low physical demand and are satisfied when their extremity is saved.[1–7]

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