An Original Study

Surgical Stabilization of Nonplantigrade Charcot Arthropathy of the Midfoot

Michael S. Pinzur, MD, and James Sostak, MD

Abstract

Fifty-one adults (28 men, 23 women) with Charcot arthropathy of the midfoot underwent surgical correction. Mean patient age was 58 years (SD, 9.9 years). All affected feet were nonplantigrade and at high risk for ulcers. Before surgery, mean lateral talar–first metatarsal angle was 27.6° (SD, 12.8°). Corrective osteotomy was performed to achieve plantigrade alignment. At minimum 1-year follow-up, 44 of 51 patients had the desired outcome. Mean lateral talar–first metatarsal angle had decreased to 6.4° (SD, 7.7°). Despite its associated high complication rate, corrective osteotomy can help patients become ulcer- and infection-free and maintain their ability to walk with commercially available therapeutic footwear. A treatment algorithm is presented.

Treatment for Charcot foot arthropathy—ranging from accommodative bracing of the acquired deformity to surgical stabilization at the initiation of the acute disease process—is extremely controversial, likely because of lack of a universally accepted definition of favorable or desired outcome. Our current treatment goal is for patients to maintain the ability to walk independently with an ulcer- and infection-free foot, over time, with commercially available therapeutic footwear. We started with the assumption that most patients could be treated without surgery,[1] but eventually we found that patients with sufficient deformity to apply weight-bearing loads to nonplantar skin (ie, a nonplantigrade foot) were more likely to develop skin ulceration and deep infection or osteomyelitis over that deformity.[1-3] On review, investigators learned that approximately 60% of patients with Charcot arthropathy of the midfoot could satisfy our arbitrary definition of desired outcome when initially treated with a weight-bearing total-contact cast and managed longitudinally with commercially available depth-inlay shoes and custom accommodative foot orthoses.[3,4] In the treatment algorithm that evolved, surgical stabilization is recommended when patients are clinically nonplantigrade or when they develop nonplantigrade deformity during treatment with a weight-bearing total-contact cast (Figure 1).

As reported here, the experience of a single surgeon treating a high-risk population of patients with nonplantigrade Charcot arthropathy of the midfoot led to the creation of a decision-making algorithm. Despite the high complication rate of treatment, many of these patients can become ulcer- and infection-free and maintain their ability to walk with commercially available therapeutic footwear. It is hoped that this algorithm will help surgeons avoid surgery in patients without deformity and will decrease surgically associated morbidity in patients in whom correction of deformity appears essential.

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Indications for Surgery

Patients who are not clinically plantigrade or who have a nonlinear lateral talar–first metatarsal axis on weight-bearing plain films are more likely develop skin ulceration over the bony deformity and appear to be best treated with deformity correction[2,3] (Figure 2). These patients apply weight-bearing forces to tissues that normally do not accept such loads. The most common nonplantigrade deformity is associated with dorsal-lateral subluxation/dislocation of the talonavicular joint. In these patients, weight-bearing and eventual tissue breakdown occur over the medial skin underlying the "uncovered" talar head. The second pattern involves rotational deformity of the forefoot relative to the hindfoot, with the weight-bearing forces now being applied to the lateral border of the forefoot (Figure 3). The measured talar–first metatarsal angle is nonlinear in these patients. The noncompensated "rocker-sole" deformity has a prominent plantar bony deformity without necessarily possessing a linear lateral talar–first metatarsal axis.

Description of Surgery

The nonplantigrade deformity is addressed by performing a wedge resection of sufficient bone at the apex of the deformity (ie, partial tarsectomy) to create a plantigrade foot. Stabilization was initially accomplished with crossed

Dr. Pinzur is Professor of Orthopaedic Surgery and Rehabilitation, Loyola University Medical Center, Maywood, Illinois.
Dr. Sostak is Resident, Department of Orthopaedic Surgery, Medical College of Wisconsin, Milwaukee, Wisconsin.

Requests for reprints: Michael S. Pinzur, MD, Loyola University Medical Center, 2160 S First Ave, Maywood, IL 60153 (tel, 708-216-4993; fax, 708-216-1225; e-mail, mpinzu1@lumc.edu).

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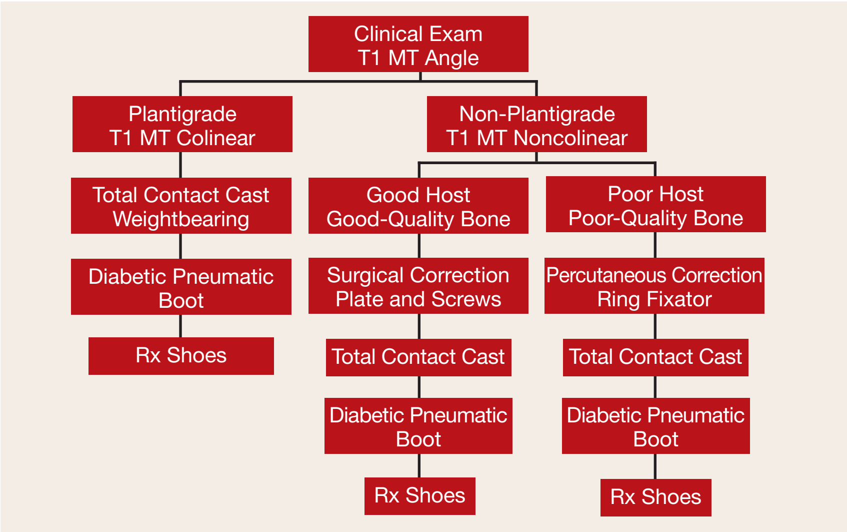

Figure 1. Treatment algorithm. (Abreviations: T1 MT= lateral talar 1st metatarsal angle; Rx = prescription) The initial treatment decision is based on clinical determination as to whether the weight-bearing surface of the foot is plantigrade and capable of working with a commercially available depth-inlay shoe and custom foot orthosis. A foot deemed plantigrade generally poses a colinear talar–first metatarsal angle, as measured from weight-bearing plain films. Surgical decision-making is described in the text.

7.0-mm cannulated screws in the first 18 patients.[1,5] It became apparent that a concentration of forces applied to the midfoot region during the stance phase of gait was responsible for overloading and bony failure in this region. There is disagreement whether this concentration of force results from simple motor imbalance caused by earlier motor neuropathy of the smaller motor nerves to the ankle dorsiflexor muscles or from static contracture when the gastrocnemius-Achilles tendon prevents the ankle from adequately dorsiflexing.[6-8] This pathophysiology was addressed by lengthening the gastrocnemius-Achilles tendon motor unit by gastrocnemius recession or percutaneous Achilles tendon lengthening.[9]

Crossed large-fragment screws appeared not to afford sufficient rigid internal fixation in regionally osteopenic bone to allow weight-bearing in a total-contact cast after surgery. A stabilization construct combining a small-fragment (3.5 mm) dynamic compression plate and large-fragment (6.5 mm) screws was used in the next 22 patients (Figure 4).

The next step in the evolution of the decision-making algorithm involved patients considered at high risk either for failure of mechanical stabilization due to severely osteopenic bone or for deep wound infection due to osteomyelitis present at time of surgery. After the gastrocnemius-soleus musculotendinous motor unit was lengthened, surgical correction of the deformity was accomplished through a small incision at the apex of the deformity. An oscillating saw was used to remove enough of a wedge of bone to make the foot plantigrade and to correct any rotational deformity. The correction was then maintained with a 3-level fine-wire-ring external fixator (Figure 5).

Bone infection was treated with resection of the infected bone during partial tarsectomy and corrective osteotomy. Culture-specific parenteral antibiotic therapy was used for a minimum of 6 weeks and was often followed by oral antibiotic therapy (under consultation with Infectious Disease) for a variable period. Patients treated with crossed-screw or screw-plate internal fixation constructs were treated with a weight-bearing total-contact cast for 6 to 8 weeks after surgery and then with a pneumatic diabetic walking boot until the volume of the limb stabilized. Patients treated with ring external fixation were to wear a weight-bearing total-contact cast for 4 to 6 weeks after the 6 to 8 weeks of external fixation. Given the morbid obesity of this population, patients could not maintain non–weight-bearing status.[10] Offloading with a walker or crutches was encouraged, but patients did not adhere to this recommendation.

Methods

Fifty-one consecutive patients (28 men, 23 women) with diabetes-associated Charcot arthropathy between the talonavicular and tarsal-metatarsal joints underwent surgical stabilization by a single surgeon over a 79-month period. All patients had been diagnosed with diabetes mellitus on the basis of American Diabetes Association criteria.[11] All were categorized as late Eichenholtz stage II or as stage III.[12] Mean age was 58.0 years (SD, 9.92 years). Mean follow-up was 33.22 months (SD, 21.25 months). Patients were advised to undergo surgery when, in the opinion of the treating orthopedic foot and ankle surgeon, they were clinically considered nonplantigrade and would not be able to use commercially available therapeutic footwear. Patients were considered nonplantigrade when they exhibited one of the 3 weight-bearing patterns described earlier. The lateral talar–first metatarsal angle was retrospectively measured from weight-bearing anteroposterior x-rays obtained before surgery and at longitudinal follow-up. Patients were excluded if they had a plantigrade foot that could be successfully managed without surgery.[3]

There were 3 evolutionary phases in the decision-making algorithm (Figure 1). In the first phase, 18 surgical patients underwent excision of bone at the apex of the deformity (ie, partial tarsectomy) and stabilization with crossed 7.0-mm cannulated screws. The second phase of treatment (22 patients) was characterized by addition of musculotendinous lengthening of the gastrocnemius-soleus motor unit and more rigid internal fixation with the screw-plate construct described earlier. The third phase attempted to address 11 patients who had wounds over the deformity, who had bony infection, or who appeared to be at increased risk for mechanical failure due to poor-quality bone.

A successful treatment outcome was defined as maintenance of walking independence with an ulcer- and infec-

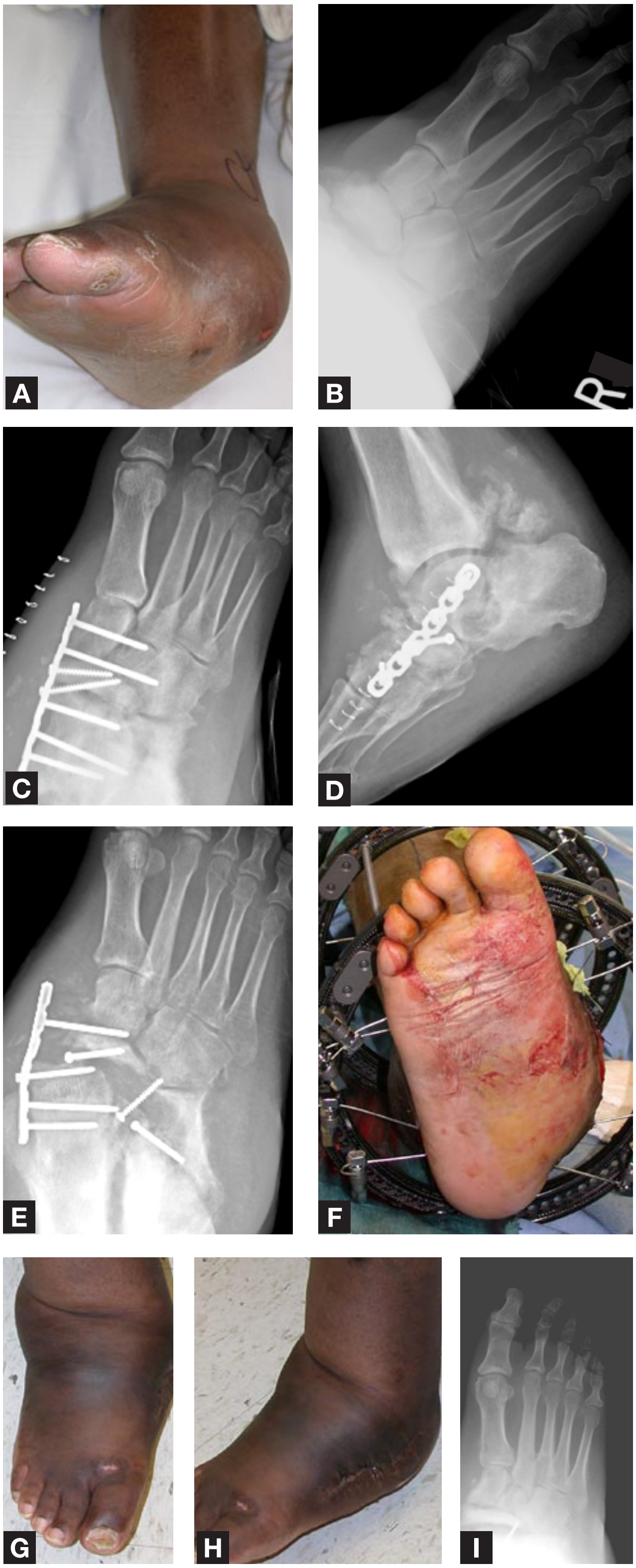

Figure 2. **(A)** This 400-pound man with diabetes developed repeated ulcers under the talar head. **(B)** For this standing plain film, he could not maintain non–weight-bearing status. **(C,D)** Initial surgery included percutaneous Achilles tendon lengthening and deformity correction. **(E)** Despite attempts to limit weight-bearing in a cast, surgery was unsuccessful in maintaining correction. **(F)** Correction was tried again; stabilization was achieved with a ring external fixator apparatus. **(G,H)** At 1 year, the patient was ambulating with therapeutic footwear. **(I)** Weight-bearing film at 1 year.

Figure 3. **(A)** Weight-bearing dorsal-plantar plain film of colinear lateral talar–first metatarsal axis. **(B)** The lateral weight-bearing radiograph reveals a rotational deformity. This deformity is best treated with corrective osteotomy.

tion-free foot and being managed longitudinally with commercially available therapeutic footwear (ie, depth-inlay shoes and custom accommodative foot orthoses).

Results

At the minimum follow-up, 1 year (mean, 33.2 months), 44 of 51 patients had the desired outcome of walking independently with an ulcer- and infection-free foot and being managed longitudinally with commercially available depth-inlay shoes and custom accommodative foot orthoses. Mean lateral talar–first metatarsal angle was 27.61° (SD, 12.78°) before surgery and 6.44° (SD, 7.70°) at follow-up. One patient had died (unrelated cause). Three patients in the first phase of experience underwent transtibial amputation for unresolvable infection, inability to maintain bony alignment, or both. Three patients had a successful clinical result but felt more secure with a Charcot restraint orthotic walker or an ankle-foot orthosis. For 2 patients in the dynamic-compression-plate-and-screw group, the initial fusion healed, but they developed aseptic progression of the destructive Charcot arthropathy process to the ankle. Both cases resolved after successful ankle fusion (Figure 3). One patient in the ring-external-fixator group developed a tibial stress fracture, which resolved after immobilization in a weight-bearing below-knee total-contact cast. Three patients had persistent plantar ulcers, which resolved after secondary excision of prominent bony exostoses plus culture-specific parenteral antibiotic therapy.

Figure 4. (A,B) In this 57-year-old man with diabetes, the ulcer at the apex of the "rocker-bottom" deformity could not be resolved with standard treatment. **(C,D)** Preoperative weight-bearing x-rays. **(E,F)** Plain films after successful bony union. **(G,H)** Photograph and lateral film 2 years after resection of the deformity and surgical stabilization.

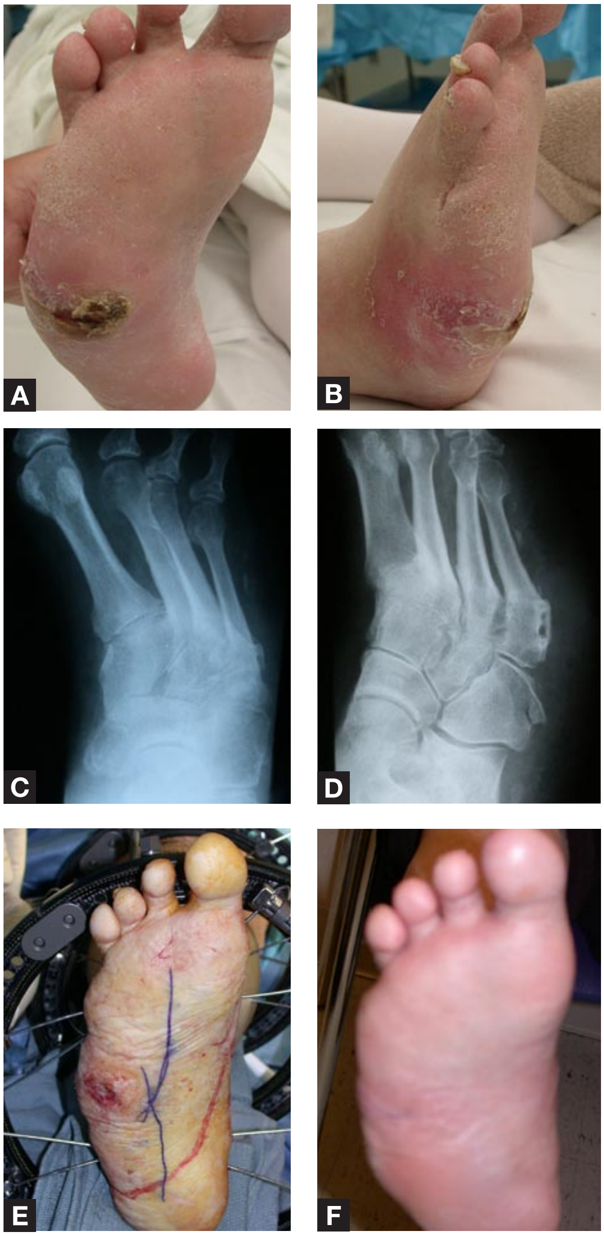

Figure 5. (A,B) This woman with long-standing diabetes had recurring infections in the lateral border of the foot and multiple surgeries, including a fifth ray resection; she could not be accommodated with custom footwear. **(C,D)** Preoperative weight-bearing plain films. **(E)** A wedge of infected bone was resected at the apex of the deformity and removed; after correction of the rotational deformity, the forefoot was aligned with the hindfoot; stabilization was achieved with a ring external fixator. **(F,G)** At 1 year, the patient could ambulate with commercially available therapeutic footwear.

Discussion

The American Orthopaedic Foot and Ankle Society (AOFAS) Diabetic Foot Questionnaire developed convincing evidence that Charcot foot arthropathy severely impairs patients' quality of life.[13] People who develop Charcot foot arthropathy are often morbidly obese and are prone to the diabetes-associated morbidities of vision loss, cardiac vascular, and renal disease.[3,5,10] Starting with the premise that most patients with Charcot arthropathy of the foot can be managed with accommodative bracing, it became apparent that their cumbersome bracing and constant wound issues were significant factors in impairing their quality of life.[1,13,14]

On the basis of this experience, a treatment algorithm was developed (Figure 1). The first step is determining which patients cannot satisfy our arbitrary definition of a favorable outcome without surgical correction of deformity. The second decision point is more subjective. Smaller patients with no open wounds, no history of deep infection, good quality bone, and minimal medical comorbidities can be successfully surgically treated with any of several methods of internal or external fixation.[1,15-18]

Conclusions

This investigation represents the evolving experience of a single surgeon attempting to correct Charcot midfoot deformities in the patient population at highest risk. An arbitrary definition of a successful outcome includes maintenance of walking independence with an ulcer- and infection-free foot and longitudinal management with commercially available therapeutic footwear.

The experience-based algorithm that was developed limits surgery to patients who cannot have a favorable outcome without deformity correction. When that surgery is advised, we attempt to determine which patients can be managed with traditional surgery and which require "masters" techniques. Despite the high complication rate of treatment, most patients can satisfy our arbitrarily defined favorable outcome.

Authors' Disclosure Statement and Acknowlegments

Dr. Pinzur wishes to note that he is a consultant for DePuy Orthopaedics Inc., Warsaw, Indiana, and for Small Bone Innovations, Morrisville, Pennsylvania.

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References

1. Pinzur MS, Sage R, Stuck R, Kaminsky S, Zmuda A. A treatment algorithm for neuropathic (Charcot) midfoot deformity. *Foot Ankle Int*. 1993;14:189-197.
2. Bevan WP, Tomlinson MP. Radiographic measure as a predictor of ulcer formation in midfoot Charcot. *Foot Ankle Int*. In press.
3. Pinzur MS. Surgical vs. accommodative treatment for Charcot arthropathy of the midfoot. *Foot Ankle Int*. 2004;25:545-549.
4. Pinzur MS, Lio T, Posner M. Treatment of Eichenholtz stage I Charcot foot arthropathy with a weight bearing total contact cast. *Foot Ankle Int*. 2006;27:324-329.
5. Pinzur MS. Benchmark analysis of diabetic patients with neuropathic (Charcot) foot deformity. *Foot Ankle Int*. 1999;20:564-567.
6. Herbst SA, Jones KB, Saltzman CL. Pattern of diabetic neuropathic arthropathy associated with the peripheral bone mineral density. *J Bone Joint Surg Br*. 2004;86:378-383.
7. Ledoux WR, Shofer JB, Ahroni JH, Smith DG, Sangeorzan BJ, Boyko EJ. Biomechanical differences among pes cavus, neutrally aligned, and pes planus feet in subjects with diabetes. *Foot Ankle Int*. 2003;24:845-850.
8. Mueller MJ, Sinacore DR, Hastings MK, Strube MJ, Johnson JE. Effect of Achilles tendon lengthening on neuropathic plantar ulcers. *J Bone Joint Surg Am.* 2003;85:1436-1445.
9. Hansen ST Jr. Diabetic Foot Problems. In: Hansen ST Jr, ed. *Functional Reconstruction of the Foot and Ankle*. Philadelphia, Pa: Lippincott Williams & Wilkins; 2000:246-247.
10. Pinzur MS, Freeland R, Juknelis D. The association between body mass index and diabetic foot disorders. *Foot Ankle Int.* 2005;26:375-377.
11. American Diabetes Association. Clinical practice recommendations 2004. *Diabetes Care*. 2004;27(suppl 1).
12. Eichenholtz SN. *Charcot Joints*. Springfield, Ill: Charles C. Thomas; 1966.
13. Dwahan V, Spratt K, Pinzur MD, Baumhauer J, Rudicel S, Saltzman CL. The AOFAS Diabetic Foot Questionnaire: stability, internal consistency, and measurable difference. *Foot Ankle Int*. 2005;26:717-731.
14. Pinzur MS, Evans A. Health related quality of life in patients with Charcot foot. *Am J Orthop*. 2003;32:492-496.
15. Early JS, Hansen ST. Surgical reconstruction of the diabetic foot. *Foot Ankle Int.* 1996;17:325-330.
16. Farber DC, Juliano PJ, Cavanagh PR, Ulbrecht J, Caputo G. Single stage correction with external fixation of the ulcerated foot in individuals with Charcot neuroarthropathy. *Foot Ankle Int*. 2002;23:130-134.
17. Papa J, Myerson M, Girard P. Salvage, with arthrodesis, in intractable diabetic neuropathic arthropathy of the foot and ankle. *J Bone Joint Surg Am*. 1993;75:1056-1066.
18. Simon SR, Tejwani SG, Wilson DL, Santner TJ, Denniston NL. Arthrodesis as an early alternative to nonoperative management of Charcot arthropathy of the diabetic foot. *J Bone Joint Surg Am.* 2000;82:939-950.