Tibiotalocalcaneal Arthrodesis with Retrograde Intramedullary Nail in Patients with Charcot Neuroarthropathy of the Ankle and Hindfoot

Ana C. Parise, Virginia M. Cafruni, N. Marina Carrasco, Julián M. Parma, Julieta Brué, Daniel S. Villena, Leonardo Á. Conti, Pablo Sotelano, María Gala Santini Araujo

Foot and Ankle Medicine and Surgery Department, Hospital Italiano de Buenos Aires, Autonomous City of Buenos Aires, Argentina.

ABSTRACT

Introduction: Tibiotalocalcaneal (TTC) arthrodesis is the treatment of choice for the surgical management of Charcot neuroarthropathy (CN) affecting the ankle. The primary goal is to avoid major amputation and restore a functional lower limb suitable for ambulation, thereby improving patients' quality of life. **Objective:** To describe the clinical and radiological characteristics and evolution of patients with diabetes mellitus and Charcot neuroarthropathy who underwent TTC arthrodesis using a straight retrograde intramedullary compression nail. **Materials and Methods:** This retrospective case series included consecutive patients with CN of the ankle and hindfoot and diabetes mellitus who underwent TTC arthrodesis with a retrograde intramedullary nail. Radiographic union, complications, reoperations, limb salvage, and preoperative metabolic parameters (serum albumin and HbA1c) were evaluated. **Results:** Eight patients were included, with a median follow-up of 58 months (IQR 40.75–75.5). The median preoperative HbA1c was 6.6% (IQR 5.7–7), and the median serum albumin level was 3.41 g/dL (IQR 3.05–3.71). Three patients required revision surgery. Radiographic union was achieved in seven patients; two developed stable fibrous union, and one patient remains under follow-up. No patient required amputation. **Conclusions:** TTC arthrodesis with a retrograde intramedullary nail is a viable surgical option for diabetic patients with Charcot neuroarthropathy involving the ankle. Optimizing preoperative metabolic status and comorbidities, along with appropriate management of osteomyelitis, is essential to reduce complications and promote bone healing.

Keywords: Charcot neuroarthropathy; ankle; hindfoot; diabetes mellitus; tibiotalocalcaneal arthrodesis; retrograde intramedullary nail.

Level of Evidence: IV

Artrodesis tibio-talo-calcánea con clavo endomedular retrógrado en pacientes con neuro-osteoartropatía de Charcot de tobillo y retropié

RESUMEN

Introducción: La artrodesis tibio-talo-calcánea es el tratamiento de elección para la corrección quirúrgica de la neuro-osteoartropatía de Charcot que compromete el tobillo. El objetivo es evitar la amputación mayor y lograr un miembro inferior apto para la deambulación y así mejorar la calidad de vida. **Objetivo:** Describir las características y la evolución clínica y radiológica de los pacientes con diabetes mellitus y neuro-osteoartropatía de Charcot que se sometieron a una artrodesis tibio-talo-calcánea con un clavo endomedular retrógrado recto con compresión. **Materiales y Métodos:** Serie de casos retrospectiva de pacientes consecutivos con neuro-osteoartropatía de Charcot del tobillo y retropié, y diabetes, sometidos a una artrodesis tibio-talo-calcánea con un clavo endomedular retrógrado. Se evaluaron la consolidación radiológica, las complicaciones y reoperaciones, el salvataje del miembro y los parámetros metabólicos preoperatorios (albúmina sérica y HbA1c). **Resultados:** Se incluyó a 8 pacientes con un seguimiento de 58 meses (RIC 40.75-75.5). La HbA1c preoperatoria fue del 6,6% (RIC 5,7-7) y la albúmina, de 3,41 g/dl (RIC 3,05-3,71). Tres requirieron una cirugía de revisión. En 7 pacientes, se observó la consolidación, dos de ellos desarrollaron una consolidación fibrosa estable y uno continúa en seguimiento. Ninguno requirió una amputación. **Conclusiones:** La artrodesis tibio-talo-calcánea con clavo endomedular retrógrado es una opción válida en pacientes con diabetes y neuro-osteoartropatía de Charcot que compromete el tobillo. La optimización de los parámetros metabólicos preoperatorios y las comorbilidades, y el tratamiento de la osteomielitis son necesarios para disminuir las complicaciones y favorecer la consolidación.

Palabras clave: Neuro-osteoartropatía de Charcot; retropié; tobillo; diabetes mellitus; artrodesis tibio-talo-calcánea; clavo endomedular retrógrado.

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Received on February 11th, 2025. Accepted after evaluation on February 24th, 2025 • Dr. ANA C. PARISE • ana.parise@hospitalitaliano.org.ar https://orcid.org/0000-0001-7308-3693

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INTRODUCTION

Charcot neuroarthropathy (CN) is a rare but serious and debilitating complication of diabetes mellitus (DM), typically occurring in patients with peripheral neuropathy. It is a progressive, non-infectious inflammatory process that predominantly affects the foot and ankle. CN affects approximately 0.1% to 5% of individuals with DM and may present bilaterally in 5.9% to 39.3% of cases.[1]

The midfoot is the most commonly affected site, followed by the hindfoot (34%). Involvement of the ankle is less frequent (11%), but it is often associated with joint instability and progressive deformity, which frequently lead to ulceration.[2] The primary treatment during the acute phase of CN consists of immobilization and offloading. For cases involving the ankle and hindfoot, conservative management may require prolonged immobilization until the disease becomes inactive; however, residual instability often persists.[3,4] Misalignment, bony prominences, and protrusion of the malleoli can interfere with footwear and support surfaces, increasing the risk of ulceration, osteomyelitis, and eventual amputation.[5]

Tibiotalocalcaneal (TTC) arthrodesis is the preferred surgical treatment for correcting Charcot neuroarthropathy of the ankle. Several internal and external fixation techniques have been described.[2,6] The objectives of surgical reconstruction in these patients include preventing major amputation (i.e., amputation proximal to the ankle), achieving a functional, weight-bearing limb suitable for ambulation and proper footwear, preventing ulceration and infection, and ultimately improving quality of life.[2,3]

The aim of this study was to describe the clinical and radiological characteristics and postoperative outcomes of patients with DM and Charcot arthropathy of the hindfoot and ankle who underwent TTC arthrodesis using a straight retrograde intramedullary nail with compression.

MATERIALS AND METHODS

A retrospective case series was conducted, including patients with diabetes mellitus (DM) and Charcot neuroarthropathy (CN) of the ankle and hindfoot who underwent tibiotalocalcaneal (TTC) arthrodesis with a straight retrograde intramedullary nail with compression, between January 2011 and December 2021.

This study was approved by the institution's Ethics Committee and complies with the principles of the Declaration of Helsinki and Good Clinical Practice guidelines. Data confidentiality was maintained in accordance with Argentine Personal Data Protection Law No. 25,326.

Inclusion criteria were: patients over 18 years of age, with a diagnosis of DM and unstable hindfoot and ankle CN (types 2, 3a, and 4 according to the Brodsky-Trepman classification), and a minimum postoperative follow-up of 2 years. Exclusion criteria included incomplete medical records and TTC arthrodesis performed for acute traumatic fractures.

Preoperative evaluation included anteroposterior and lateral foot and ankle radiographs, as well as computed tomography (CT) scans. Demographic characteristics and data related to DM diagnosis were recorded. All patients were assessed preoperatively by an interdisciplinary team to optimize metabolic and clinical conditions. Peripheral neuropathy was assessed using the Semmes-Weinstein monofilament test. Vascular status was evaluated via arterial Doppler ultrasound with measurement of the ankle-brachial index, complemented by a clinical examination by the Cardiovascular Surgery team.

Preoperative laboratory parameters included serum albumin levels (as a nutritional marker) and glycated hemoglobin (HbA1c) levels (as a metabolic control marker).

To determine the disease stage at the time of surgery, the Eichenholtz and Shibata classifications were used. Resolution of the acute resorptive phase was defined clinically by the absence of local signs of inflammation, such as erythema and elevated skin temperature compared to the contralateral foot and ankle.[7] The anatomical location of CN was classified according to the Brodsky-Trepman system.[8]

Additionally, the use of structural bone grafts or bioactive crystals during the procedure was recorded.

Postoperative systemic and local complications were evaluated. Local complications were categorized as infectious and non-infectious. A superficial infection was defined as one managed with local wound care and oral antibiotics, without hospitalization. A deep infection required hospitalization, intravenous antibiotics, and surgical debridement. Non-infectious complications included nonunion, symptomatic hardware removal, and periprosthetic fractures.[9] Re-ulceration events were also documented.

Radiological healing was considered to be the continuity of the bony fabric through the arthrodesis foci in the anteroposterior and laterolateral views, or in the computed tomography in the three planes of at least 50% of the fusion surface.[9] Nonunion was defined as failure to achieve fusion at the 12-month follow-up or the presence of catastrophic implant failure.[9] Fibrous union[10] was considered when there was no radiographic healing but no clinical or radiological signs of instability, and no revision surgery was required at the end of follow-up.

Surgical Technique

The procedure was performed under regional anesthetic block combined with general anesthesia. Patients were positioned in lateral decubitus, and a thigh tourniquet was applied. A lateral approach to the ankle and hindfoot was used. The distal fibula (5–10 cm) was resected, and debridement was carried out to remove fibrous tissue, articular debris, and loose fragments. The remaining tibiotalar and subtalar joint surfaces were prepared for fusion. Proper alignment of the tibia, talus, and calcaneus was ensured to maximize bony contact and achieve a plantigrade foot. In cases with significant bone defects, bone bank grafts (femoral head) or bioactive crystals were used. If the resected fibula presented good bone quality and additional bone was needed at the fusion site, it was ground and added as graft material. The target foot position was 0° dorsiflexion, 5° valgus, and 5–10° external rotation.

The patient was then repositioned to dorsal decubitus. A plantar incision was made for insertion of a guide pin, and its correct position was verified in all planes. The intramedullary canal was prepared with progressively larger drills. A straight retrograde intramedullary nail (Panta®, Integra LifeSciences, Plainsboro, NJ, USA) was inserted, and two distal locking screws were placed in the calcaneus. Compression was applied at the arthrodesis sites, followed by the placement of two proximal locking screws. A cast boot was then applied.

Postoperatively, antibiotic prophylaxis, analgesia, and thromboprophylaxis were administered. Patients were typically discharged 48 hours after surgery.

One week postoperatively, the initial cast was removed, surgical wounds were evaluated and dressed, and a new non-weight-bearing cast boot was applied. At 45 days postoperatively, the cast was replaced by a removable Charcot Restraint Orthotic Walker (CROW) boot, if available, and the patient remained non-weight-bearing. Immobilization and offloading durations were individualized, often prolonged due to the nature of the disease. Approximately 8 weeks after surgery, if clinical and radiological progress was favorable, patients began partial weight-bearing using a progressive boot. Full weight-bearing in custom-made footwear with orthotic support was allowed upon confirmation of bone healing. Patients unable to perform partial weight-bearing continued with complete offloading until clinical and radiological signs of healing were observed. In cases of intolerance to weight-bearing, progression was postponed. Follow-up assessments were conducted at 1 and 4 weeks postoperatively, and then monthly. At each visit, anteroposterior and lateral radiographs were obtained until healing was confirmed. If radiographs were insufficient, CT imaging was used. Once healing was confirmed, weight-bearing anteroposterior, lateral, and panoramic radiographs of the lower limbs were obtained.

Postoperative evaluation and follow-up were performed by an interdisciplinary team.

Statistical Analysis

Categorical variables are presented as absolute frequencies and percentages. Continuous variables with a normal distribution are expressed as mean and standard deviation, while those not meeting normality assumptions are reported as median and interquartile range (IQR). Statistical analyses were performed using Stata 17® Version 2021 (StataCorp LLC).

RESULTS

Eight patients (five men) were included in the study. The median age was 52.5 years (IQR 25-75%: 50–56), and the median duration from diabetes mellitus (DM) diagnosis to surgical intervention was 25.5 years (IQR 25-75%: 18.75–30). The median follow-up period was 58 months (IQR 25-75%: 40.75–75.5). Six patients had a history of foot ulcers at the arthrodesis site, all of which had healed by the time of surgery. None had a diagnosis of osteomyelitis at the time of the procedure. Six procedures required bone bank grafts, and one utilized bioactive crystals. The median preoperative HbA1c was 6.6% (IQR 25-75%: 5.7–7), and the median preoperative serum albumin was 3.41 g/dL (IQR 25-75%: 3.05–3.71). No patients presented with significant vasculopathy prior to surgery. According to the Eichenholtz classification, seven of the eight patients underwent surgery during stage III and one during stage II. Additional demographic characteristics are provided in Table 1.

Table 1. Demographic data.

	n = 8
Age, years, median (IQR)	52.5 (50-60)
Male sex, n (%)	5 (62.5)
Kidney failure, n (%)	1 (12.5)
Dialysis, n (%)	0 (0)
Kidney transplant, n (%)	1 (12.5)
Pancreas transplant, n (%)	1 (12.5)
Insulin-dependent, n (%)	3 (37.5)
Peripheral neuropathy, n (%)	8 (100)
Cardiopathy, n (%)	2 (25)
Retinopathy, n (%)	3 (37.5)
Obesity, n (%)	5 (62.5)
Smoking, n (%)	1 (12.5)
Dyslipidemia, n (%)	5 (62.5)
Hypothyroidism, n (%)	1 (12.5)
Previous amputation, n (%)	1 (12.5)
Time since diagnosis of diabetes, years, median (IQR)	25.5 (18.75-30)
Pre-operative glycated hemoglobin, median (IQR), %	6.6 (5.7-7)
Pre-surgical albumin, median (IQR), g/dl	3.41 (3.05-3.71)

IQR = interquartile range.

Three patients required revision arthrodesis: one due to implant failure following a fall and two due to nonunion (Figures 1 and 2). Revision procedures involved implant removal, debridement of the arthrodesis site, and re-arthrodesis using a new nail. All revision surgeries were preceded by optimization of metabolic parameters and comorbidities.

At the end of follow-up, seven patients had achieved stable healing of the TTC arthrodesis (Figures 3 and 4). Two developed fibrous healing, which allowed ambulation with orthotic support. One patient required a delayed revision and remains under follow-up. The median time to radiographic healing was 8.6 months (IQR 25-75%: 4.7–8.6).

Figure 1. Preoperative anteroposterior (**A**) and lateral (**B**) radiographs of the foot and ankle showing Charcot neuroarthropathy of the ankle.

Figure 2. Postoperative radiographs of the foot and ankle. **A.** Anteroposterior view showing nonunion with implant failure. **B.** Lateral view showing nonunion with implant failure. **C.** Anteroposterior view following revision arthrodesis showing signs of healing. **D.** Lateral view following revision arthrodesis showing signs of healing.

Figure 3. Preoperative anteroposterior (**A**) and lateral (**B**) radiographs of the foot and ankle. Marked bone destruction is observed, particularly involving the talus (hindfoot).

Figure 4. Anteroposterior (**A**) and lateral (**B**) radiographs of the foot and ankle taken four years postoperatively. Bone healing is evident, with breakage of the distal locking screw during the healing process.

Complications are detailed in Table 2. Six patients experienced some form of complication requiring additional surgical intervention: three required re-arthrodesis, four underwent surgical debridement, and three required implant removal. In cases of deep infection, the implant was removed and targeted antibiotic therapy was administered according to sensitivity testing. All such patients showed favorable clinical and radiographic evolution of inflammatory parameters, and no recurrences were recorded. No patient required limb amputation during the follow-up period.

Table 2. Complications

Superficial infection	2
Deep infection	3
Rupture of the osteosynthesis material	1
Reulceration	2
Nonunion	2

DISCUSSION

This is the first published series in our country of patients diagnosed with diabetes mellitus (DM) and neuroarthropathy (CN) undergoing tibiotalocalcaneal (TTC) arthrodesis using a compressive retrograde intramedullary nail (Brodsky-Trepman types 2 and 3).

Patients with DM typically present with comorbidities and target organ damage, placing them at higher risk for postoperative complications and impaired bone healing. In our series, both preoperative and postoperative follow-up were conducted in an interdisciplinary manner; however, several postoperative complications and secondary surgeries were recorded. Nevertheless, by the end of follow-up, outcomes were satisfactory: 7 of 8 patients achieved stable healing and a plantigrade foot, and none required amputation.

Several studies have reported on patients with DM and CN treated with TTC arthrodesis using retrograde intramedullary nails. Limb salvage rates range between 77.8% and 100%[5,11-13] with average healing times of up to 12 months in this population.[14] Delayed union or nonunion occurs in approximately 22% of TTC arthrodeses, particularly in high-risk patients.[12,14] Additionally, rates of stable nonunion or fibrous union allowing ambulation—considered satisfactory outcomes—range from 4.4% to 22.2%.[3,5,11,12] In our study, primary radiographic healing was achieved in 3 patients, while 3 others required revision arthrodesis (1 due to a fall and 2 due to nonunion). At the end of follow-up, 7 patients had stable healing (5 with complete union and 2 with fibrous union allowing ambulation with bracing). One patient remains under follow-up. All limbs were salvaged.

Although 6 of the 8 patients experienced postoperative complications, all recovered favorably following appropriate treatment. Multiple studies have demonstrated higher complication rates in patients with DM undergoing ankle or hindfoot arthrodesis.[4,7,15] Patients with complicated DM are ten times more likely to develop surgical site infections compared to those without DM, and six times more likely than patients with uncomplicated DM.[16] DM, peripheral neuropathy, peripheral vascular disease, HbA1c >7%, and tobacco use are associated with increased postoperative infection rates. Similarly, DM, preoperative blood glucose >200 mg/dL, smoking, and solid organ transplantation are associated with a higher risk of non-infectious complications.[15] In one series, all patients who developed complications had preexisting ulcers of more than 6 months' duration.[12] In our series, the two patients without a history of ulceration experienced postoperative complications, while two patients with prior ulcers did not, suggesting that larger series are needed for statistically significant conclusions. For patients with a history of ulceration or infection, active infection should be ruled out prior to reconstructive surgery.[4]

Richman et al. reported 11 revision surgeries in 14 patients with CN treated with intramedullary nailing.[17] Caravaggi et al. documented 14 reoperations among 45 patients, including major amputations.[11] Regauer et al., in their series of midfoot and hindfoot CN reconstructions, reported a complication rate of 89% and a revision surgery rate of 46%.[18] In our study, 3 revision arthrodeses, 4 surgical debridements, and 3 implant removals were performed during follow-up; nevertheless, as in other similar series, limb salvage rates remained high at final follow-up.[11,17]

Individualized treatment selection and preoperative optimization of metabolic parameters and comorbidities are essential to minimizing the risk of complications.[19]

Major amputation rates of up to 20% have been reported following TTC arthrodesis with retrograde intramedullary nailing.[12,13] DM has been identified as a risk factor for amputation,[13] and uncontrolled DM as a predictor of TTC arthrodesis failure.[20] Preoperative assessment, inpatient management, and follow-up should all be conducted by an interdisciplinary team. Surgical indications should be individualized based on metabolic status, comorbidities, vascular health, and bone stock, in order to determine the feasibility of reconstruction and fixation method. Patients should be fully informed regarding surgical risks, recovery timelines, and the need for offloading strategies in the postoperative period.

Long-term glycemic control appears to be a modifiable risk factor for reducing postoperative complications. Although the relationship between HbA1c levels and bone healing remains inconclusive, values >7% have been associated with impaired bone healing.[21] Additionally, perioperative HbA1c >7.5% has been identified as a significant risk factor for surgical site infections.[22] Although our case series is too small for statistically significant conclusions, we consider HbA1c an important factor in preoperative planning and recommend individualized, interdisciplinary assessment. The median preoperative HbA1c in our series was 6.6% (range: 5.7–7). One of the three patients who progressed to nonunion had a preoperative HbA1c >8%. Following metabolic optimization, this patient's HbA1c decreased to 6.9% prior to revision surgery, after which healing was achieved without further complications.

Some authors have used serum albumin as a marker of nutritional status in orthopedic patients. Albumin levels <3.5 g/dL have been associated with increased postoperative complications,[23] and levels <2.5 g/dL with a higher risk of wound complications in patients with DM.[24] The median preoperative albumin level in our series was 3.41 g/dL. Notably, 2 of the 3 patients requiring revision arthrodesis had albumin levels <3.5 g/dL. The evidence remains inconclusive and is largely based on retrospective studies. Further research is warranted to assess nutritional status as a potential factor influencing postoperative outcomes in patients with DM undergoing foot and ankle surgery.

Traditionally, surgical reconstruction in CN was deferred until the inactive phase—characterized by resolution of soft tissue edema, temperature normalization, and cessation of bone destruction—to reduce postoperative complications. However, this paradigm is being reexamined. Wukich et al. suggest that delaying surgery until severe deformities or bone loss occur may not be necessary; instead, they advocate treating active CN similarly to intra-articular fractures or dislocations in selected patients.[25] This strategy is viable when supported by interdisciplinary care that enables better metabolic and comorbidity control, reduces complications and reinterventions, improves healing rates and timelines, shortens recovery, and enhances quality of life—ultimately lowering the socioeconomic burden of CN treatment.

A limitation of our study is its retrospective design and small sample size. Nevertheless, one strength is the inclusion of consecutive cases managed by the same interdisciplinary team at a single institution, with outcomes comparable to those in international series. Moreover, given the limited regional literature on this topic, understanding the characteristics and outcomes of our patient population is essential for improving treatment strategies. Another strength is the incorporation of serum albumin measurement as a preoperative nutritional assessment parameter.

CONCLUSIONS

Tibiotalocalcaneal (TTC) arthrodesis using a retrograde intramedullary nail with compression is a viable surgical option for limb salvage in patients with DM and CN of the ankle and hindfoot who are at risk for major amputation.

This patient population is characterized by a high incidence of complications, reoperations, and delayed or difficult healing, often resulting in a prolonged postoperative course requiring continuous monitoring and care. Nevertheless, the long-term limb salvage rate remains high. Optimization of metabolic parameters and comorbidities—both preoperatively and throughout follow-up—may help reduce complication rates. Additionally, it is critical to rule out osteomyelitis in patients with a history of ulceration.

Comparative, multicenter studies with larger patient cohorts are needed to obtain statistically significant results.

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V. M. Cafruni ORCID ID: https://orcid.org/0000-0002-8115-6300
N. M. Carrasco ORCID ID: https://orcid.org/0000-0002-1251-4936
J. M. Parma ORCID ID: https://orcid.org/0000-0003-0337-289X
J. Brué ORCID ID: https://orcid.org/0000-0001-8378-0863
D. S. Villena ORCID ID: https://orcid.org/0000-0001-5742-1226
L. Á. Conti ORCID ID: https://orcid.org/0000-0003-2333-5834
P. Sotelano ORCID ID: https://orcid.org/0000-0001-8714-299X
M. G. Santini Araujo ORCID ID: https://orcid.org/0000-0002-5127-5827

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