Calcaneotalotibial arthrodesis by retrograde intramedullary nailing for Charcot osteo-neuroarthropathy of the foot and ankle

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Background
The Charcot's foot and ankle presents a significant and complex clinical challenge for foot and ankle surgeons. Neuropathic arthropathy of the foot and ankle is a degenerative deformity that gradually worsens over time. It is most frequently observed in individuals with diabetic neuropathy.
Aim and objectives
To evaluate the efficacy, advantages, and disadvantages of calcaneotalotibial arthrodesis by retrograde intramedullary nailing for Charcot osteo-neuroarthropathy of the ankle.
Patients and methods
This prospective research was done on 20 cases with Charcot osteoarthropathy of the ankle using calcaneotalotibial interlocking nails at Helwan University Hospital, Al Helal Hospital, Boulak El Dakror General Hospital, and Kasr Al Ainy Hospital during the period between January 2021 and January 2022.
Results
Patients had both types of diabetes mellitus. As regard complications, they occurred in seven (35%) patients as follows: one patient had an intraoperative distal tibial crack during nail introduction, two patients had loosening of proximal screws and infection, three patients had skin infection at the site of distal screws, and one patient had deep infection improved with parenteral antibiotics. There was a statistically significant improvement in the American Orthopedic Foot and Ankle Society score among the studied patients with a *P* value less than 0.001.
Conclusion
We observed a satisfactory result in the treatment of severe abnormalities of the ankle and hind foot in Charcot neuroarthropathy utilizing the retrograde intramedullary arthrodesis nail. The transcalcaneal retrograde intramedullary represents a safe and efficacious fixation option.

Keywords:
calcaneotalotibial interlocking nail, Charcot ankle, diabetic neuropathy

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Introduction

The Charcot foot and ankle pose significant challenges and difficulties for foot and ankle surgeons, making it one of the most difficult clinical issues they encounter. Neuropathic arthropathy of the foot and ankle is a destructive deformity that gradually worsens over time. It is primarily observed in individuals with diabetic neuropathy. The beginning of this condition is gradual, and its consequences typically result in severe impairment. Patients with diabetic Charcot neuroarthropathy of the foot and ankle are most likely to need lower extremity amputation [1].

Additional disorders that may be associated with the presence of Charcot neuroarthropathy include CP, leprosy, myelomeningocele, tabes dorsalis, alcoholism, polio, congenital insensitivity to pain, syringomyelia, and tertiary syphilis [2].

The mainstay of conservative treatment is immobilization and repeated total-contact cast, which is the most accessible and utilized modality for decreasing swelling and maintaining stability. For the treatment of osteopenia, pharmacologic therapy with anti-resorptive drugs is used [3].

Surgical management includes arthrodesis using intramedullary nailing, plates, screws, stables, Illizarov fixator, or a combination of more than one of these methods [2,4].

Unless managed early, the result of Charcot's ankle may be amputation, which has been designated for prior surgical failure, arthrodesis instability, recurrent ulceration, or infection [5,6].

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Intramedullary nailing in the fusion of Charcot's ankle is increasing in popularity. It gives more stiffness and increases stability, which helps increase the fusion rate. It also provides a simple technique with less soft tissue invasion. The advancements have shown promising surgical results with increased rates of healing [7].

The objective of this research was to assess the efficacy, advantages, and disadvantages of calcaneotalotibial arthrodesis by retrograde intramedullary nailing for Charcot osteo-neuroarthropathy of the ankle.

Patients and methods

This prospective research was done on 20 cases with Charcot osteoarthropathy of the ankle using calcaneotalotibial interlocking nails at Helwan University Hospital, Al Helal Hospital, Boulak El Dakror General Hospital, and Kasr Al Ainy Hospital during the period between January 2021 and January 2022. The study was approved by the Faculty of Medicine Helwan University Research Ethics Committee. All participants were signed an informed consent before inclusion in the study.

The surgical treatment was consistently done throughout the quiescent phase of the illness, which is characterized by the lack of infection symptoms, edema, and disparity in skin temperature between both feet, as indicated by the classifications of Eichenholtz [8].

Inclusion criteria: patients of both sexes, patients with or without fractures, patients with deformed feet and ankles, and active patients with failed conservative methods of treatment, patients with HbA1C less than or equal to 7%.

Exclusion criteria: bed-ridden patients, presence of active infections, critically ill patients, patients with poor skin or soft tissue condition, patients having malalignment, blocked and/or deformed medullary canal of the tibia, which may interfere with nail introduction, and patients having severe vascular disease affecting vitality of the limb.

Preoperative evaluation

All patients were subjected to full history taking, local examination of the ankle, grading of ulcer, radiological investigations (plain anteroposterior, lateral and oblique radiograph films, and computed tomography ankle and/or Duplex study if needed), and laboratory tests.

Operative procedure

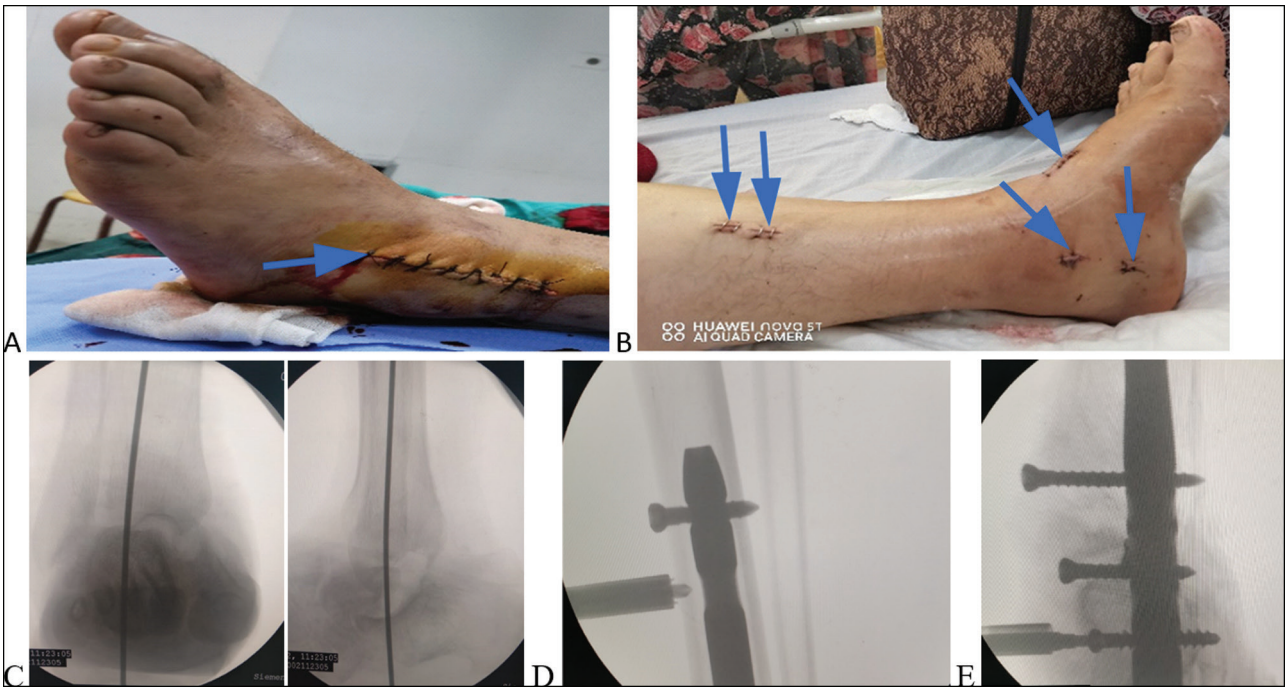
Lying flat on the back with the heel positioned at the edge of the operation table. The patient's back on the same side was raised until the entire lower limb was in a strictly upward posture. A tourniquet may be needed in open cases (in which joint preparation is done) and deflated after joint preparation (we did not have any complications of this in our cases) and was applied to the thigh at a pressure of 350 mmHg. The procedure was done under general or spinal anesthesia. Preoperative and postoperative prophylactic antibiotics were given. Complete antiseptic technique to minimize the risk of infection. Sterilization of the whole leg, ankle, and foot by povidone–iodine. To access the ankle and subtalar joints for reduction, drilling, cartilage excision, and curettage of subchondral bone, an anteromedial or anterolateral approach to the ankle is utilized. In certain instances, these procedures have been executed percutaneously, requiring only an incision on the entry site and for locking screws. Correct ankle positioning before reaming was done by putting the ankle in the neutral position in about 90° of dorsiflexion with 5°s of external rotation and 5° of hind foot valgus.

Entry point: like with the majority of nail insertion operations, accurate placement of the initial point is crucial. The entry point was determined under anteroposterior and lateral ankle views under the C-arm. It is at the point of transection of the longitudinal axis of the calcaneus and the bimalleolar axis of the tibia anterior to subcalcaneal fat pad. A line is drawn in the sagittal plane from the point of the second toe to the middle of the heel, and another line is drawn in the coronal plane that divides both malleoli. A small calcaneal incision was done over the plantar aspect, and a guide wire was advanced proximally from the calcaneus to the tibia with the guidance of the fluoroscopy through the talus.

Reaming: reamer was introduced over the guide wire and advanced through the calcaneus, talus, and tibial shaft. Flexible reamers were inserted sequentially.

Nail insertion: the tibial medullary canal was reamed 1–2 mm wider than the nail diameter that had been used, which was between 10 and 12 mm. The nail was inserted over the guide wire. The preferred depth was achieved when the distal locking screw was in the calcaneus and the proximal hole in the talus. The length of nails used was between 18 and 24 cm lengths. The two bicortical screws were inserted via the proximal portion of the nail. Subsequently, the distal tibial, talar, and calcaneal locking screws were inserted through the distal portion of the nail. Wounds were irrigated and closed in layers, and incisions were covered with a

Figure 1



Operative procedure. (A) The skin incision (anterolateral approach intraoperative image). (B) The skin incisions for locking screws (intraoperative image). (C) The skin incision for nail entry. (D) Passage of guide wire with the guidance of the fluoroscopy (intraoperative image). (E) Application of proximal locking screws with guidance of the fluoroscopy (intraoperative image). (F) Application of distal locking screws with the guidance of the fluoroscopy (intraoperative image). (G) Preoperative radiograph of one of our cases. (H) Postoperative radiograph of the case. (I) Radiograph after 1 year.

sterile dressing and applied to the below knee slab. The procedure took from 60 to 110 min with a mean time of 85 min, which varied according to the complexity of the case (Fig. 1).

Postoperative management

Postoperative radiograph in anteroposterior and lateral views of the ankle to check the position, size, and length of the nail, the locking screws, and the position of the joint. All patients were discharged after good recovery within 24 h after surgery, nonweight bearing on oral antibiotics (broad-spectrum and anaerobic antibiotics), prophylactic anticoagulant oral drugs, and with close monitoring of blood glucose level.

Methods of evaluation

Following a successful recovery, it is advised to avoid putting any weight on the affected area for the first 24 h after the operation. After 2–3 weeks, the slab and sutures were taken out, and the foot was changed to a lower leg cast for a further 4–8 weeks. During each visit, the patients had clinical examinations to assess wound healing, the neurovascular condition of the limb, and the presence of any infection. In addition, they had a radiographic examination to assess bone healing and alignment in the ankle area. The patient was permitted to bear partial weight on the affected limb utilizing a walking orthosis after 6–10 weeks, as long as it was tolerated. This was done after the radiograph showed evidence of bone healing. After that, the patient's weight bearing was gradually increased, and they were monitored every 3 months for any potential issues. A comprehensive rehabilitation program was implemented, which included physical therapy techniques such as gait training, strengthening exercises for the lower leg muscles, and localized interventions to decrease swelling. The American Orthopedic Foot and Ankle Society (AOFAS) score for ankle and hind foot (AOFAS A/H) was administered at the 6-month follow-up and after the follow-up period (18–24 months). In postoperative follow up, we use the modified AOFAS score, whose maximum is 86 because hind motion and sagittal motion are excluded because of arthrodesis.

The AOFAS score for ankle and hind foot:

It consisted of nine questions covering three categories: function (50 points), alignment (10 points), and pain (40 points). These are cumulatively recorded for a total of 100 points: an excellent score of 90–100 points, a good score of 80 to 89 points, a fair score of 70 to 79 points, and a poor score of less than 70 points (Table 1).

Table 1 American Orthopedic Foot and Ankle Society of ankle and hindfoot

I Pain (40 points)	
None	40
Mild, occasional	30
Moderate, daily	20
Severe, almost always present	0
II Function (50 points)	
Activity limitation, support requirement	
No limitations, no support	10
No limitation of daily activities, limitation of recreational activities, no support	7
Limited daily and recreational activities, cane	4
Severe limitation of daily and recreational activities, walker, crutches, wheelchair, brace	0
Maximum walking distance, blocks	
Greater than 6	5
4–6	4
1–3	2
Less than 1	0
Walking surfaces	
No difficulty on any surface	5
Some difficulty on uneven terrain, stairs, inclines, ladders	3
Severe difficulty on uneven terrain, stairs, inclines, ladders	0
Gait abnormality	
None, slight	8
Obvious	4
Marked	0
Sagittal motion (flexion plus extension)	
Normal or mild restriction (30º or more)	8
Moderate restriction (15º–29º)	4
Marked restriction (less than 150)	0
Hindfoot motion (inversion plus eversion)	
Normal or mild restriction (75–100% normal)	6
Moderate restriction (25–74% normal)	3
Marked restriction (less than 25% normal)	0
Ankle-hindfoot stability (anteroposterior, varus-valgus)	
Stable	8
Definitely unstable	0
III Alignment (10 points)	
Good, plantigrade foot, midfoot well aligned	10
Fair, plantigrade foot, severe malalignment, symptoms	5
Poor, nonplantigrade foot, severe malalignment, symptoms	0
	Total=)100)

Results

The mean age of the studied patients was 60.0 ± 4.39. There were 11 (55%) female patients and nine (45%) male patients. Thirteen cases were right-sided, while seven cases were left-sided. Postoperative radiograph were done for all patients (Table 2).

Patients had both types of diabetes mellitus. Twelve (60%) patients of type I and eight (40%) patients of type II (Table 3).

Table 2 Demographic data and characteristics of the studied patients

	Total no.=20 [*n* (%)]
Occupation	
Office worker	6 (30)
Housewife	8 (40)
Manual worker	2 (10)
Retired	3 (15)
Teacher	1 (5)
Age	
Mean±SD	60.0 ± 4.39
Range	50–68
Sex	
Female	11 (55)
Male	9 (45)
Side	
Right	13 (65)
Left	7 (35)
Technique	
Open (joints were prepared)	6 (31.6)
Closed (percutaneous)	13 (68.4)
Postoperative radiograph	
Done	20 (100)

Table 3 Distribution according to type of diabetes

	Type I	Type II	Total
N	12	8	20
Percentage	60	40	100

Table 4 Presence of postoperative complications among the studied patients

	Total no.=20 [*n* (%)]
Complication	
No complicated	13 (65)
Complicated	7 (35)
Loosening proximal screw	2 (10)
Crack shaft tibia	1 (5)
Infection	1 (5)
Skin infection distal screw	3 (15)

The complications occurred in seven (35%) patients as follows: one patient had an intraoperative distal tibial crack during nail introduction, which was managed by a longer nail and delayed weight bearing for 2 months. Two patients had loosening of proximal screws and infection, three patients had skin infection at the site of distal screws, and one patient had deep infection improved with parenteral antibiotics (Table 4).

Table 5 showed that there was a statistically significant improvement in AOFAS score among the studied patients with *P* value less than 0.001.

There was nonsignificant variance among complicated and not complicated cases as regards AOFAS score pre, AOFAS score 6 months, and AOFAS score end (Table 6).

Table 5 American Orthopedic Foot and Ankle Society score preoperative, 3 months postoperative, and at last follow-up among the studied patients

Scores	Pre	6 months	Last follow-up	Test value	*P* value	Significance
Median (IQR)	0.34 (0.27–0.45)	0.76 (0.72–0.78)	0.91 (0.82–0.95)	40.000	<0.001*	HS
Range	0.2–0.54	0.64–0.93	0.81–0.97			
Pre vs. 6 month		Pre vs. last FU		3 months vs. last FU		
<0.001*		<0.001*		<0.001*		

FU, follow up; IQR, interquartile range.
P value more than 0.05: nonsignificant; *P* value less than 0.05: significant; *P* value less than 0.01: highly significant
*Friedman test.

Table 6 Comparison between complicated and noncomplicated cases regarding radiographs and scores at different times of the studied patients

	No complicated [*n* (%)]	Complicated [*n* (%)]	Test value	*P* value	Significance
	N=13	*N*=7			
1 month radiograph					
Done	13 (100)	7 (100)	–	–	–
2 months radiograph					
Done	13 (100)	7 (100)	–	–	–
3 month radiograph					
Done	13 (100)	7 (100)	–	–	–
AOFAS score pre					
Median (IQR)	0.33 (0.29–0.4)	0.35 (0.25–0.48)	–0.040‡	0.968	NS
Range	0.24–0.54	0.2–0.52			
AOFAS score 6 months					
Median (IQR)	0.76 (0.73–0.78)	0.77 (0.71–0.78)	–0.080‡	0.936	NS
Range	0.64–0.93	0.7–0.78			
AOFAS score end					
Median (IQR)	0.83 (0.81–0.95)	0.94 (0.88–0.95)	–0.766‡	0.444	NS
Range	0.81–0.97	0.81–0.97			

AOFAS, American Orthopedic Foot and Ankle Society; IQR, interquartile range.
‡Mann–Whitney test.

Discussion

Our results showed that the mean age of the studied cases was 60.0 ± 4.39. There were 11 (55%) female patients and nine (45%) male patients. Thirteen cases were right-sided, while seven cases were left-sided. A postoperative radiograph was done for all cases. Patients had both types of diabetes mellitus. Twelve (60%) patients of type I and eight (40%) patients of type II. As regards complications, they occurred in seven (35%) patients as follows: one patient had an intraoperative distal tibial crack during nail introduction managed by a longer nail and delayed weight bearing for 2 months. Two patients had loosening of proximal screws and infection. We removed the screws for one of them then the infection subsided. For the other one, the ankle was united, so we removed the nail. Three patients had skin infections at the site of distal screws, and their ankles were united, so we removed the screws. One patient had a deep infection that improved with parenteral antibiotics. There was a statistically significant improvement in the AOFAS score among the studied patients, with a *P* value less than 0.001. There was nonsignificant variance among complicated and not complicated cases as regards AOFAS score pre, AOFAS score 6 months, and AOFAS score end.

In their publication, Pinzur and Noonan [9] detailed the results of arthrodesis utilizing a lengthy femoral nail on nine separate Charcot ankles. The outcomes demonstrated a perfect union rate, with a single postoperative infection and a single postoperative wound hematoma.

An analysis of 18 patients treated with a retrograde arthrodesis nail for Charcot neuroarthropathy of the ankle without ulceration by Paola and colleagues revealed a limb salvage rate of 100%. Although four (22.2%) patients were able to obtain a stable fibrous union that permitted weight bearing in a protective boot or brace, 14 (77.8%) patients were able to acquire a firm union that permitted shoe usage. Three (16.7%) patients experienced minor hardware issues that necessitated the removal of the proximal screw, and four (22.2%) patients experienced minor difficulties overall [10].

With a minimum follow-up time of 1 year, Vasukutty and colleagues operated on 42 feet in 40 consecutive patients (20 men and 20 women) who had ankle and hind foot reconstruction between June 2008 and September 2015. The age range was 33–89 years. On the day of the operation, 23 out of 22 patients' feet already had ulcers. Forty patients had their deformities corrected in the rear foot, and 18 feet had their deformities corrected in the middle foot either all at once or in stages. Results showed a mean follow-up of 42 months. There were 35 patients available at the final follow-up out of a total of 37 due to five deaths that occurred throughout the follow-up period. All patients had their deformities corrected and their limbs salvaged, except one who would need amputation. A union rate of 97% was achieved, as all other patients showed signs of excellent bone union, both clinically and radiologically. Ulcer healing was achieved in 19 (83%) feet out of the 23 that had chronic ulceration. At the time of the final follow-up, 29 patients (or 83% of the total) were able to bear weight in their surgical shoes or custom orthoses fully. Following this, six patients were placed in a bivalved total-contact cast and subsequently orthotics [11].

From 2011 to 2016, 42 patients with diabetes, ranging in age from 38 to 59 (with a mean age of 49.6 years), had surgery by Emara and colleagues. Eleven women and 31 men underwent surgery; 19 were on the right side and 23 on the left. A total of 14 (33.3%) patients underwent uneventful uncomplicated fusion; eight (19%) patients experienced loosening; six (14.3%) patients had superficial infection; and four (9.5%) patients had ulcers. The average AOFAS ankle-hindfoot score went up from 44.57 (22–77) before surgery to 57.07 after that, and then to 71.19 (45–88) during the last follow-up appointment. For patients at high risk for Charcot's neuroarthropathy, this study found that retrograde nailing is a good alternative for tibia-talo-calcaneal arthrodesis. Its load-sharing characteristics enable significant compression across the ankle and talocalcaneal joints with early weight bearing and satisfactory functional results, and it may be performed through small incisions with reduced soft tissue problems [12].

Utilizing data collected from 24 patients treated for diabetic Charcot arthropathy of the ankle with tibiotalar joint fusion utilizing combined retrograde intramedullary arthrodesis nail (IMN) and Ilizarov external fixator between 2010 and 2015, El-Mowafi *et al.* [13] performed a prospective analysis. Fifteen ladies and seven males were present. They ranged in age from 43 to 62 years old, with a mean age of 50.7 ± 6.9. Solid bone fusion was obtained in 22 (91.7%) patients in a neutrally aligned plantigrade foot, as confirmed by radiographs and clinical examinations. Due to a prominent nail, two patients experienced talar collapse and a heel ulcer. After the nail was removed, the ulcer healed. In line with previous reports of pin tract infection, eight individuals experienced this condition [14].

Our series shows that single-stage deformity correction and fusion with a retrograde calcaneotalotibial IMN is an effective technique in this difficult cohort of patients. With 45% of our patients having chronic ulcers, we achieved 100% limb salvage initially, 100% deformity correction, and 88.8% ulcer healing. Ninety percent of patients were able to mobilize in custom-made footwear and return to activities of daily living.

Conclusion

We report a satisfactory prognosis for corrective fusion of severe ankle and hindfoot deformities in patients with Charcot neuroarthropathy who were treated with an IMN. The objectives that were established were accomplished: ulcer healing, painless ankle procedure, limb salvage, correction of deformity, and return of independence in daily activities. The successful treatment of this challenging patient population is possible with a retrograde IMN. Both patients and physicians must recognize that salvage attempts are complicated but that a functional, stable limb is a realistic objective. A transcalcaneal retrograde intramedullary fixation is an effective and risk-free alternative.

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Conflicts of interest

There are no conflicts of interest.

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