Arthrodesis in the Charcot foot: a systematic review

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Abstract

The Charcot foot is a condition characterized by a progressive derangement of the foot. The type of deformity and patient clinical conditions will lead to the proper surgical approach among exostectomy, arthrodesis (through external and/or internal fixation) and amputation. Many authors report good clinical outcomes performing the arthrodesis in Charcot foot; however, the choice of the most appropriate hardware is still an issue. The aim of this study is to analyze the outcomes of different hardware in midfoot and hindfoot Charcot arthrodesis.

Introduction

Neuropathic arthropathy was first described in 1868 by Jean-Martin Charcot as a progressive derangement of the joints.[1,2] Historically, this condition was related to syphilis, but was later ascribed also to other conditions such as diabetes, leprosy, HIV, spina bifida, amyloidosis, alcoholism and renal dialysis.[3]

The Charcot Neuroarthropaty (CN) has a multifactorial pathogenesis. The loss of sensibility and the alteration of peripheral autonomic nervous system play a central role in the genesis of the acute phase. At this stage, an inflammatory cascade activates the osteoclastogenesis that promotes progressive bone resorption and subsequent dislocations, fractures and ulcer.[4,5] Literature also suggests the presence of autoantibodies in CN population and genetic predisposition appears to favour the disease onset.[6,7] Nevertheless, the real trigger of this condition is still unknown.

About 5% of diabetic population develops peripheral neuropathy but only 8.5‰ will present a suffering of foot joints due to CN.[8,9]

Sanders-Frykberg classification describes five patterns based on bone and joint involvement localization. Each pattern gives valuable prognostic information concerning the disease development.[10]

Surgical treatment is often reserved to the management of deformities and ulcerations that featured the CN chronic phase.[10] The type of deformity and patient clinical conditions will lead to the proper surgical approach among exostectomy, arthrodesis (through external and/or internal fixation) and amputation.

Many authors report good clinical outcomes performing the arthrodesis in CN patients, however the choice of the most appropriate hardware is still an issue.[11]

The aim of this review is to highlight the pros and cons of all kinds of hardware employed in the arthrodesis with regard to the anatomical region affected by CN.

Materials and Methods

A systematic review of the literature indexed in PubMed, MEDLINE and Cochrane Library databases using as search-terms "*Charcot" AND "Arthodesis*" was performed. The Preferred Reporting Items for Systematically Reviews and Meta-Analyses (PRISMA) was followed as reported in Figure 1. Only English publications were evaluated. In ordered to be considered for this review the articles needed to present some inclusion criteria: at least a section of the population understudy needed to be affected by Charcot Neuroarthropathy, demographic characteristics, localization of the disease, the type of arthrodesis performed, possible complications and outcomes needed to be explicit. Abstracts and full texts were independently screened by two authors (L.C. and D.D.M.), any discordance was solved by consensus with a third author (C.P.).

Results

Twenty-five articles were finally included in the review (Figure 1).

Among the studies there were two case report, one case series, one systematic review, while all others were prospective or retrospective cohort studies.

We reached a population of 450 patients. The two most common localization according to the Sanders-Frykberg classification were type II-III (7 studies) and IV (17 studies) or both (1 studies).

Among the articles focused on the hindfoot arthrodesis we considered the following cases: 8 studies regarding intramedullary nailing (IN), 4 studies external fixation (EF), and 2 studies open reduction and internal fixation (ORIF) by plate and screw.

Among the studies focused on the midfoot arthrodesis we considered the following cases: 2 studies concerning ORIF, 1 study the use of screws only and 1 comparative study regarding ORIF and the use of a different hardware.

One paper includes both hindfoot and midfoot arthrodesis through EF.

The functional outcome and quality of life status were evaluated by the American Orthopaedic Foot & Ankle Society score (AOFAS), the Foot Function Index (FFI), the Perfusion, Extent, Depth, Infection and Sensation (PEDIS) Classification System and the SF-36. The pain evaluation was performed by the Visual Analogic Scale (VAS). Several types of hardware were considered (Table 1). The most frequent complications recorded were surgical site and deep infections, hardware failure, non-union, recurrent ulcer and amputation (Table 2).

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Key words: Charcot, foot, arthrodesis, nail, external fixator.

Contributions: the authors contributed equally.

Conflict of interest: the authors declare no potential conflict of interest.

Funding: none.

Availability of data and materials: On request.

Ethics approval and consent to participate: Not applicable.

Informed consent: Not applicable.

Received for publication: 11 April 2020.
Accepted for publication: 17 June 2020.

Orthopedic Reviews 2020; 12(s1):8670
doi:10.4081/or.2020.8670

Midfoot Charcot

In this review we collected several articles concerning the midfoot Charcot arthropathy evaluating different treatment techniques and outcomes.

Eschler *et al*. in two different studies, for a total of 50 feet, used intramedullary screws in the treatment of type II and III CN. Impaired wound healing and infection were the most common complications.[12,13] Twenty-five per cent of patients required amputation. The authors suggested the use of PEDIS score (Perfusion, ulcer Extension, ulcer Depth, Infections, Sensation) to layer the patient's risk and concluded that a pre-operative PEDIS score <7 predicts a lower incidence of post-operative complications.

Similarly Sammarco *et al*. evaluated 22 patients with Charcot midfoot Arthropathy treated by intramedullary screws.[14] The high amount of partial/fibrous union (about 22%) and persistent ulcerations (about 18%) often required revision surgery. In conclusion, according to the authors it is necessary to treat ulcers and infections prior to surgery to reduce the incidence of complications.

In a further work, Eschler *et al*. used either a locked compression plate, an intramedullary screw or both in the arthrodesis of the medial column among 21 feet.[15] The clinical outcomes were quite good, about 50% of the patients were satisfied with the treatment and without pain. Radiographic results also were suitable. Nevertheless the rate of minor and major complications was very high, 2 patients only had a complications free healing. More than with intramedullary implant, to the authors it is possible to perform a more stable fixation through an open reduction and internal fixation(ORIF) with plate and screws.

Jin-Soo *et al*. employed a dorsal modified sliding calcaneal plate for extensive midfoot arthrodesis in 10 patients.[16] Bone union was achieved in all the patients in 4 months and the patients satisfaction rate was in line with other procedures. In two patients (20%) a second surgery was required.

Due to decrease the surgical trauma, Matsumoto *et al*. performed the midfoot arthrodesis with the Multi-Axial Correction (MAC) monolateral external fixation system in 9 patients.[17] The functional outcomes were good, with a full weight-bearing in a mean of 4 months, comparable to internal fixation. However, in about 50% of patients a second surgery was required.

At last, Wang *et al*. have deepened the role of arthrodesis with plate and screw during prohibition of weight load with a total contact cast.[18] The arthrodesis reduced the risk of recurrent ulcers and provided nerve function improvement. In conclusion, this trial makes it clear that surgery can improve sensory impairment and restore protective sensation in patient with Charcot arthropathy.

The hindfoot Charcot foot treatment includes arthrodesis with intramedullary nailing, external fixations, plate and/or screws and a combination of all previous

Firstly, considering the arthrodesis with intramedullary (IM) nailing only, in our review we identified 9 articles for a total of 152 patients and 154 feet treated.

Dalla Paola L *et al*. in 2007 enrolled 18 diabetic patients with hindfoot Charcot neuroarthropathy with-out a history of ulcerations.[19] Limb salvage occurred in all patients and 14 obtained complete bony union of the ankle arthrodesis. This study suggests that treatment with retrograde nailing arthrodesis is successful treatment for ankle instability in patients with Charcot arthropathy without ongoing or past ulcerations. Similar result was obtained by Lee *et al* on seven patients.[20]

Oesman *et al*. reported a case of a single patient from which emerged both good clinical and radiographic outcomes and no after surgery complications were observed.[21] Nevertheless the follow up was only 3 months long. However, Intramedullary nailing is a surgical option often burdened by an high rate of complications. Chraim M *et al*. reported indeed 26% of minor complications and 15% of major complications in their study.[22]

To assess whether there are differences across the various CN Eichenholtz stages, Sundararajan *et al*. selected 33 patients with different stages of neuropathic arthropathy of the ankle with marked disability from joint instability (9 stage I, 13 stage II and 11 stage III).[23] To the authors no major differences in terms of outcomes and complications exist across the stages.

Caravaggi C *et al*. collected a cohort of 45 diabetic patients with Charcot neuroarthropathic ankle deformity strictly without ulceration and bone infection.[24] The authors support that performing ankle and hindfoot arthrodesis with IM nail during the early chronic stage of the Charcot disease process, instead of postponing surgical reconstruction until later stages of the disease, may reduce the risk of progressive deformation that often leads to cutaneous and articular breakdown and osteomyelitis.

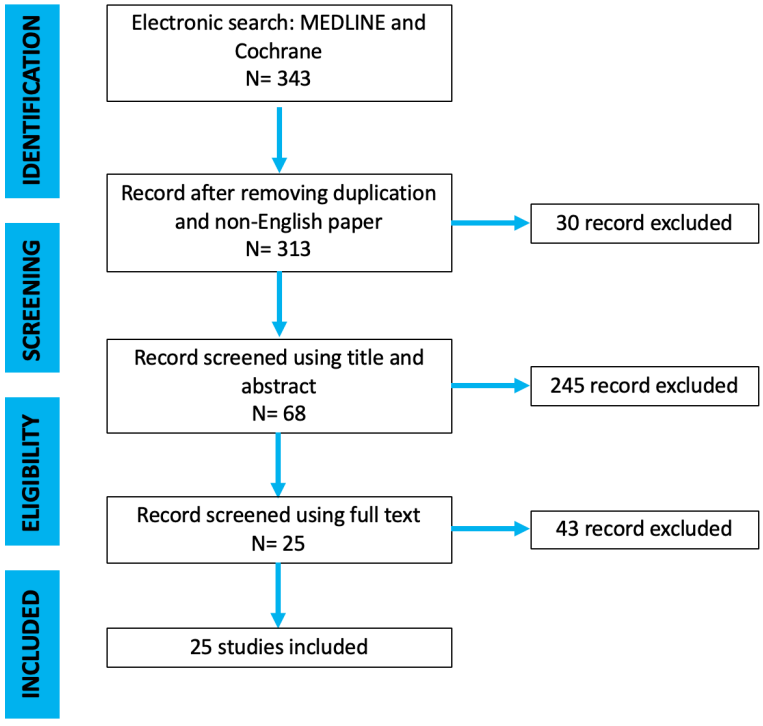

Figure 1. Prisma flow-chart.

Siebachmeyer M *et al*. in 2014 on the contrary followed 20 patients (21 feet) with Charcot neuroarthropathy and severe deformities of the ankle and hindfoot.[25] Limb salvage was achieved in all patients, all but one achieved full weight-bearing and 90% radiological fusion. Complications occurred mostly in patients who underwent simultaneous midfoot fusion.

In literature high rate of mechanical complications have been associated with standard-length nails, Pinzur MS *et al*. in 2005 studied 9 diabetic individuals with Charcot arthropathy of the ankle who underwent ankle arthrodesis with a longer retrograde locked femoral nail.[26] Given the results, Pinzur MS *et al*. agree with previously mentioned authors in supporting that IM nailing is an efficient salvage procedure in Charcot foot neuroarthropathy and further argue that the use of a longer nails and dynamic locking may reduce mechanical complications rate such as stress fracture of the tibia at the proximal aspect of the nail.

Considering instead the hindfoot and ankle arthrodesis with external fixation only, in our review we identified 5 articles for a total of 92 patients and 93 feet treated.

In a following paper Dalla Paola L *et al*. collected data about 45 patients with Charcot arthropathy complicated by ulcers with tarsal or ankle osteomyelitis instead.[27] All the patients were treated with aggressive local care of the lesion with precise debridement and the application of a hybrid external fixation. A stable ankle fusion was obtained in 39 out of 45 individuals. The infection could not be controlled in 4 patients who underwent below knee amputation. Low rate of minor as well as limb-threatening complications occurred. In conclusion according to the authors results external fixation seems to be a reasonable alternative to below-knee amputation in selected patients. Similar results were achieved through circular external fixation from Fabrin *et al* (2007) on 12 feet, El-Gafary *et al* (2009) on 20 patients, Zarutsky *et al* (2005) on 11 patients.[28-30] Similarly, La Porta *et al*. in 2014 achieved good clinical outcomes in 5 patients with unstable Charcot hindfoot.[31] The rate of amputation remains high (about 20%). Moreover, the authors conclude that with external fixation alone for hindfoot fusion in Charcot arthropathy can be achieved successful results, both with and

Table 1. Overview of the available studies on arthrodesis in Charcot neuroarthropathy.

Authors	Year	Patients	Follow-up (months)	Localization (Sanders-Frykberg)	Hardware	Type of Hardware	Post-surgery AOFAS score
Oesman I	2019	1	3	IV	1 IN	Expert Tibial Nail (Synthes)	83
Chraim M	2018	19	46	IV	19 IN	12 Panta Nails (Integra) 7 Valor Nails (Wright)	71,5
Lee BH	2017	7	28	IV	7 IN	Hindfoot Arthrodesis Nail (Synthes)	76
Richman J	2017	27	35	IV	16 IN	Ilizarov frame	
El Alfy B	2017	27	31	IV	13 IN 14 EF	Ilizarov frame	IN 75 EF 80
Sundararajan S	2017	33	40	IV	33 IN		
Eschler A	2015	7	54	II-III	7 ORIF	Midfoot Fusion Bolt (Synthes)	
Wang Y	2015	21	12	II-III	12 ORIF 9 B		
Matsumoto T	2015	11	29	II-III	3 EF 8 ORIF + EF	Multi-Axial Correction monolateral external fixation (Biomet)	
Eschler A	2015	21	48	II-III	11 IN 5 ORIF	5 screw + ORIF	
Siebachmeyer M	2014	21	25	IV	21 IN	TRIGEN Hindfoot Fusion Nail (Smith & Nephew)	
La Porta G	2014	5	32	IV	5 EF	Ilizarov frame	
Eschler A	2014	7	24	II-III	7 ORIF		
Caravaggi C	2012	45	60	IV	45 IN		
DeVries GJ	2012	52	8	IV	45 IN 7 IN + EF		
Cinar M	2010	4	24	IV	4 ORIF		
Sammarco JV	2009	22	52	II-III	22 screw		
Dalla Paola L	2009	45	12	IV	45 EF	Orthofix external fixator	
El-Gafary K.A.M.	2009	20	20	II-III + IV (9 IV (11)	20 EF	Ilizarov frame	
Dalla Paola L	2007	18	14	IV	18 IN	Ankle Arthrodesis Nail (Orthofix)	
Fabrin J	2007	12	48	IV	12 EF		
Wagner A	2005	1	24	IV	1 ORIF		
Pinzur M	2005	9	32	IV	9 IN	Retrograde locked femoral nail (Synthes)	
Jin-Soo Suh S	2005	4	26	II-III	2 ORIF 2 EF + ORIF	7 nonlocking calcaneal plate (Depuy) 2 locking calcaneal plate (Synthes)	
Zarutsky E	2005	11	27	IV	11 EF		

IN= intramedullary nailing; EF= external fixation; ORIF = open reduction internal fixation; B= brace .

without concomitant osteomyelitis.

Lastly, given the hindfoot and ankle arthrodesis achieved by osteosynthesis with plate and/or screws, we reached 2 articles for a total of 5 patients and feet.

Wagner A *et al*. in 2005 reported a case of a report of a two-stage procedure which ended with arthrodesis achieved by a compression osteosynthesis with screws.[32] However, about 26 months later below-knee amputation became unavoidable.

Cınar M *et al*. in 2010 followed 4 diabetic patients with hindfoot Charcot arthropathy.[33] All patients underwent tibiocalcaneal arthrodesis with a blade-plate through a posterior approach. Clinical and radiographic solid osseous fusion was confirmed in 3 patients, while the fourth achieved a stable fibrous ankylosis at the final follow-up. All of the patients were satisfied with the post-arthrodesis pain relief and correction of deformity.

Hardware comparison in the hindfoot

The majority of the studies about Charcot foot treatment focus on one hardware hindfoot and midfoot arthrodesis. Despite this, in our review we evaluated 7 studies that compare two or more hardware outcome, nevertheless we had to exclude 2 of them because of non-discriminatory data between the different study groups.

Richman *et al*. in 2017 published a study involving 27 patients who performed either external fixation or intramedullary nailing.[34] In the ring fixator group, there were 18% of major amputation, 18% of pin site infection and 9% of surgery revision rate. In the retrograde nail group, there were 6% of major amputation, but 68% of surgery revision rate instead.

El Alfy *et al*. compared external fixation with intramedullary nailing too, as opposed to Richman *et al*. the complications incidence was higher among the external fixator group than in the intramedullary nailing group.[34,35] Yammine *et al*. in 2019 compared the external fixation and the intramedullary nailing in a metanalysis examining 117 CN patients.[36] Seventy patients were treated with nail and 47 with external fixation. The authors found a high rate of hardware (33,6%) and wound (23%) infection in the external fixation group. The fusion rate was 90,7% and 74%, and the amputation rate was 2,2% and 13,1% respectively in the intramedullary nailing and in the external fixation groups. Intramedullary nailing thus seems to be safer and with less complications than external fixation. Finally, to the authors, this latter approach is recommended only in the treatment of CN complicated with plantar ulcers. In 2012 DeVries *et al*. concluded that the addition of circular external fixation to the arthrodesis with intramedullary nail has to be pursued in patients requiring extensive deformity correction or with higher risk of complications.

Table 2. Complications of the available studies on arthrodesis in Charcot neuroarthropathy.

Authors	Year	Patients	Wound Infection	Deep Infection	Implant failure	Non-union	Recurrent ulcer	Amputation
Oesman I	2019	1						
Chraim M	2018	19			2	3		3
Lee BH	2017	7	4	3		4		1
Richman J	2017	27	1 EF	1 EF	1 EF	1 EF		2 EF
			5 IN		3 IN	1 IN		1 IN
El Alfy B	2017	27	14 EF		1 EF	5		
			1 IN		2 IN			
Sundararajan S	2017	33	5		2	5		3
Eschler A	2015	7	2	3				
Wang Y	2015	21						
Matsumoto T	2015	11						
Eschler A	2015	21	6	3	9		7	5
Siebachmeyer M	2014	21			2	1	3	
La Porta G	2014	5	1		3	2	1	
Eschler A	2014	7	6		2			2
Caravaggi C	2012	45	10		10	2		4
DeVries GJ	2012	52						12
Cinar M	2010	4	2		1			
Sammarco JV	2009	22			12	5	4	
Dalla Paola L	2009	45			2	6		
El-Gafary K.A.M.	2009	20	15					
Dalla Paola L	2007	18			3	4		
Fabrin J	2007	12				6		1
Wagner A	2005	1						1
Pinzur M	2005	9	1					
Jin-Soo Suh	2005	4	3		4	3		
Zarutsky E	2005	11				10		3

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