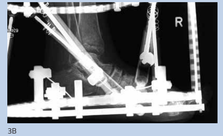
Two Clinical Cases

The first clinical case is that of a 58 year-old woman suffering from type 2 diabetes for the last 14 years. She had experienced a minor trauma and presented a trimalleolar fracture-dislocation of the ankle joint, which is typical in Charcot foot disease. Attempts to repair the injury by casting was unsuccessful and trauma surgeons were reluctant to perform surgery on the patient. In an attempt to address her condition, surgeons used the hexapod resulting in full reposition and consolidation.

Fig. 1A-B. AP and lateral X-ray of the ankle.

Fig. 2. AP X-ray of the third attempt to close reduction in a cast.



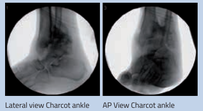
3B

Fig. 3 A-B. AP and lateral X-ray after gradual reduction using a hexapod frame, showing initial consolidation.

Fig. 4 A-B. AP and lateral X-ray of the ankle joint after removal of the hexapod frame, and application of an orthotic boot for after treatment.

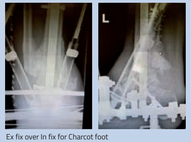
4B

The second case is that of a 47 year-old diabetic man with a history of Charcot ankle. Four months prior to treatment, the patient who was on dialysis felt a pop in his ankle but continued to walk on it. The surgical decision was made to perform an ankle fusion with the placement of an Orthofix Ankle Compression Nailing System (ACN). Due to his severe neuropathic status the surgeon decided to augment the nail with a TL-HEX TRUELOK HEXAPOD SYSTEM™ external fixator. The fixator remained on for three months and the patient's fusion site healed uneventfully.



Lateral view Charcot ankle with dislocation

AP View Charcot ankle



Ex fix over In fix for Charcot foot

Fusion at 10 weeks

Orthofix TL-HEX with walker rails over Infix

9 months post-op

This brochure is the result of a consensus process that has involved a panel of nine independent, highly experienced orthopaedic and DPM surgeons from Europe and the U.S.

The methodology applied to the consensus process has been an adapted Delphi technique. A critical review of the scientific literature has been important to establish an evidence-based approach to the CN Management.

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Economic Data on Diabetes and CN

People suffering from diabetes

In the world
150-170 million in 2000
350-422 million today
595 million in 2035

World prevalence among adults 6.4%; it will increase to 7.7% by 2030

Diabetes mellitus (type 2)
285 million in 2010
438 million in 2030

In the USA
29.1 million in 2012
1.4 million new cases every year
208,000 young Americans under 20 years old

The seventh leading cause of death in the USA in 2010, but may be underreported.
Type 2 diabetes accounts for 90-95% of all cases

In the European Region (EU)
56 million in 2013
10.3% men
9.6% women
Diabetes mellitus (type 2)
33 million in 2010
38 million in 2030

High blood glucose kills about 3.4 million people annually

Rates of diabetes: in Spain 10.98% of the population has diabetes, in Germany 11.52%, in UK 6.6%, in Turkey 14.71%; France and Netherlands the lowest rates, between 5 and 6%

Diabetes vs. Charcot Foot

Gender
Patients with Charcot foot are more likely to be men

Age
Over 50 as average

Incidence rate of Charcot foot in patients with diabetes
0.3-7.5%
other sources: from 7.5% up to 13% of all diabetic patients in the USA

Data sources

American Diabetes Association 2016 www.diabetes.org
www.diabetes.co.UK
www.indexmundi.com

The Lancet 2016. *Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants* (NCD Risk Factor Collaboration)
www.thelancet.com

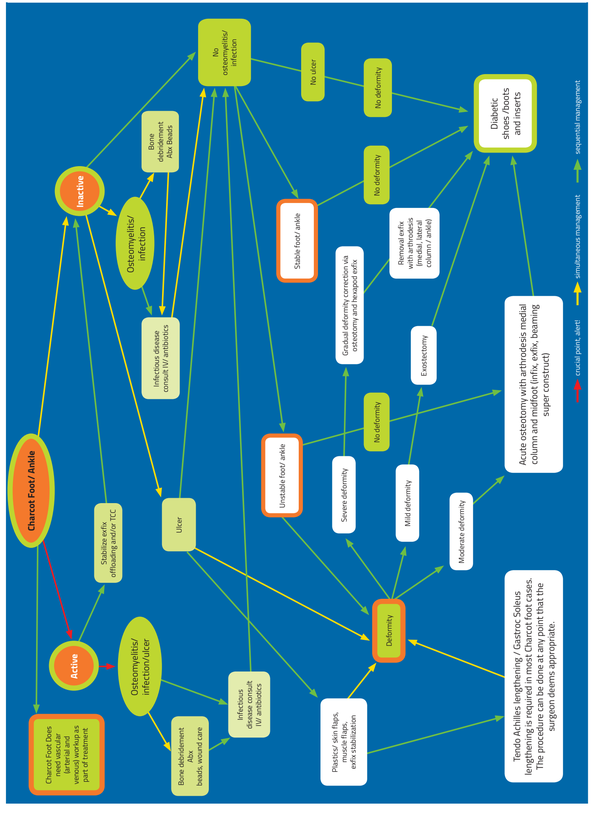
World Health Organization (WHO): WHO Europe 2007
WHO Fact sheet reviewed 2016.
www.europa.eu/health/major_chronic_diseases/diseases/diabetes

The Charcot Foot

A challenging surgical management

ORTHOFIX

The Charcot Foot FlowChart



What is Charcot Foot?

FIG 1
1. Normal foot
2. Charcot foot
Source: American College of Foot and Ankle Surgeons (ACFAS) 2017

The Charcot Neuroarthropathy (CN) is a condition causing weakening of the bones in the foot that can occur in people who have significant nerve damage (neuropathy). The bones are weakened enough to fracture and, with continued walking, the foot eventually changes shape. As the disorder progresses, the joints collapse and the foot takes on an abnormal shape, such as a rocker bottom appearance (American College of Foot and Ankle Surgeons 2017). If left untreated, this destructive process leads to deformity, ulceration, infection, and ultimately – at worst – to amputation.

Published descriptions of this neuropathic arthropathy initially appeared in 1868 by Jean-Martin Charcot, a French neurologist often referred to as one of the world's pioneers of neurology, who was professor of anatomical pathology for 33 years at the Salpêtrière Hospital in Paris.

Jean-Martin Charcot

FIG 2
Ulcerated foot.
Authorized source.

Most frequent causes

The etiology is not yet entirely understood, but experts consider peripheral neuroarthropathy a conditio sine qua non. There is no singular cause for the development of CN, but there are factors that predispose to its development (Rogers LC 2011):

A complex mix/interaction of polyneuropathy, repeated trauma, hypervascularization, molecular biological alteration, metabolic abnormalities of bone
Diabetes mellitus (the most common cause in economically developed countries)
Long term alcohol abuse, plus other neurotoxins (i.e. nicotine, metrotrexate)
Idiopathic
Congenital insensitivity to pain, lack of protective sensations
Rheumatoid arthritis ("Rheumatic Charcot foot" rarely described)
Sarcoma of the spine
Infectious etiology
Leprosy (the most common cause in less economically developed countries)
HIV-associated neuropathy

CN affects from 0.1 to 5% of the patients suffering from diabetes. There are currently 347 million diabetes cases in the world, a number that may increase to 595 million cases by 2035. In the United States some experts state that the rate is from 7.5 to 13% in diabetic patients, and the incidence of diabetes is increasing 1% a year (WHO Fact sheet, updated 2014).

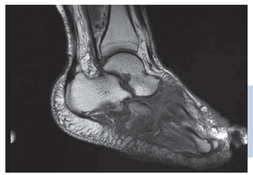


FIG 3
Charcot Foot MRI.
Authorized source.

Clinical signs for a correct diagnosis

Inflammation plays a key role in the pathophysiology of the Charcot foot and is the earliest clinical finding: if inflammation is present, the Charcot foot is active. The terms *active* or *inactive* should be used to describe an inflamed or stable CN (Rogers LC 2011). In a diabetic patient with long-standing neuropathy, a warm foot and/or ankle that may be several degrees warmer than the contralateral foot, and is swollen and sometimes erythematosus must be considered Charcot until proven otherwise (Chantelau EA et al. 2014; Caputo GM et al. 1998; Sommer TC et al. 2001).

There may be **concomitant ulceration in the foot**. Experts state that **some patients may report pain and discontent** (about 10%); a few of them suffer of hypersensitivity and hyperalgesia, but generally the level of pain reported by patients is considerably less than expected from the observed pathology.

Timely diagnosis facilitates treatment and decreases long-term disability. The best safeguard is a high index of suspicion, especially in any diabetic patient with a swollen warm foot and the presence of somatic or autonomic neuropathy.

Investigations for a correct diagnosis

Investigations should include:

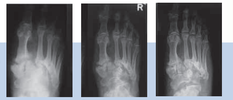
Radiography. Plain and serial X-rays show demineralization, bone destruction, periosteal reaction
Radionuclide (Isotope) imaging. Valuable sensitivity of 80-90% for correct diagnosis if there is a penetrating ulcer underneath the deformity
Computerized Tomography (CT). Presence of sequestra, cortical destruction, periosteal reaction, and intraosseous gas (which might not be detected on an MRI)
Magnetic Resonance Imaging scans (MRI) of foot are extremely sensitive in detecting 100% of the abnormalities, especially in the early stages of the disease. MRI is superior for soft tissue imaging, and gives excellent anatomical details; besides it is capable of revealing in greater detail the nature of the bony damage and evidence of inflammation in the bone (sub-chondral bone marrow edema with or without microfractures) as well the adjacent soft tissue (Edmonds ME et al. 2005; Chantelau E et al. 2006)

Classification systems to define the course

Experts adopt the most commonly used classification systems to characterize CN foot, even if they don't provide a sufficient prognostic value, or direct treatment. They think that each system has a flaw, and this is why some of them use personal, unpublished but practical and effective methods of classification to define the course of CN and prevent the risk of amputation.

In 1966 **Eichenholtz** described the three stages of neuropathic joint progression based primarly on radiographic changes. A prodromal stage 0 was added in 1990 by **Shibata**, **Schon** and **Marks**.

FIG 4
Authorized source.



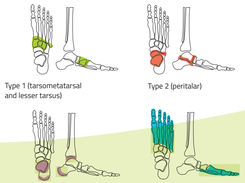
Stage 1: fragmentation, bone resorption, dislocations, fractures

Stage 2: coalescence, sclerosis, fracture healing, debris resorption

Stage 3: remodelling

In 1987 **Brodsky** (in 1991 improved by **Sanders** and **Frykberg**, in 1998 by Schon) suggested an anatomically based system which divides the foot in 5 zones or patterns, according to the joints involved and the severity of collapse.

FIG 5
source: www.foothyperbook.com/elective/diabetes/diabeticClassnCharcot.htm (modified).



Type 1 (tarsometatarsal and lesser tarsus)

Type 2 (peritalar)

Type 3a (ankle) and 3b (posterior calcaneum)

Trepman added type 4 (multiple sites) and type 5 (forefoot) as shown here

In 1996 the **University of Texas** Wound Classification System classified ulcers, often accompanying CN, using four stages and four grades in each stage.

A multidisciplinary team is always necessary to manage CN care successfully. It should include a diabetologist, an orthopaedic surgeon, a vascular surgeon, an endovascular interventionist/radiologist, a podiatrist, a diabetes nurse, a pedorthist/orthotist and a physical therapist.

Charcot Foot Surgery

Goals of Surgery

- Create a stable plantigrade foot, that one can brace with a shoe, or with a Charcot restraint orthotic walker (CROW)
- Heal relevant ulcers
- Prevent amputation
- Restore a normal life for the patient as much as possible

Primary indications

- Severe instability, significant but not plantigrade
- Severe arthropathy
- Instability of the ankle
- Acutely dislocated foot and/or ankle
- Infected, long standing and recalcitrant non-healing ulcers
- Failure of the previous conservative treatment or therapy

Secondary indications

- Progression of deformity
- Severity of deformity
- Weight-bearing incapacity
- Bone infection

Main controversial issues

Surgical intervention in the early stages/acute phase of Charcot is generally considered one of the most significant controversial issues: early surgical stabilization instead of accommodation when deformity first develops. Many foot and ankle surgeons still prefer a conservative approach as a treatment. For the expert panel any stage is suitable for surgery, as active Charcot foot/active stages are not contraindications. If active Charcot foot presents with dislocation, surgical reconstruction is suggested. Surgery is essential as soon as possible to correct any foot deformity: the treatment option might be external fixation to maintain bone alignment and preventing further deformity. If active Charcot shows no dislocation pathway, then immobilization, compression, and non-weight bearing are suggested.

Ulcers are not an obstacle to surgery. An infected ulcer, however, should be first treated with debridement, moist dressings, and antibiotics. All infections should be treated with antibiotics and should not be confused with inflammation; phlegmon, abscess, and osteomyelitis may indicate urgent surgery, but this is septic surgery with its own rules, and not Charcot reconstruction (Koller A et al. 2011).

For the expert panel poor bone quality influences the operative technique and/or the choice of hardware/external fixation, and it depends on where it is located: if in the area of Charcot joint, or the foot skeleton is involved in general.

Suggested surgical options

	ATL	Osteotomy/ Exostectomy	Plantar realignment osteotomy	Open reduction with different techniques	Arthrodesis	Gradual correction with ex fix	Debridement	Bone stimulation with different techniques
Infected ulcerations			●			●	○	
Recurrent ulcerations	●	○	○	●	○	○	●	
Failure of non-op treatment					●	●		
Foot deformity	●	●	○	●	●	●		
Equinus contracture	○							
Bone pressure		○						
Instability				○	○	○		
Malunions/Nonunions				●	●			●
Salvage of failed prior interventions				●				●

● = full consensus

Most effective surgical procedure

The use of external fixation is recommended nearly always when deformity is present, and in the case of open wounds with active infection. It is often used in combination with internal fixation, when there is the need for supplemental fixation.

Circular external fixation allows a more stable fixation and simultaneous compression and stabilization and it's an additional tool to properly offload grafts or flaps in patients who are unable to tolerate conventional techniques such as cast immobilization (Short D) et al. 2017).

Use of an external fixator offers the advantage that all the hardware is removed after six weeks; thus, there is no risk of broken screws or plates, and the associated potential complications (Illgner U et al. 2014).

In our practice we use external fixation in combination with internal beaming. The beams align the medial-lateral columns while the external fixation compresses the columns. (Grant W et al. 2015).

The primary utility of external fixation is the ability to insert fixation wires proximal and distal to potentially infected joints or severely destroyed joints (Giurini J 2005).

The circular external fixator has been demonstrated to achieve a high potential for clinical enhanced outcomes with a minimum risk for treatment-associated morbidity (Pinzur MS 2006).

Post surgical therapy

The key to a successful post surgical course is **long-term bracing or casting**, from 3 to 7 months.

Key points

- Understand the disease, try simple solutions first, use the most appropriate approach
- Active Charcot foot is not contraindicated for surgery
- Staged reconstruction is recommended in the ulcerated and/or infected Charcot foot
- External fixation can provide simultaneous compression, stabilization and surgical offloading
- Unstable Charcot foot and/or ankle should always be surgically stabilized with appropriate fusions
- Superconstructs are feasible, but not mandatary
- Osteomyelitis does not mean amputation
- A multidisciplinary health care team that addresses the overall medical and surgical Charcot foot management is necessary for the successful outcome of the patient
- Close post-op monitoring of the patient's medical comorbidities is essential throughout the healing process

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