The Surgical Management of Neuropathic (Charcot) Foot

A Practical Guideline

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Contents

Introduction

This *Practical Guideline* has been based both on existing clinical literature and on experts' opinions and their clinical practice. If the review of the literature has been helpful in establishing an evidence-based approach, it has emerged clearly from the study that management of neuroarthropathic (Charcot) foot (CN) often shows poor adherence to evidence-based protocols.

Lack of consensus on diverse controversial issues, among international orthopaedic surgeons and physicians, is mainly due to:

- lack of solid scientific data supporting the different approaches,
- poor documentation – risk factors and clinical examination findings,
- poor interdepartmental referral rates,
- lack of uniform outcome measures,
- different individual experiences,
- different medical schools,
- multiple visions and approaches,
- countries with different health policies and related insurance/reimbursement systems.

Therefore, the surgical treatment of CN foot seems to be based primarily on experts' opinion, their proved experience and related results. However, the research of a consensus among a panel of experts has been important to formulate better models of care and transmit their competence to younger and less experienced surgeons. Regarding the applied methodology, see page 3.

Methodology

The methodology applied to the consensus process has been an adapted Delphi technique, by means of a cloud-based software with the involvement of 9 international experts – independent, highly experienced surgeons and clinicians, mainly from Europe and USA.

We started with the critical review of the scientific literature regarding the neuropathic (Charcot) foot: considering the limited numbers of available studies, the sources were selected starting from 1990. A report was prepared, with the most recurrent indications and controversial issues: on the latter, two questionnaires were developed, submitted to the panellists and filled in blind in two consecutive rounds.

The results were summarized, shared and discussed among panel's members – through dialogue and open confrontation – in order to reach a consensus regarding some crucial matters of the CN foot, with a focus on the surgical management of the pathology. The project duration was one year.

Pathology in brief

Charcot foot 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) [**FIG. 1**]. 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 as one of the world's pioneers of neurology, professor of anatomical pathology for 33 years at the Salpêtrière Hospital, in Paris.

The most common foot anatomical lines involved in the Charcot neuro-osteoarthropathy are the **Lisfranc joint** (the articulation between the midfoot and forefoot) – the name comes from Jacques Lisfranc de Saint Martin (1790-1847), a field surgeon in Napoleon's army serving on the Russian front, who described a new amputation technique across the 5 TMT joints. Some experts have suggested that the term "Lisfranc joint complex" should refer to the 5 tarsometatarsal articulations, and the term "Lisfranc joint" should be applied to medial articulation involving the first and second metatarsal with the medial (first) and middle (second) cuneiforms. It regards about the **60% of the patients**.

Secondly, the **Chopart joint** (transverse/midtarsal joint – talus and calcaneus proximally, navicular and cuboid bone distally) is involved. When seen from above, the joint line of the transverse tarsal articulation has a shape of an S. It regards about the **30% of the affected population**.

Thirdly, the **ankle joint**: about the **10%**.

Charcot Foot affects from 0.1 to 5% of the patients suffering from diabetes – 347 million diabetes cases in the world, which in 2035 could reach 595 million cases. In the United States, some experts refer 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). See also *Appendix 1* page 34.

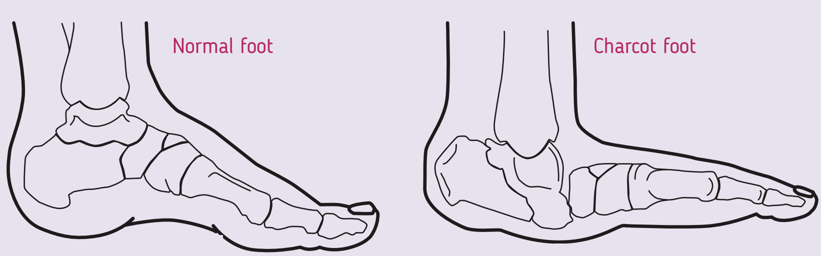


FIG .1 Normal foot, Charcot foot. *Source: American College of Foot and Ankle Surgeons (ACFAS) 2017.*

Diagnosis

It seems to be a matter of general consensus that 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 in the presence of somatic or autonomic neuropathy.

1. **Inflammation clinical signs:** a warm (may be several degrees warmer than the contralateral one), swollen, sometimes erythematosus and red foot and/or ankle, in a diabetic patient with long standing neuropathy, must be considered Charcot's until proven otherwise (**Chantelau** EA et al. 2014) (**Caputo** GM et al. 1998) (**Sommer** TC et al. 2001). Primary care physicians must consider the diagnosis of Charcot arthropathy in any neuropathic patient presented with erythema, oedema and warmth regardless of local or systemic signs of infection (**Galhoum** AE 2016).

Inflammation plays a key role in the pathophysiology of the Charcot foot and is the earliest clinical finding. Active or inactive should be used to describe an inflamed or stable CN, respectively. Acute and chronic can also be used in this regard, but there is no accepted measure that defines the transition point (**Rogers** LC et al. 2011).

For the 83.33% of the expert panel involved in the study, if inflammation is present, the Charcot foot is active.

2. May be **concomitant ulceration** in the foot. Crepitus may be noted on manipulation of the foot. The patient may recall previous microtrauma.

3. Often described as **painless** (90%), CN is generally characterized by a predominantly painless destruction of pedal bone sand joints.

A few experts of the panel report that some patients may refer 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.

4. **Investigations** for a correct diagnosis should include:

- **Radiography** – Plain and serial X Rays show demineralization, bone destruction, periosteal reaction;
- **Radionuclide** (Isotope) imaging – Valuable sensivity 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 intraosseus gas (which might not be detected on MRI);
- **Magnetic Resonance Imaging** scans (MRI) of foot is however extremely sensitive in detecting 100% of the abnormalities, especially in the early stages of the disease. It's superior for soft tissue imaging, and gives excellent anatomical details. MRI can capture both soft tissue and bone and can help in diagnosis due to altered signal intensity of the affected bone (**Shank** CF et al. 2006). Only Magnetic resonance imaging (MRI) is capable of revealing in greater detail the nature of the bony damage and evidence of inflammation in the bone (subchondral bone marrow oedema with or without microfractures) as well the adjacent soft tissues (**Edmonds** ME et al. 2005) (**Chantelau** E et al. 2006) [**FIG. 2**];

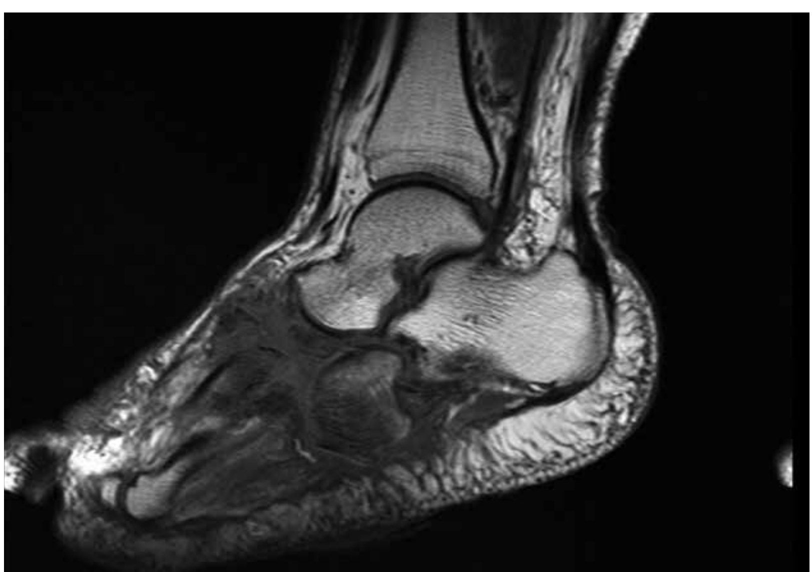


FIG .2 Charcot Foot MRI.
Authorized source 2017.

Classification systems

Different **classification systems** have been proposed in time to recognize and classify a Charcot foot:

A In 1966 **Eichenholtz** described the stages of neuropathic joint progression detailed from a **radiographic (imaging) standpoint**; it helps experts to decide whether further casting or protected weight bearing is necessary [**FIG. 3**].

Stage I	**Destruction**; developmental stage with radiographic evidence of debris formation, bone fragmentation, subluxation or dislocation. Symptoms: warm foot, swelling, dramatic oedema.
Stage II	**Coalescence**; the stage of coalescence shows debris absorption, coalescence of bone fragments, sclerosis of bony ends. Symptoms: decreasing swelling and redness.
Stage III	**Consolidation**; reconstruction phase with remodelling of bone fragments, decreasing sclerosis, partial reformation of the architecture of the foot and ankle. Decreased swelling and redness to point of a normal temperature. May create pressure points for ulceration.

This radiographic staging system has been well accepted internationally.

B In 1987 **Brodsky** anatomical classification looked at the **disease distribution**; it helps experts to predict outcome, especially with regard to complications of the Charcot event [**FIG. 4**].

Type 1	tarsometatarsal (Lisfranc) and lesser tarsus
Type 2	transverse tarsal (Chopart), subtalar and peritalar
Type 3a	ankle, tibiotalar
Type 3b	posterior calcaneum, compromised longitudinal arch, Achilles insufficiency
Type 4	(added by Trepman) multiple sites
Type 5	(added by Trepman) forefoot, metatarsophalangeal

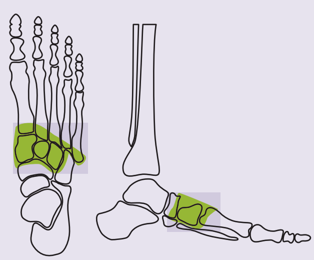
FIG . 3 Eichenholtz classification. *Authorized source 2017.*

Stage 1: fragmentation, bone resorption, dislocations, fractures

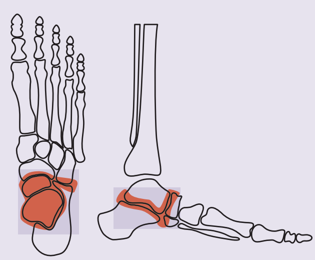
Stage 2: coalescence, sclerosis, fracture healing, debris resorption

Stage 3: remodelling

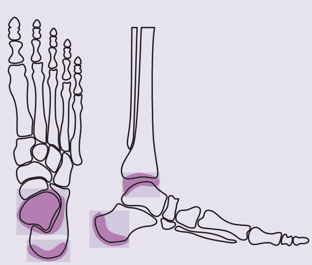
FIG . 4 Brodsky anatomical classification, *source: www.foothyperbook.com/elective/diabetes/diabeticClassnCharcot.htm* (modified).



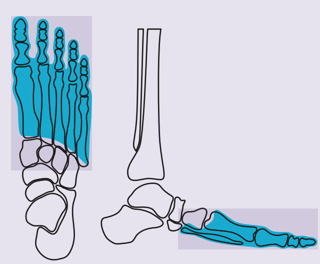
Type 1 (tarsometatarsal and lesser tarsus)



Type 2 (peritalar)



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



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

C In 1990 **Shibata, Schon** and **Marks** (and also **Sella** and **Barrette**) added one more stage, a prodromal, pre-radiographic stage, to **Eichenholtz**'s classification:

Stage O	**Mild fracture or joint space widening without debris on radiographic examination.** Unilateral red, usually somewhat painful foot and leg, in which plain xrays are normal (apart from increased soft tissue volume), but bone bruise apparent on magnetic resonance imaging (MRI). Even little, minimal pain, or no pain at all, should alert physicians and patients not to ignore the first signs of this debilitating desease (**Baravarian** B et al. 2004).

Any suspicion of Eichenholtz stage O must include MRI or scintigraphy or isotope scanning to plain film radiographs.

In **Koller** et al. (2011) the name of the stages slightly changes: **stage I: destruction; stage II: resolution; stage III: coalescence.**

D In 1991 **Sanders** and **Frykberg** suggested an **anatomically based system** which divides the foot in 5 zones, according to the joints involved:

Type I	forefoot joints, metatarsophalangeal and interphalangeal
Type II	tarsometatarsal joints, metatarsal bases, cuneiforms and cuboid
Type III	Chopart's/tarsal joints
Type IV	ankle, subtalar joints
Type V	calcaneum

E In 1996 the **University of Texas Wound Classification System** classified ulcers, often accompanying CN, using 4 stages and 4 grades in each stage:

	O	**I**	**II**	**III**
A	Areas of pressure which are sometimes called pre-ulcerative lesions	Superficial ulcers not including tendon, capsula or bone	Deep ulcers including tendon, capsula but not bone	Deep ulcers including bone and articulation
B	infection	infection	infection	infection
C	ischemia	ischemia	ischemia	ischemia
D	infection + ischemia	infection + ischemia	infection + ischemia	infection + ischemia

According to the **Australian and International Guidelines on Diabetic Foot Disease** (2016), the University of Texas Wound classification is "one of the longest standing classification systems, and is recommended in the Australian Guidelines". The treating physician should be encouraged to learn and use this classification, because it's easier to document the patient ongoing progress and communicate with orthopaedic surgeons and members of the multidisciplinary team. For other experts, this classification has shown to be predictive of poor outcomes, but it's difficult to remember, and doesn't include all the diabetic foot complications (**Amit Kumar** CJ 2012).

F In 1998 **Schon** described a more precise classification, based on **anatomy** plus **severity of collapse.** This classification has been validated, but it has not yet shown that the additional complexity is clinically useful and relevant.

Type	Stage	Association
Lisfranc pattern	Deformity doesn't collapse to plantar surface or foot	Dislocation
Cuneonavicular pattern	Deformity collapses, is coplanar to plantar surface	Anteroposterior talar first metatarsal angle of more than 35°
Perinavicular pattern	True rockerbottom foot; midtarsus inverted beneath the forefoot and hindfoot	Lateral talar-first metatarsal angle of more than 30°
Transverse tarsal pattern		Lateral fifth metatarsocalcaneal angle of 0° or less

G In 2015 **Chantelau** proposed a new **staging approach** based on:

disease activity demonstrated by MRI	active	(A)
	inactive	(B)
presence of deformity	present	(1)
	absent	(O)

A-O is the equivalent of Eichenholtz stage O: desirable stage for identification and treatment; better chance of achieving healing without deformity; lower long term risk of ulcers and amputation.

B-O is the objective/end of the therapy, the result of care.

A-1 is equivalent Eichenholtz stage 1-3. Surgery in these stages should be avoided, although there are some contrary arguments (**Simon** SR et al. 2000).

B1 – inactive disease with deformity – represents a stable end stage, with **risk of ulceration.** Orthotic treatment and follow-up are essential to minimize the risk. Surgery may be considered to reduce the risk of ulceration.

The expert panel refers to adopt the most commonly used classification systems, mentioned above, in order to recognize and characterize a Charcot foot.
For some of the panellists, existing classification systems are not particularly helpful, as they do not provide sufficient prognostic value[1]. That's why some of them use personal, unpublished but practical and effective methods of classification.

[1] "Existing classifications do not provide prognostic value or direct treatment" (**Rogers** LC et al. 2011).

The importance of a **multidisciplinary team** to organize the Charcot/diabetic foot and/or ankle care is stressed in most of the examined scientific literature and published guidelines. The team should include: diabetologist, orthopaedic surgeon, vascular surgeon, endovascular interventionist/radiologist, podiatrist, diabetes nurse and pedorthist/orthotist.

Surgery

Goal of surgery

Full consensus among the expert panel referring to the scope of surgery:
- **create a stable plantigrade foot, that one can brace with a shoe, or with Charcot restraint orthotic walker (CROW)**
- **heal relevant ulcers**
- **prevent amputation**
- **restore a normal life for the patient as much as possible.**

From literature

- "Prevent recurrent ulceration, further deformity and further foot fracture" (**Güven** MF et al. 2013).
- "Restore alignment and stability, prevent amputation, prepare for a shoe or brace, allow the patient to be ambulatory" (**Lamm** BM et al. 2006).
- "An unstable ankle may be more difficult to control with an orthosis and may be susceptible to ulceration and secondary deep infection. Therefore, surgery in the Charcot ankle may prevent ulceration and amputation" (**Galhoum** AE 2016).

Indications or contraindications for surgery

Some relevant functional/mobility conditions of the patient, plus some significant clinical signs, have been classified into three different level of indication's strength:

Level A (Primary)
Level B (Secondary)
Level C (Controversial)

LEVEL A – Primary indications

Valued by the expert panel as most important, necessary and sufficient conditions:

- **severe instability, significant not plantigrade[2]**
- **severe arthropathy**
- **instability of the ankle[3]**
- **acutely dislocated foot and/or ankle**
- **infected, long standing and recalcitrant non healing ulcers[4, 5, 6]**
- **failure of the previous conservative treatment or therapy[7].**

[2] "A deformed but plantigrade foot capable of full weight bearing in a shoe or orthosis, and without increase of deformity, is not a candidate for surgery" (**Koller** A et al. 2011).

[3] "Unstable fractures should be treated operatively; if the diabetic patient presents with neuroarthropathic Charcot changes, treat differently: serial casting until consolidated, consider long-term bracing and fusion as salvage if needed... Be aware of risk factors, double everything – fixation, time of non-weight-bearing, number of office visit..." (**Pinzur** MS et al. 2017).

[4] "The single indication for surgery in the early stages of Charcot was reported to be repeated infection and deep ulcerations of the ankle or forefoot" (**Shibata** T et al. 1990) (**Shade** VL et al. 2015).

[5] "The estimated cost for foot ulcers care in the US ranges from 4.595 dollars per ulcer episode to nearly 28.000 dollars for the 2 years after diagnosis" (**Ramsey** SD et al. 1999).

[6] "Ulcers are not necessarily an obstacle to surgery. An infected ulcer, however, should be first treated with debridement, moist dressings, and antibiotics" (**Koller** A et al. 2011).

[7] "Early surgical intervention should be considered in case of severe dislocation, unstable deformity, non-reducible deformity or failure of conservative treatment to maintain a stable plantigrade foot" (**Shade** VL et al. 2015).

***LEVEL A** from literature*

- Failure of conservative therapy. CN cases refractory to off-loading or immobilization (among others, **Rogers** LC et al. 2011)
- Patients with unstable foot and ankle (among others, **Rogers** LC et al. 2011)
- Severe CN of the ankle (among others, **Rogers** LC et al. 2011)
- Infected, recalcitrant and recurrent ulcerations; concern for skin breakdown (among others, **Rogers** LC et al. 2011) (**Shade** VL et al. 2015)
- Unshoeble, non braceable deformities (among others, **Koller** A et al. 2011)
- Acute fracture dislocations (among others, **Koller** A et al. 2016)
- Progression to later stages of Eichenholtz classification, stage 2-3 (among others, **Lamm** BM et al. 2007 in **Rozbruch** RS, **Ilizarov** S eds) (**Koller** A et al. 2011).

LEVEL B – Secondary indications

Valued by the expert panel as necessary conditions in combination with other co-factors:
· progression of deformity
· severity of deformity
· weight bearing incapacity
· bone infection.

LEVEL C – Controversial issues

There are some indications and contraindications, whether to operate or not.

Active Charcot **(Eichenholtz stage 1 and 2),** in presence of **inflammation.**

For the expert panel, no inflammation means most often that Charcot foot is inactive.

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. From literature, for some experts surgical treatment is necessary only in the 25% of all patients with acute Charcot neuroarthropathy, when for some others operative therapy has to start as soon as possible. No recommendations are made on surgical interventions in the Australian guidelines (**Australian International Guidelines on Diabetic Foot Disease** 2016), but they positively recommend considering Achilles tendon lengthening and flexor tenotomy, and a recommendation against nerve decompression is given. Any surgical intervention presents the risk of complications, but also the advantage of permanently changing foot shapes to reduce plantar pressure without the need for any treatment adherence.

For the expert panel any stage is suitable for surgery, as active Charcot foot/active stages are no contraindication. 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, preventing further deformity. If active Charcot shows no dislocation pathway, then immobilization, compression and non weight bearing are suggested. The use of bisphosphonate therapy[8] has been suggested by some experts, but it remains a controversial issue.

[8] There is good evidence for the use of bisphosphonates in the treatment of early Charcot's neuroarthropathy. This is aimed at reducing osteoclastic activity and the resultant bone weakness which is thought to play a major role in the evolution of this process (**Banskota** B et al. 2010) (**Jude** EB et al. 2001).

If a shoeable foot is not reached, surgery may follow the period of total contact cast (TCC). In active Charcot, for some experts, inflammation can be considered a contraindication to surgery in case of - a) phlegmon: the suggested therapy is rest, unloading, antibiotics and wound cleaning; or in case of - b) osteomyelitis: the therapy should be staged salvage at best with antibiotic spacer, prolonged targeted antibiotics and return to salvage when infection is resolved. Some experts suggest surgical debridement of the infected bone, IVAB, cement spacer or antibiotic spacer. Once osteomyelitis has been cleared, then Charcot reconstruction should be considered. Some experts also suggest, in some cases, Achilles Tendon Lengthening (ATL) plus immobilization with external fixator to maintain anatomy.

In synthesis, infections should be treated with antibiotics and shouldn't be confused with inflammation; phlegmon, abscess and osteomyelitis may even indicate urgent surgery, but this is septic surgery with its own rules, and not Charcot reconstruction.

PRO *from literature*

- "Early surgical treatment in the acute phase may be a feasible alternative to non operative management. However the optimal timing of surgery remains to be determined" (**Simon** SR et al. 2000).
- "The surgical principle of obtaining a correction and then maintaining the correction applies not only to fracture reduction but also to deformity correction with the use of the Ilizarov device. The first stage of reconstructing a Charcot foot is to obtain a correction (i.e. acute or gradual soft tissues correction and osseous realignment) and the second stage is to maintain the correction (i.e. arthrodesis or stabilization)… Almost all corrections require Achilles tendon Z- lengthening or gastrocnemius-soleus recession" (**Lamm** BM et al. 2006).
- "Surgery must be considered as the most effective therapeutic approach to diabetic Charcot foot complicated by wounds and osteomyelitis" (**Pinzur** MS 2007).
- "Perform urgent surgical interventions in cases of deep abscesses, compartment syndrome and virtually all necrotizing soft tissue infections. Consider surgical intervention in cases of osteomyelitis accompanied by soft tissue infection, destroyed soft tissue envelope, progressive bone destruction through X-ray or bone protruding through the ulcer" (**Australian International Guidelines on Diabetic Foot Disease** 2016).
- Operative therapy has to start as soon as possible. In recent studies the advantages of earlier surgical correction of deformity and arthrodesis have been proposed, which are based on the assumption that surgical stabilization would increase the patient's quality of life (**Mittlmeier** T, et al. 2010) **(Güven** MF et al. 2013).
- "The co-factors to consider for deciding positively to act surgery in the acute

phase of Charcot are, from literature: the vascular supply to the affected limb, the anatomic location of breakdown, the patient's medical and surgical histories, the patient's history of alcohol and tobacco use, the patient's ability to comply with post-operative weight-bearing restrictions, the patient's support network and the methods of fixation. "There is no doubt that there are specific indications for conservative management versus surgical. Regardless of the chosen treatment pathway, all protocols should be specific to the patient based on the lower extremity pathology, overall medical status, ability to comply with the given therapy" (**Grover Pàez** F et al. 2013).

- "Many surgeons will not surgically address this pathology because of its progressive nature, the patient pool, and patient compliance problems. Past surgical methods of treating this pathology usually involved simple lump-and-bump exostectomies. Internal fixation methods using screws and plates have been incorporated with some success, but external fixation has changed the way this disease process is addressed, allowing foot and ankle surgeon to correct both simple and complex Charcot pathology in a safe and aggressive manner" (**Wang** JC 2003).

CONTRA *from literature:*

- "The major contraindication for surgery is active inflammation. Studies have shown less favourable outcomes when surgery is performed on the acute joint" (**Mrugeshkumar** S 2016).
- "There is little evidence to support the role of any operative intervention in stage I. Concerns lie with the potential for wound healing complications and infection that can occur when operating on an oedematous limb" (**Shade** VL et al. 2014).
- "Due to the increased risk of wound infections and mechanical failure of fixation, surgery should be avoided during the active inflammatory stage" (**Güven** MF et al. 2013).

Poor bone quality/bone resorption

For the expert panel, during the Eichenholtz stages 1 and 2, bone is considered to be weak, but the active stages should not prevent from operation. Bone quality rather influences the operative technique or the choice of hardware/external fixation, and it also depends on where the poor bone quality is located: if only in the area of the Charcot joint, or it is the foot skeleton in general involved. It also depends on the amount of poor bone quality and anatomical location of the poor bone area. In some cases of active Charcot, and with no dislocation pathway, the suggested therapy prior to surgery could be total contact cast (TCC) and non-weight bearing, plus medical therapy. It can also be sometimes considered a contraindication to surgery when structural integrity is under question; it may change with the advent of custom titanium grafting. If the clinical picture is consistent with salvage over amputation, and significant bone loss is present, structural grafting may be considered.

PRO *from literature*

- "Bone quality is less a concern with the use of external fixation as it does not rely on cortical purchase for stabilisation" (**Zgonis** T et al. 2007).
- "Surgical intervention even with poor bone quality and tenuous soft tissue, through a modification of external fixation to correct deformity with a limited risk of surgical-associated morbidity" (**Rogers** LC et al. 2011).

CONTRA *from literature*

- "The primary concern, however, is with the quality of the bone as it is undergoing a pathogenic process of osteoclastic resorption and fragmentation, and its quality is feared to be less than optimal for adequate fixation purchase" (**Simon** SR et al. 2000) and (**Sinacore** DR et al.1999) (**Shade** VL 2015).
- "Contraindications to arthrodesis include the poor bone stock for fixation" (**Galhoum** AE 2016).

Poor soft tissues envelope
Oedema

For some experts of the panel, to operate it's necessary to have adequate soft tissue coverage including incision with stable/reduced oedema prior to reconstruction. It would require ulcer healing, graft or flap for closure prior to or at the time of recon, if possible; oedema control and lymphedema clime for wraps and casting. In severe cases very big ulcerations or significant oedema may require preoperative treatment by conservative means. If there is vasculopathy or excessive oedema, then there is more risk of wound complications: in these cases the suggested therapy is CROW boot, off loading and minimal percutaneous surgery, or no surgery at all. Poor soft tissue envelope can also mean atrophy, thin skin, stiff skin, among others. Usually, these conditions are permanent, whereas an oedema often is temporary or can be treated before an operation. For some other experts of the panel, either poor soft tissues envelope, or oedema are never to be considered contraindications, and the suggested therapy is percutaneous Beaming and frame.

CONTRA *from literature*

- "Active soft tissue is contraindication to arthrodesis" (**Galhoum** AE et al. 2016).

Morbid obesity

For the expert panel, morbid obesity is not a contraindication, and standard surgical care is suggested. Morbid obesity is not a standing alone condition to decide whether operate or not. Other means and co-factors need to be carefully considered. If other options are fully explored, then surgery is a reasonable decision. Mostly has to do with remaining non weight bearing during recovery: if the obese patient cannot be non weight bearing because of obesity, then surgery is generally contraindicated. In these cases, the suggested therapy is total contact casting (TCC), crow boot, BKA (if not possible, social service arrangements may be necessary). Elevated glycemic levels, which are present in this population, may require medical optimization with surgical delay, and modification of weight. Morbid obesity can be considered a contraindication if there are general risks against operation, such as anaesthesia. It is necessary to balance patient morbidity against potential benefit of foot & ankle surgery. For this reason, morbid obesity rather influences the surgical technique and the operative method, which should be less complex in these cases.

PRO *from literature*

- Michael **Pinzur**, orthopaedic surgeon at Loyola University Health System (LUHS, IL, USA) evidences that "Charcot foot typically occurs in morbidly obese diabetics who have neuropathy … which impairs the ability to feel foot pain … two morbidly obese patients with severe Charcot foot arthropathy were treated successfully with percutaneous correction of their deformity followed by a stepwise application of a pre-assembled neutrally aligned multiplane ring external fixator. This technique transfers well to the trauma environment in which alignment can be maintained without further violation within the zone of injury. … Taking this technology from the domain of the deformity surgeon to the general orthopaedic community will require the suppression of bad memories from residency. Using the device solely as a method of maintaining alignment eliminates many of the dynamic attributes that contribute to pain and morbidity" (**Pinzur** MS 2006).

Surgical reconstruction

Historically surgeons have utilized circular and monolateral external fixation for the management of complicated high-energy orthopedic trauma and reconstruction of congenital or post-traumatic deformities through Ilizarov and de Bastiani principles of callotasis and distraction osteogenesis. Proving success in bone healing and deformity correction, external fixation has found its way into the treatment of Charcot foot, and in some studies it seems to be the next step in Charcot treatment (**Liu** G 2008).

In 1996 Sticha and collegues reported the use of Kirschner wire fixation and three unilateral miniexternal fixators for midfoot arthrodesis in patients with chronic Charcot neuroarthropathy deformity (**Sticha** RS et al. 1996, quoted by **Ramanujam** CL et al. 2013).

Some doubts still remain if surgical reconstruction, with devices often not designed for structures as small as the foot, is superior to total contact casting (TCC), and whether external fixation is superior to internal fixation. Besides, there is no robust, strong evidence in most of the studies regarding the best method of surgical fixation to be used in reconstruction, either internal or external, or together.

Suggested surgical options

Achilles Tendon Lengthening (A.T.L.)		*Expert panel consensus*
mainly in presence of:	equinus contracture	100%
	recurrent ulceration	83.33%
	foot deformity	50%
	acute stage of deformity (stage 0-1)	33.33%

also with bone pressure, non infected wounds, failure of non-operative treatments, infected ulcerations, instability, severe pain, malunions/non-unions, salvage of previous failed interventions.

From literature

- "Equinus deformity imparts a major deforming force on the foot and is almost always concurrent with Charcot foot deformities. Surgical strategies to correct equinus deformity of the ankle are based on clinical evaluation. The Silverskiöld test is the gold standard for determining whether a patient has gastrocnemius equinus deformity or gastrocnemius-soleus equinus deformity. With most Charcot deformities, a severe gastrocnemius-soleus equinus contracture is present; therefore, maximum lengthening is necessary…" (**Lamm** BM et al. in: **Rozbruch** RS, **Ilizarov** S eds 2007).
- "Sometimes CN can be a result of a shortened Achilles tendon. In this case, and in the presence of a mobile ankle joint, Tendoachilles lengthening should be considered" (**Koller** A et al. 2011).

Osteotomy/Exostectomy		*Expert panel consensus*
mainly in presence of:	recurrent ulcerations	66.67%
	bone pressure	66.67%
	foot deformity	66.67%
	with bone quality amenable	33.33%
	non infected wounds	33.33%
	infected ulcerations	33.33%

and in presence of instability, failure of non-operative treatments, no history of osteomyelitis, no growth of organisms after the initial surgical wounds debridement, eradicated soft tissues infections, absence of infections, adequate soft tissues coverage, equinus contracture.

From literature

- "The difficulty with exostectomy lies in ensuring that one resects an adequate amount of bone to minimize the potential for recurrent ulceration while avoiding excessive resection, which could potentially destabilize the foot. There is currently no widely accepted protocol to quantify how much bone to resect. Wieman and colleagues describe a method in which one performs osseous resection in such a way as to recreate the arch of the foot. They emphasize a curvilinear approach to osseous resection, extending from the inferior aspect of the first metatarsal to the inferior aspect of the calcaneus and approximately one-third superiorly into the arch of the foot" (**Shade** VL 2015).

Plantar-realignment osteotomy		*Expert panel consensus*
mainly in presence of:	foot deformity	83.33%
	recurrent ulcerations	83.33%
	infected ulcerations	50%
	failure of non-operative treatments	33.33%
	malunions/non-unions	33.33%
	bone pressure	33.33%
	salvage of previous failed interventions	33.33%
	equinus contracture	33.33%

and in presence of instability, no history of osteomyelitis, acute stage of deformity, eradicated soft tissues infections, large bone loss/defects, high risk obesity, retained/broken hardware, adequate soft tissues coverage, bone quality amenable, absence of infections, active Charcot.

Open reduction with different techniques		*Expert panel consensus*
mainly in presence of:	instability	83.33%
	foot deformity	66.67%
	recurrent ulcerations	50%
	malunions/non-unions	50%
	infected ulcerations	33.33%
	failure of non-operative treatments	33.33%
	bone pressure	33.33%
	acute stage of deformity (stage 0-1)	33.33%
	large bone loss/defects	33.33%
	retained/broken hardware	33.33%

and in presence of severe pain, non infected wounds, with history of foot and/or ankle osteomyelitis, equinus contracture, active Charcot.

Arrhodesis with different techniques		*Expert panel consensus*
mainly in presence of:	instability	100%
	recurrent ulcerations	66.67%
	foot deformity	66.67%
	failure of non-operative treatments	50%
	malunions/non-unions	50%
	salvage of previous failed interventions	50%
	severe pain	33.33%
	acute stage of deformity (stage 0-1)	33.33%
	infected ulcerations	33.33%
	bone pressure	33.33%
	large bone loss/defects	33.33%

and with history of foot and/or ankle osteomyelitis, non infected wounds, retained/broken hardware, bone quality amenable, equinus contracture, active Charcot.

From literature

- "When performing arthrodesis in the neuropathic foot the most rigid form of fixation suitable to the procedure is necessary. Preferably this involves the use of screws and/or plates" (**Healios Wound Solutions** 2017).

Gradual correction with external fixation		*Expert panel consensus*
mainly in presence of:	instability	100%
	recurrent ulcerations	83.33%
	foot deformity	66.67%
	infected ulcerations	50%
	failure of non-operative treatments	50%
	bone pressure	33.33%
	acute stage of deformity (stage 0-1)	33.33%
	large bone loss/defects	33.33%
	salvage of previous failed interventions	33.33%
	equinus contracture	33.33%

also with severe pain, non infected wounds, with history of foot and/or ankle osteomyelitis, malunions/non-unions, retained/broken hardware, active Charcot.

Debridement (most often)		*Expert panel consensus*
mainly in presence of:	infected ulcerations	100%
	recurrent ulcerations	50%
	failure of non-operative treatments	16.67%
	bone pressure	16.67%
	non infected wounds	16.67%
	history of foot and/or ankle osteomyelitis	16.67%
	eradicated soft tissues infections	16.67%
	immunocompromised	16.67%

Bone stimulation with different techniques yes (50%); no (50%)		*Expert panel consensus*
mainly in presence of:	previous failed interventions	50%
	malunions/nonunions	50%

and with failure of non-operative treatments, acute stage of deformity (stage 0-1), large bone loss/defects, immunocompromised and absence of infection.

From literature

- “Findings in a pilot study suggest that the use of a combined magnetic field bone growth stimulator may be an effective adjunctive modality in the treatment of acute Charcot” (**Hanft** JR et al. 1998).

Surgical procedures

Use of internal fixation

For the expert panel the use of internal fixators is recommended in certain cases.

From literature

- “Surgeons may also consider internal fixation when the patient presents with non-infected wounds, no history of osteomyelitis and no growth of organisms after the initial surgical debridement of the wounds associated with the diabetic Charcot neuroarthropathy deformity” (**Ramanujam** CL et al. 2013).
- “Internal fixation is best suited for subluxed joints with minimal bony destruction. Good bone quality and substance are essential for screw purchase. It is also preferable to place screws where an intact soft tissue envelope exists” (**Giurini** J 2005).

Modality	*Most important reasons*
Screws including cannulated screws: yes/most often (66.67%)	more stable fixation (66.67%), simultaneous compression and stabilisation (66.67%), preserving natural length of the foot (33.33%), minimally invasive, others.
Cannulated screws/beaming: yes (66.67%), no (33.33%)	more stable fixation (66.67%), simultaneous compression and stabilisation (50%), minimally invasive (50%), preserving the natural foot length, limiting neurovascular compromise, others.
Locking/non locking plates: yes/most often (66.67%), no (33.33%)	more stable fixation (50%), simultaneous compression and stabilisation (50%), earlier partial weight bearing, others.
IM nails: yes (66.67%), no (33.33%)	more stable fixation (33.33%), simultaneous compression and stabilisation (33.33%), minimally invasive (33.33%), preserving the natural foot length, others.
K-wire: yes (50%), no (50%)	minimally invasive (50%), limiting neurovascular compromise.

Use of external fixation

From literature

- "Absence of pain allows different surgical techniques, neuroarthropathic fractures have a twofolds time to healing, fusion needs stable implants, additional external protection or rigid external fixation" (**Koller** A et al. 2011).
- "Reconstructive surgery of Charcot feet using external fixation is a safe and economically feasible procedure... Use of external fixator offers the advantage that all extraneous material is removed after 6 weeks; thus, there is no risk of broken screws or plates and the associated potential complications" (**Illgner** U et al. 2014).
- "Recently external fixation has become popular and advocated as a treatment option for Charcot arthropathy in the earlier stages and/or in cases complicated with open wounds or infection… The advantages of external fixation include biomechanical stability, access to soft tissue, early ability to bear weight, and the ability to make adjustments post-operatively" (**Lavery** LA et al. 2010).
- "In the diabetic population, external fixation may be indicated in the acute management of certain ankle fractures and/or dislocations to provide further stabilisation in the presence of dense peripheral neuropathy" (**Ramanujam** CL et al. 2013).
- "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).

- "Bone quality is less a concern with a use of external fixation as it does not rely on cortical purchase for stabilization. Advantages of external fixation are also the neutralization of stressed placed across the foot, the ability to allow weight sharing with a static construct and deter inappropriate or excessive weight bearing, the assistance in deformity correction when dynamic constructs are used, the lower extremity stabilization when large bone voids exist, the ability to perform bone transport if needed, all via minimal incisions that preserve soft tissue and osseous vascular supply, and useful for monitoring the limb when advanced soft tissue plastic surgery techniques are used for closure" (**Shade VL** et al. 2015).
- "Good results have been reported with external fixation techniques in patients who were not suited for internal fixation and otherwise may have required amputation" (**Güven** MF et al. 2013).

For the expert panel the use of external fixation is recommended in most cases, nearly always when deformity is present, and in case of open wounds with active infection. It is often used in combination with internal fixation, when there is the need for supplemental fixation[9].

[9] See also *Appendix II*, a clinical case of surgical treatment of Charcot Foot with external fixation.

Modality	*Most important reasons*
Circular external fixation: yes (100%)	more stable fixation (100%), simultaneous compression and stabilisation (83.33%), additional tool to properly offload grafts or flaps in patients who are unable to tolerate conventional techniques such as cast immobilization (83.33%), minimally invasive (66.67%), make necessary adjustments in post operative phase (50%), limiting neurovascular compromise (50%), shorten osseous segments and obtain wounds closure (50%), earlier partial weight bearing (33.33%), preserving the natural foot length (16.67%).

From literature

- "The fixator (a device, called a circular external fixator, is a rigid frame made of stainless steel and aircraft-grade aluminium. It cointains three rings that surround the foot and lower calf. The rings have stainless-steel pins that extend to the foot and secure the bones after surgery) has been demonstrated to achieve a high potential for clinical enhanced outcomes with a minimum risk for treatment-associated morbidity" (**Pinzur** MS 2006).
- "Off-loading circular external fixation provides stabilization and continued access for local wounds care" (**Ramanujam** CL et al. 2006).

- “Proponents of circular frames indicate that patients can begin early weightbearing. This is especially true with Ilizarov style frames which allow surgeons to dissipate weightbearing forces through a set of wires and frames proximally in the lower extremity. This will often counteract the disuse osteopenia that results in these patients from long-term nonweightbearing or immobilization” (**Giurini** J 2005).

Modality	*Most important reasons*
Open osteotomy with static external fixation and ulcer excision: yes (83.33%), no (16.67%)	simultaneous compression and stabilisation (83.33%), additional tool to properly offload grafts or flaps in patients who are unable to tolerate conventional techniques such as cast immobilization (83.33%), make necessary adjustments in post operative phase (66.67%), shorten osseous segments and obtain wounds closure (66.67%), limiting neurovascular compromise (50%), more stable fixation (33.33%), minimally invasive (33.33%), earlier partial weight bearing (33.33%), preserving the natural foot length (16.67%).
Hybrid external fixation: yes (66.67%), no (33.33%)	more stable fixation (66.67%), simultaneous compression and stabilisation (66.67%), earlier partial weight bearing (66.67%), additional tool to properly offload grafts or flaps in patients who are unable to tolerate conventional techniques such as cast immobilization (50%), minimally invasive (33.33%), limiting neurovascular compromise (33.33%), shorten osseous segments and obtain wounds closure (33.33%), make necessary adjustments in post operative phase (16.67%), preserving the natural foot length (16.67%).
Acute open reduction with mostly static external fixation: yes/most often (66.67%), no (33.33%)	more stable fixation (66.67%), simultaneous compression and stabilisation (66.67%), additional tool to properly offload grafts or flaps in patients who are unable to tolerate conventional techniques such as cast immobilization (66.67%), minimally invasive (50%), limiting neurovascular compromise (50%), shorten osseous segments and obtain wounds closure (50%), make necessary adjustments in post operative phase (33.33%), earlier partial weight bearing (33.33%).
Unilateral mini external fixators: yes (33.33%), no (66.67%)	*(among the 33.33% of the responders):* simultaneous compression and stabilisation (16.67%), minimally invasive (16.67%), limiting neurovascular compromise (16.67%).

Use of internal and external fixation together

From literature

- "With adequate soft tissue coverage, bone quality amenable to fixation and an absence of infection" (**Ramanujam** CL et al. 2013).
- "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).
- "Internal and external fixation used in conjunction:
  - bridge the arthrodesis site neutralizing stresses applied
  - increase the bending stiffness and torsional resistance of the constraint enhancing mechanical stability
  - stabilize adjacent joints
  - function as a splint to maintain any soft tissue equinus correction.

  Internal fixation can be placed once osseous consolidation has been achieved with the use of external fixation alone, if concerns for motions still exist" (**Shade VL** et al. 2015).
- "… their preferred surgical management of unstable, progressive and non-infected CN foot and ankle deformities with a combination of internal and external fixation, which provides both stability and compression across the arthrodesis sites. Deliberate restraint and frequent follow-up are crucial during resumption of protected weight bearing for these patients. Ultimately, after the predicted protracted post-operative course, most patients are able to return to diabetic shoe gear or braces with long-term activity modification" (**Capobianco** CM et al. 2010).

For the expert panel the use of internal and external fixation together is sometimes recommended for maximizing fixation, when severe or gross deformity is present. Most often when the case is not infected, depending upon the deformity, the level of needed correction and bone quality.

Modality	*Most important reasons*
Cannulated screws/beaming: yes (100%)	more stable fixation (66.67%), simultaneous compression and stabilisation (66.67%), minimally invasive (33.33%), additional tool to properly offload grafts or flaps in patients who are unable to tolerate conventional techniques such as cast immobilization (33.33%), earlier partial weight bearing (33.33%).
IM nails: yes (100%)	more stable fixation (66.67%), simultaneous compression and stabilisation (66.67%), earlier partial weight bearing (33.33%).
Locking/non locking plates: yes (66.67%), no (33.33%)	more stable fixation (66.67%), simultaneous compression and stabilisation (33.33%).

Super constructs: yes (66.67%), no (33.33%)	more stable fixation (66.67%), simultaneous compression and stabilisation (33.33).
Solid screws: yes (33.33%) no (66.67%)	more stable fixation (33.33%), simultaneous compression and stabilisation (33.33%).
K-wire: yes (33.33%) no (66.67%)	minimally invasive (33.33%).

Use of TCC with internal fixation

For the expert panel the use of TCC with internal fixation is most often recommended with highly unstable Charcot ankle, if soft tissue is adequate, always to provide additional protection and external stabilization for 2 months at minimum.

Surgical fixation complications

The expert panel agree about the most common surgical fixation complications, which are the following:
· wire or half pin breakage
· unexpected soft tissues infections
· unexpected osseous infections
· internal/external fixation instability
· malalignment and malunion-nonunion
· fractures and joint dislocations

From literature

- “Despite the potential for significant operative complications, the overall success rate of limb salvage reconstruction is approximately 80% to 90%” (**Johnson** JE et al. 2008).

Post surgical treatment

Consensus among the expert panel regarding the key to a successful post surgical therapy: long term bracing or casting (from 3 to 7 months).

From literature

- "Patients with arthrodesis or bilateral Charcot's arthropathy after surgery casted for a long period of time (4-6 months) and a longer period to return to permanent foot wear (6-11 months)" (**Amstrong** DG et al. 1998).
- "Post operative regimen, non weight bearing and total-contact cast for 3 months and 2 months in a weight bearing total-contact cast" (**Johnson** JE 1998).
- "Continued bracing for 6 months" **(Jones** KB et al. 2005).
- "Postoperative treatment is key to success. Long term bracing or casting (3-6 months)" **(Koller** A et al. 2011).
- "Total-contact cast for 5 months (range 4-9)" **(Myerson** M et al. 1994).
- "Postoperative non-weight-bearing for 6 weeks, and then 6 months of bracing" **(Schon** LC et al. 1998).
- "Immobilization of the limb in a non weightbearing cast for minimum 6 weeks. If radiographs show bone incorporation without negative side effects, the patient can wear a weightbearing cast boot for 1 additional month" **(Simon** SR et al. 2000).
- "Healing time to produce bony stability after surgical fixation or arthrodesis exceeds 3 months" **(Sinacore** DR et al. 1998).

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APPENDIX I

Some population/economic data on diabetes

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 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 cases.

In 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%.

In China

"The age-standardized prevalence of total diabetes were 9.7% accounting for 92.4 million adults with diabetes... The prevalence of diabetic foot ulcers ranges from 4% to 10% in the hospitalized patients and the risk of patients with diabetes developing a foot ulcer in their life time could be as high as 25%" (**Wu** L. et al 2015).

In the Middle East

Saudi Arabia has the fourth highest diabetes rate in the world: 22%.

In Oceania

The country with the highest value of percentage of people who have diabetes (ages 20-79) is Palau with a value of 20.90; the lowest is in Australia with a value of 5.10.

In India

63 million in 2013
100 million in 2030

The rates on China and India are lower than many countries from Oceania and Middle Eastern countries.

Cost of diabetes

In USA

$ 245 billion: total cost of diagnosed diabetes in the USA in 2012.
From $ 4,595 per ulcer episode to 28,000 $ for the two years after diagnosis per patient.
From $ 6,000 to $ 30,000 per patient for initial therapy with external fixation.

In European Region (EU)

Each country spends differently: i.e. Spain $ 3,090 per patient, Germany $ 4,943, Turkey $ 895 on each person with diabetes.

In UK

9% National Health Service (NHS) hospital budget
5% NHS whole budget
50% spent in treating complications

Diabetes vs. Charcot foot

"…In a quoted assessment, based on a random sample of 6,992 patients from USA to define the prevalence and risk factors for diabetes in racial ethnic minorities, is emerged that they are less likely to have Charcot foot compared to non-hispanic whites, but the are no racial/ethnic differences in amputation" (**McEwen** LN et al. 2013).

Pathology association

- Higher BMI
- Longer duration of diabetes and use of insulin
- History of microvascular and macrovascular disease
- Higher Charlson comorbidity compared to patients with no foot conditions
- Biomechanical loading of obesity plays a substantial role in the development of Charcot foot
- BMI associated with Charcot foot, but not with amputation
- Hemoglobin A1 C levels >7%
- Not observed association between smoking and Charcot foot

Blacks, Whites, Latinos

no difference regarding amputation, not depending on socioeconomic status (see ref. above)

Gender

patients with Charcot foot are **more likely men**

Age

over 50 as average

Incidence rate of Charcot foot

- 0.8% in the above quoted assessment
- other sources: from 7.5% up to 13% of diabetic patients in USA

Data sources:

American Diabetes Association 2016
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

APPENDIX II

Clinical cases

Case 1

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 fracturedislocation 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 . 1 A
AP X-ray of the patient. Few days earlier, she had had a minimal trauma and presented a trimalleolar fracture-dislocation of the ankle joint, which is typical in Charcot foot disease.

FIG . 1 B
Lateral view of the same patient.

FIG . 1 C-D AP and lateral view of the clinical aspect.

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

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

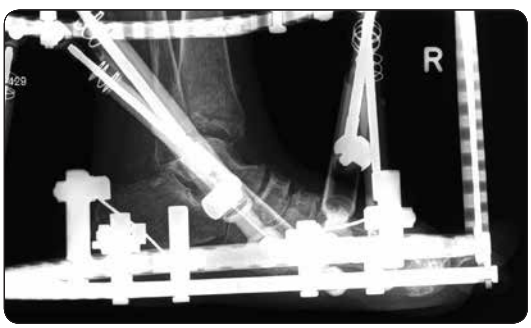

FIG . 3 B

FIG . 4 A-B AP and lateral view of the clinical aspect during treatment.

FIG . 5 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.

FIG . 5 B

FIG . 6 A-B AP and lateral view of the clinical aspect after consolidation (the hallux valgus deformity had not yet been treated because the patient didn´t complain and the deformation fit well in the orthotic boot).

FIG . 6 B

Case 2

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.

FIG . 1
Lateral view Charcot ankle with dislocation.

FIG . 2
AP View Charcot ankle.

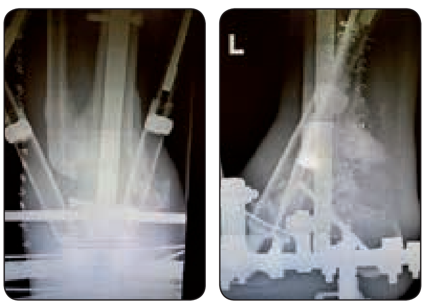

FIG . 3
Ex fix over In fix for Charcot foot.

FIG . 4
Fusion at 10 weeks.

FIG . 5
Orthofix TL-HEX with walker rails over Infix.

FIG . 6
9 months post-op.

Case 3

FIG . 1
Charcot deformity with equinovarus position of the right foot.

FIG . 2
Charcot deformity of the midfoot with deformity of the fifth metatarsal.

FIG . 3
X-ray which demonstrates the extensive Charcot fracture-dislocation of the ankle and hindfoot.

FIG . 4
Intraoperative clinical picture demonstrating the pantalar arthrodesis.

FIG . 5
Lateral view revealing the external fixation with compression of the ankle and hindfoot.

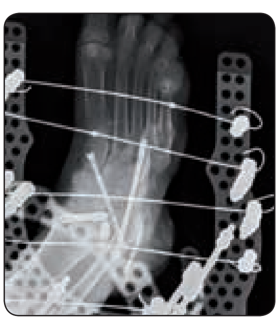

FIG . 6
AP view revealing midfoot and ankle arthrodesis.

FIG . 7
6 Months postop pantalar arthrodesis with internal fixation.