Surgical Optimization for Charcot Patients

Kelsey J. Millonig, DPM, MPH[a,*], Rachel Gerber, DPM[b]

KEYWORDS

• Charcot • Peripheral vascular disease • metabolic bone profile • hemoglobin A1c • vitamin D • osteomyelitis

KEY POINTS

- Patients with Charcot Neuroarthopathy have multiple morbidities that make them a challenge pre and post-reconstruction.
- Partner with colleagues in endocrinology, vascular, nutrition, primary care, etc. These individuals are essential in being able to perform a successful reconstructive surgery.
- Optimizing patients prior to surgery takes time, effort, and patients; to have successful outcomes we need to have multiple visits with these patients prior to surgery and honestly describe best and worse case scenarios.

Abbreviations	
TSH	Thyroid Stimulating Hormone
PTH	Parathyroid Hormone
DM	Diabetes Mellitus
CRPPS	Charcot Reconstruction Preoperative Prognostic Score
PEDIS	Perfusion, Extent, Depth, Infection, Sensation

INTRODUCTION

Reconstruction of the Charcot foot and ankle demonstrates significant challenges to the foot and ankle surgeon. At present, there is limited clear consensus on the best approach for preoperative optimization. The primary aim of Charcot reconstructions is to limit the risk of ulceration by providing a stable plantigrade foot allowing ambulation. However, often with or without reconstructive treatment there is a significant risk of amputation. The reported limb salvage rates in this population have been variable. Although there is a presence of outcome-based research, the role of preoperative

[a] East Village Foot & Ankle Surgeons, 500 East Court Avenue, Suite 314, Des Moines, IA 50309, USA; [b] AMITA Health Saint Joseph Hospital Chicago, 2900 North Lake Shore Drive, Chicago, IL 60657, USA
* Corresponding author.
E-mail address: Kelsey.J.Millonig@gmail.com

Clin Podiatr Med Surg 39 (2022) 595–604
https://doi.org/10.1016/j.cpm.2022.05.006
podiatric.theclinics.com

optimization to provide the best success of limb salvage and prevention of amputation is still relatively understudied. Pinzur and colleagues reported data with preoperative considerations including large bone deformity, long-standing ulceration with concomitant infection, regional osteopenia, obesity, and immunocompromised states as risks to intervention. Eschler and colleagues identified high-risk criteria associated with Charcot reconstructions using the CRPPS scoring system.[1] The investigator identified a PEDIS score of <7 as associated with successful limb salvage. However, the optimization of modifiable factors was not discussed. The focus of this article is the discussion of modifiable risk factors associated with Charcot reconstruction for preoperative optimization. The remainder of this article is organized as follows.

- Diabetes
  - Hemoglobin A1C
- Peripheral vascular disease
- Tobacco Use
- Chronic Kidney Disease
- Obesity
- Hypertension
- Edema
- Albumin/Prealbumin
- Metabolic Bone Profile
  - Vitamin D/Calcium
  - Thyroid TSH, PTH
  - Osteopenia
- Infection
  - Wound
  - Osteomyelitis

Diabetes

The presence of diabetes itself is an increased risk for loss of limb. Nondiabetic patients with Charcot neuroarthropathy are still 15 times more likely to return to ambulation after reconstruction than diabetic patients with well controlled glucose levels.[2] It is important to educate patients regarding their risk because of the metabolic impact of diabetes systemically and therefore the importance of optimizing their glucose control. It is estimated that 0.1% to 7.5% of patients with diabetes develop Charcot neuroarthropathy.[3]

Hemoglobin A1C

Surgical site infections have been found to increase when patients have a hemoglobin A1C (HbA1c) $\geq$ 8%, so it is recommended to delay surgery until the HbA1c can be decreased below that level.[4] In addition to referrals to endocrinology for management, it would also be beneficial to consider referral for nutritional education as the long-term health of these patients mostly depends on their nutrition. There may be clinical scenarios where the level of the deformity with impending soft tissue compromise requires surgical reconstruction with an HbA1c greater than 8%. Postoperative glycemic control will also reduce complication rates.[5] Sadoskas and colleagues[5] found that patients with a serum glucose greater than 200 mg/dL have a significantly higher risk of surgical site infection.

Peripheral Vascular Disease

The prevalence of peripheral vascular disease (PVD) in patients with Charcot neuroarthropathy has been heavily debated in the literature with ranges from 4% to 40% being recorded in the last 20 years.[4,6–12] In patients greater than 40 year old, the prevalence of peripheral arterial disease (PAD) is estimated to be twice as high in patients with diabetes mellitus (10%) compared with that of the nondiabetic patients (5%).[9] In addition, in the presence of a diabetic foot ulcer, the incidence of PAD is found to be 49%.[13]

It is imperative to understand that there is no definitive noninvasive method for diagnosing PAD in the diabetic population. Owing to diabetic individuals having calcification of vessels, ankle-brachial indexes (ABIs) are frequently falsely elevated. The best results for diagnosing PVD in diabetics have been found by combining ABI tests with the toe-brachial index (TBI) tests especially in patients with an ABI $\geq$ 1.3.[14–16] This is because of ABI having high specificity and the TBI with high sensitivity. Qualitative waveform analysis has also been found to be a highly sensitive screening method for PVD in individuals with diabetes.[15] Alternatively, an arterial duplex may be used in combination with ABIs or TBIs as a reference standard to allow for more definitive information and diagnosis regarding vascular status.[17]

Patients who had Charcot with diabetes, PVD, and critical limb ischemia were found to have significantly lower rates of limb preservation (59.1%) a year after balloon angioplasty. Conversely, patients with just DM and critical limb ischemia had a limb preservation rate of 92.7%.[18] The risk of lower extremity amputations in patients with Charcot and PVD continues to be a concern even after surgical reconstructions. PVD caused by a 2.012 times increase in likelihood of having delayed healing and increased the risk of major lower extremity amputation by 4.414 fold in individuals with Charcot.[10]

It is imperative that preoperatively patients are evaluated preoperatively with vascular analysis beyond clinical examination findings. Even in the setting of palpable pedal pulses, the authors suggest obtaining arterial studies. With abnormal findings, it is imperative to provide an appropriate referral for revascularization before elective surgery to increase success for limb preservation.

Tobacco Use

It is well established that tobacco use is a risk factor for impaired wound healing, infection, delayed fracture healing, and prolonged hospital stay. Complications can be reduced by 40% if tobacco cessation is completed perioperatively.[19] The ideal time frame for this has been described as cessation not later than 8 weeks before surgery.[20] In elective lower extremity orthopedic surgery, patients required to quit preoperatively, 48% maintained smoking cessation for at least 1 year postoperatively. Of those who relapsed, approximately half stated that they did not resume smoking until at least 3 months postoperatively. Therefore, this particular period may be an important time for intensified smoking cessation counseling.[19] The use of tobacco products has been commonly associated with PVD and wound healing complications even in nondiabetic individuals. Charcot patients who had a history of smoking were found to have 2.4 times higher odds of having PVD.[10] These same individuals had a significantly increased likelihood to have delayed healing than their nonsmoking counterparts.[10]

Chronic Kidney Disease

Valabhji and colleagues found that 30% of patients with Charcot neuroarthropathy had end-stage renal disease (ESRD).[21] Patients with renal disease (renal disease: ESRD and chronic kidney disease [CKD]) are 3.5 times more likely to have PVD and

if on dialysis have a 10 times higher rate of amputation.[10,22] The risk of major lower extremity amputations is also statistically higher for patients with renal disease.[10] This is secondary to wound healing complications, inhibited osseous union, sepsis, and cardiovascular disease. Raspovic and colleagues found that diabetic patients with ESRD requiring dialysis and lower extremity complications were found to have increased higher creatinine levels, lower hemoglobin levels, lower albumin levels, and higher rates ofPAD.[23]

Obesity

There is an association that has been established between increased body mass index (BMI) and the occurrence of Charcot neuroarthropathy.[24] Once patients are diagnosed with Charcot neuroarthropathy, these higher values of BMI values are associated with a higher occurrence of amputations.[24] Although the effect of BMI has not been well studied in regard to its effect on Charcot reconstructions, the general mentality is higher BMIs may lead to increased complications. This has been supported by prior research on BMI and foot and ankle surgery. In a case series of 18 patients who underwent tibiocalcaneal arthrodesis, Love and colleagues found that patients were at an increased risk of postoperative complications if they had a BMI >25; these complications included nonunions, infections, and hardware failures.[25] Increased BMIs have been associated with decreased physical function after fixation of ankle fractures.[26] These studies may provide useful insight regarding the effect of BMI on patients undergoing reconstructive surgery for Charcot joints.

Hypertension

Hypertension has been found to be a statistically significant risk factor for delayed healing.[10] In addition, hypertension is a known independent risk factor for PAD.

Edema

Preoperative edema control is important to consider in prevention of wound healing complications postoperatively. In addition, consideration for edema is important if using an external fixator to ensure adequate space is left with ring fixation. Minimally invasive techniques for Charcot neuroarthropathy may be an optimal consideration for concern of edema.

Albumin/Prealbumin

Evaluating these laboratory results is important for consideration for protein markers of nutritional status for wound healing.[23] It is well established that preoperative hypoalbuminemia can impact wound healing. However, this is even more critical in the diabetic population. Cheng and colleagues found that patients with a diabetic foot infection with hypoalbuminemia (<3.5 g/dL) demonstrated a 2.5-fold higher risk of nonhealing at postoperative 28 days than patients with normal levels.[27] Therefore, preoperative serum albumin levels should be analyzed, optimized, and used as a biomarker for predicting postoperative healing.

Metabolic Bone Profile

Vitamin D/calcium

It is well understood that vitamin D is crucial for optimal arthrodesis. A 2017 study of patients undergoing elective foot and ankle surgery showed that patients with vitamin D deficiency insufficiency were 8.1 times more likely to develop a nonunion.[28] Diabetic patients both with and without Charcot neuroarthropathy have significantly lower vitamin D levels (serum 25-hydroxyvitamin D) than nondiabetic patients.[29] In addition,

owing to the need for bioactivation of 25-hydroxyvitamin D3 in the kidney, patients with concomitant renal disease are more typically deficient and also more challenging to optimize as a result.

Thyroid levels

Thyroid hormones are essential for bone mass maintenance, and hypothyroidism yields impared bone formation. Suppression of thyroid stimulating hormone can have an increased risk for osteoporotic fracture.[30] For adult patients, T3 regulates bone turnover and bone mineral density (BMD). With abnormal thyroid levels, patients lose optimal bone strength, and population studies indicate that hypothyroidism and hyperthyroidism are associated with an increased risk of fracture. In addition, literature has also demonstrated that TSH may have direct actions in bone cells. The full discussion of the endocrine pathways that regulate bone mass is beyond the scope of this article. However, completing a metabolic bone laboratory analysis should be considered preoperatively as this may affect the success rate of the patient postoperatively.[31] Appropriate referral to endocrinology should be considered as necessary.

Osteopenia

Osteopenia has long been considered to be a classic finding of Charcot neuroarthropathy.[32] Charcot patients have commonly been found to have reduced BMD in their peripheral skeleton, but it is unknown if Charcot causes reduced BMD or if decreased BMD leads to Charcot.[33–36]

Subclassification of the pattern of injury in Charcot neuroarthropathy patients has found three subgroups: fracture, dislocation, and combination fracture—dislocation type patterns.[37] Individuals with fracture Charcot neuroarthropathy were found to have significantly lower t-scores (SD from site- and gender-matched healthy young adult means) and z-scores (SDs from age-, site-, and gender-matched means) than individuals with dislocation Charcot.[37] The distribution of the fracture patients' t-scores may be found in Fig. 1. Of the patients that had dislocation Charcot, only four individuals had t-scores less than −1.0.[37]

Infection

Wound/osteomyelitis

Owing to the deformities that occur with Charcot neuroarthropathy, patients are at increased risk of lower extremity ulcerations which commonly lead to infections and

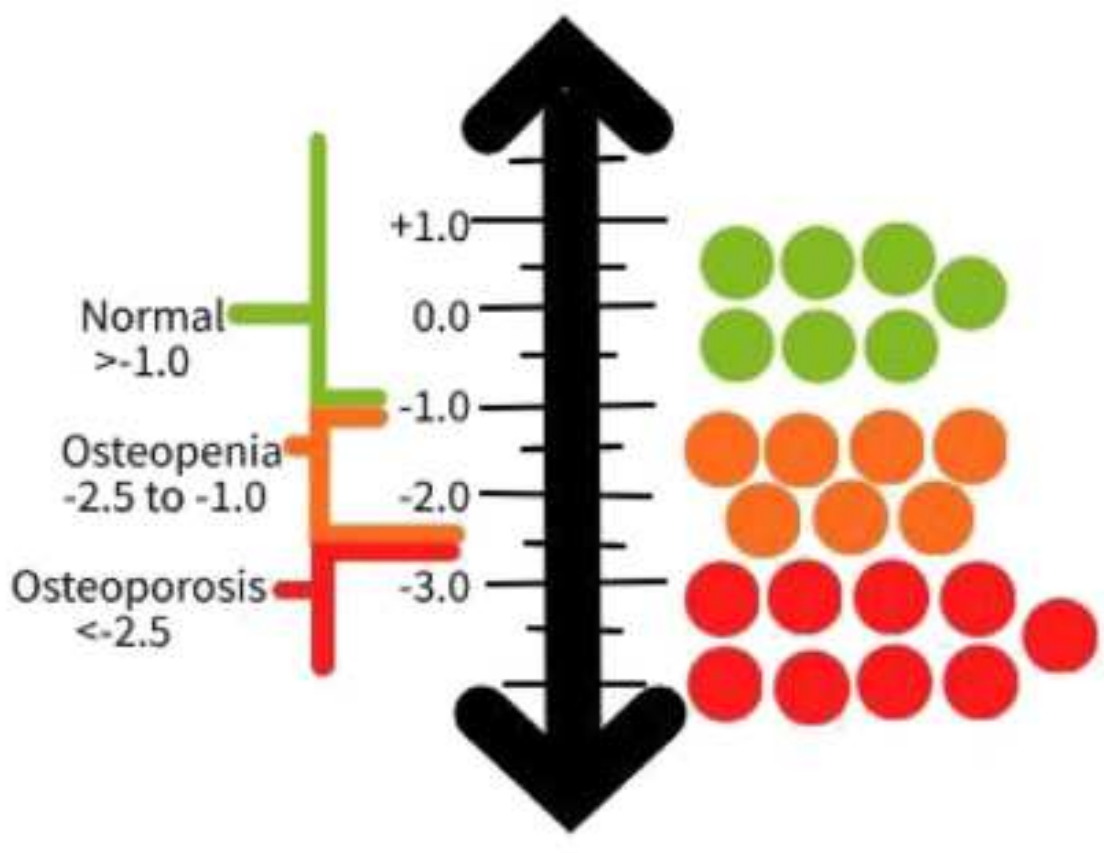

Fig. 1. Distribution of the fragmentation Charcot patients in Herbst and colleagues based on WHO criteria.[37,38]

Preoperative Charcot Reconstruction Checklist	Yes	No
1. Does the patient have diabetes?		
1a. If yes what was the last HbA1c?		
2. Does the patient have known clinical signs of PVD?		
2a. Recommend ordering ABI, TBI, and/or arterial duplex regardless of clinical findings		
3. Does the patient have any history of Tobacco use?		
3a. If yes recommend smoking cessation for minimum of 8 weeks preop to 3 months postop and completing 2a.		
4. Does the patient have Chronic Kidney Disease?		
4a. If yes recommend completing 2a.		
5. What is the patients BMI?		
6. Does the patient have Hypertension?		
6a. If yes recommend completing 2a and advising patient of possible wound healing complications		
7. Does the patient have Edema?		
7a. If yes consider treatment for edema control and minimally invasive technqiues		
8. What is the patients preoperative albumin/prealbumin?		
9. Is the patient Vitamin D deficient?		
9a. If yes consider optimizing patient prior to surgery		
10. What was the patients preoperative TSH and T3 level?		
10a. If abnormal consider sending patient to endocrinology for optimization prior to surgery		
11. Does the patient have known osteopenia?		
11a. Regardless of answer to 11, What was the patients most recent t-score/z-score?		
12. Does the patient have an ulceration?		
12a. If yes, obtain deep tissue cultures		
12b. Is there a soft tissue infection?		
12c. Is there any chance of bony involvement?		
If yes obtain bone biopsy		
12d. Is there osteomyelitis present?		

Fig. 2. Example of preoperative optimization checklist.

osteomyelitis. Foot ulcers have been reported to occur in 11% to 60% of all diabetics with Charcot deformity.[39–42] In diabetics, 50% to 60% of ulcers become infected.[43] The previous research has shown that osteomyelitis occurs in 20% of patients who experience an ulceration is more likely to occur in larger and deeper ulcerations and may be present in greater than 60% of infected diabetic foot ulcers.[44–48]

Individuals 65+ years of age with ulcerations are 13 times more likely to have a major lower extremity amputation than their age-matched nonulcerated counterparts.[49] However, age is not a large factor in the equation as individuals less than 65 years of age with an ulcer were 12 times more likely to have an amputation.[49]

Many physicians prefer to heal the ulcer before reconstructive surgery.[50–52]

In cases where resolution of the ulcer before correction is not possible, deep cultures and bone biopsies should be taken before reconstructive surgery to rule out soft tissue infection and osteomyelitis. Numerous authors have been able to perform reconstructive surgery and heal the ulcer simultaneously. Acute deformity correction has been used successfully to heal and prevent recurrence of ulceration.[53] Wrotslavsky and colleagues found using gradual correction can safely and accurately correct the Meary and calcaneal inclination angles while also healing 100% of ulcers.[54] In addition, a staged procedure with the management of ulceration or osteomyelitis with antibiotic spacer and/or masquelet technique if needed can be used.

SUMMARY

As demonstrated in this article, there are several factors that impact the success of Charcot neuroarthropathy surgical reconstruction beyond the surgical technique. It is imperative that physicians consider the factors described above for surgical optimization preoperatively (Fig. 2).

DISCLOSURE

K.J. Millonig is a Consultant for Orthofix.

REFERENCES

1. Eschler A, Gradl G, Wussow A, et al. Prediction of complications in a high-risk cohort of patients undergoing corrective arthrodesis of late stage Charcot deformity based on the PEDIS score. BMC Musculoskelet Disord 2015;16:349.
2. Cates NK, Wagler EC, Bunka TJ, et al. Charcot reconstruction: outcomes in patients with and without diabetes. J Foot Ankle Surg 2020;59(6):1229–33.
3. Frykberg Robert G, Belczyk Ronald. Epidemiology of the charcot foot. Clin Podiatric Med Surg 2008;25(1):17–28.
4. Wukich DK, Crim BE, Frykberg RG, et al. Neuropathy and poorly controlled diabetes increase the rate of surgical site infection after foot and ankle surgery. J Bone Joint Surg Am 2014;96(10):832–9.
5. Sadoskas D, Suder NC, Wukich DK. Perioperative glycemic control and the effect on surgical site infections in diabetic patients undergoing foot and ankle surgery. Foot Ankle Spec 2016;9(1):24–30.
6. Chantelau E. The perils of procrastination: effects of early vs. delayed detection and treatment of incipient Charcot fracture. Diabet Med 2005;22(12):1707e12.
7. Sohn MW, Lee TA, Stuck RM, et al. Mortality risk of Charcot arthropathy compared with that of diabetic foot ulcer and diabetes alone. Diabetes Care 2009;32(5):816e21.
8. Salini D, Harish K, Minnie P, et al. Prevalence of Charcot Arthropathy in Type 2 Diabetes Patients Aged over 50 Years with Severe Peripheral Neuropathy: A Retrospective Study in a Tertiary Care South Indian Hospital. Indian J Endocrinol Metab 2018;22(1):107–11.

9. Gregg Ew, Sorlie P, Paulos-Ram R, et al. Prevalence of lower-extremity disease in the US adult population >= 40 years of age with and without diabetes. Diabetes Care 2004;27:1591–7.
10. Cates NK, Elmarsafi T, Akbari CM, et al. Complications of charcot reconstruction in patients with peripheral arterial disease. J Foot Ankle Surg 2021;60(5):941–5. Epub 2021 Apr 1.
11. Cates NK, Elmarsafi T, Bunka TJ, et al. Peripheral vascular disease diagnostic related outcomes in diabetic charcot reconstruction. J Foot Ankle Surg 2019; 58(6):1058–63.
12. Wukich DK, Raspovic KM, Suder NC. Prevalence of peripheral arterial disease in patients with diabetic Charcot c. J Foot Ankle Surg 2016;55(4):727–31.
13. Prompers L, Huijberts M, Apelqvist J, et al. High prevalence of ischaemia, infection and serious comorbidity in patients with diabetic foot disease in Europe. Baseline results from the Eurodiale study. Diabetologia 2007;50:18–25.
14. Wukich DK, Shen W, Raspovic KM, et al. Noninvasive arterial testing in patients with diabetes: a guide for foot and ankle surgeons. Foot Ankle Int 2015;36(12): 1391–9.
15. Williams DT, Harding KG, Price P. An evaluation of the efficacy of methods used in screening for lower-limb arterial disease in diabetes. Diabetes Care 2005;28(9): 2206–10.
16. Brooks B, Dean R, Patel S, et al. TBI or not TBI: that is the question. Is it better to measure toe pressure than ankle pressure in diabetic patients? Diabet Med 2001; 18(7):528–32.
17. Crawford F, Welch K, Andras A, et al. Ankle brachial index for the diagnosis of lower limb peripheral arterial disease. Cochrane Database Syst Rev 2016;9(9): CD010680. Published 2016 Sep 14.
18. Çildağ MB, Köseoğlu ÖFK. The effect of charcot neuroarthropathy on limb preservation in diabetic patients with foot wound and critical limb ischemia after balloon angioplasty. J Diabetes Res 2017;2017:5670984. Epub 2017 Aug 29.
19. Smith DH, McTague MF, Weaver MJ, et al. Durability of smoking cessation for elective lower extremity orthopaedic surgery. J Am Acad Orthop Surg 2019; 27(16):613–20.
20. Myers K, Hajek P, Hinds C, et al. Stopping smoking shortly before surgery and postoperative complications: a systematic review and meta-analysis. Arch Intern Med 2011;171(11):983–9. Epub 2011 Mar 14.
21. Valabhji J. Foot problems in patients with diabetes and chronic kidney disease. J Ren Care 2012;38(Suppl 1):99–108. PMID: 22348369.
22. Ndip A, Rutter MK, Vileikyte L, et al. Dialysis treatment is an independent risk factor for foot ulceration in patients with diabetes and stage 4 or 5 chronic kidney disease. Diabetes Care 2010;33:1811–6.
23. Raspovic KM, Ahn J, La Fontaine J, et al. End-stage renal disease negatively affects physical quality of life in patients with diabetic foot complications. Int J Low Extrem Wounds 2017;16(2):135–42. Epub 2017 May 4.
24. Bandeira MA, Dos Santos ALG, Woo K, et al. Incidence and predictive factors for amputations derived from charcot's neuroarthropathy in persons with diabetes. Int J Low Extrem Wounds 2021. https://doi.org/10.1177/15347346211025893. Epub ahead of print.
25. Love B, Alexander B, Ray J, et al. Outcomes of tibiocalcaneal arthrodesis in high-risk patients: an institutional cohort of 18 patients. Indian J Orthop 2020;54(1): 14–21.

26. Dean Daniel M, Ho Bryant S, Lin Albert, et al. Predictors of patient-reported function and pain outcomes in operative ankle fractures. Foot Ankle Int 2017;38(5): 496–501.
27. Cheng P, Dong Y, Hu Z, et al. Biomarker prediction of postoperative healing of diabetic foot ulcers: a retrospective observational study of serum albumin. J Wound Ostomy Continence Nurs 2021;48(4):339–44.
28. Moore KR, Howell MA, Saltrick KR, et al. Risk factors associated with nonunion after elective foot and ankle reconstruction: a case-control study. J Foot Ankle Surg 2017;56(3):457–62.
29. Yoho RM, Frerichs J, Dodson NB, et al. A comparison of vitamin D levels in nondiabetic and diabetic patient populations. J Am Podiatr Med Assoc 2009;99(1):35–41.
30. Galliford TM, Murphy E, Williams AJ, et al. Effects of thyroid status on bone metabolism: a primary role for thyroid stimulating hormone or thyroid hormone? Minerva Endocrinol 2005;30(4):237–46.
31. Williams GR. Actions of thyroid hormones in bone. Endokrynol Pol 2009;60(5): 380–8.
32. Purewal T. Charcot's diabetic neuroarthropathy: pathogenesis, diagnosis and management. Pract Diabetes Int 1996;13:88–91.
33. Childs M, Armstrong DG, Edelson GW. Is Charcot arthropathy a late sequela of osteoporosis in patients with diabetes mellitus? J Foot Ankle Surg 1998;37:437–9.
34. Young MJ, Marshall A, Adams JE, et al. Osteopenia, neurological dysfunction, and the development of Charcot neuroarthropathy. Diabetes Care 1995;18:34–8.
35. Cundy TF, Edmonds ME, Watkins PJ. Osteopenia and metatarsal fractures in diabetic neuropathy. Diabet Med 1985;2:461–4.
36. Jirkovska AP, Kasalicky P, Boucek P, et al. Calcaneal ultrasonomentry in patients with Charcot osteoarthropathy and its relationship with densitometry in the lumbar spine and femoral neck and with markers of bone turnover. Diabet Med 2001;18: 495–500.
37. Herbst SA, Jones KB, Saltzman CL. Pattern of diabetic neuropathic arthropathy associated with the peripheral bone mineral density. J Bone Joint Surg Br 2004;86:378–83.
38. Kanis JA. Assessment of fracture risk and its application to screening for postmenopausal osteoporosis: synopsis of a WHO report. WHO Study Group. Osteoporos Int 1994;4:368–81.
39. Pakarinen TK, Laine HJ, Mäenpää H, et al. Long-term outcome and quality of life in patients with Charcot foot. Foot Ankle Surg 2009;15(4):187–91.
40. Leung HB, Ho YC, Wong WC. Charcot foot in a Hong Kong Chinese diabetic population. Hong Kong Med J 2009;15(3):191–5.
41. Fabrin J, Larsen K, Holstein PE. Long-term follow-up in diabetic Charcot feet with spontaneous onset. Diabetes Care 2000;23(6):796–800.
42. Armstrong DG, Todd WF, Lavery LA, et al. The natural history of acute Charcot's arthropathy in a diabetic foot specialty clinic. Diabet Med 1997;14(5):357–63.
43. Armstrong DG, Boulton AJM, Bus SA. Diabetic foot ulcers and their recurrence. N Engl J Med 2017;376:2367e2375.
44. Kagna O, Srour S, Melamed E, et al. 18F-FDG PET/CT imaging in the diagnosis of the osteomyelitis in the diabetic foot. Eur J Med Mol Imaging 2012;39:1545–50.
45. Lavery LA, Armstrong DG, Wunderlich RP, et al. Risk factors for foot infections in individuals with diabetes. Diabetes Care 2006;29(6):1288e1293.
46. Lipsky BA. Osteomyelitis of the foot in diabetic patients. Clin Infect Dis 1997;25: 1318–26.

47. Wrobel JS, Connolly JE. Making the diagnosis of osteomyelitis. The role of prevalence. J Am Podiatr Med Assoc 1998;88:337–43.
48. Norden CW. Acute and chronic osteomyelitis. Infect Dis 1999;2:43–8.
49. Sohn MW, Stuck RM, Pinzur M, et al. Lower-extremity ampu- tation risk after Charcot arthropathy and diabetic foot ulcer. Diabetes Care 2010;33(1):98–100.
50. Clohisy DR, Thompson RC Jr. Fractures associated with neuropathic arthropathy in adults who have juvenile-onset diabetes. J Bone Joint Surg Am 1988;70: 1192–200.
51. Sammarco GJ, Conti SF. Surgical treatment of neuroarthropathic foot deformity. Foot Ankle Int 1998;19:102–9.
52. Sammarco VJ, Sammarco GJ, Walker EW Jr, et al. Midtarsal arthrodesis in the treatment of Charcot arthropathy. J Bone Joint Surg Am 2009;91:80–91.
53. Mittlmeier T, Klaue K, Haar P, et al. Should one consider primary surgical reconstruction in charcot arthropathy of the feet? Clin Orthop Relat Res 2010;468(4): 1002–11.
54. Wrotslavsky P, Kriger SJ, Hammer-Nahman SM, et al. Computer-assisted gradual correction of Charcot foot deformities: an in-depth evaluation of stage one of a planned two-stage approach to Charcot Reconstruction. J Foot Ankle Surg 2020;59(4):841–8.