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Risk Factors Associated With Major Lower Extremity Amputation After Osseous Diabetic Charcot Reconstruction

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ABSTRACT

Patients with diabetic Charcot neuroarthropathy (CN) are at high risk for ulcerations and major lower extremity amputations (LEAs). Osseous reconstruction is an important component in ulcer healing and prevention; however, despite such efforts, major LEAs remain a serious postreconstruction concern. The aim of this study was to identify risk factors for major LEA in patients who underwent osseous Charcot reconstruction. A retrospective review was performed on 331 patients with the diagnosis of CN in the foot and ankle treated over a 16-year period. Two hundred eighty-five patients were included after exclusion of those without diabetes. Demographic data, anatomic wound location, surgical interventions, wound healing status, and the level of eventual amputation were recorded. Multivariate logistic regression and Fisher's exact test were used for analysis. All patients had diabetes, neuropathy, or CN and required osseous reconstruction. Risk factors and their respective odds ratios (ORs) are as follows: postoperative nonunion (OR 8.5, 95% confidence interval [CI] 2.2 to 33.5, 0.0023), development of new site of CN (OR 8.2; 95% CI 1.1 to 62.9; $p = .0440$), peripheral arterial disease (OR 4.3; 95% CI 1.7 to 11.0; $p = .0020$), renal disease (OR 3.7; 95% CI 1.6 to 8.8; $p = .0025$), postoperative delayed healing (OR 2.6; 95% CI 1.1 to 6.5; $p = .0371$), postoperative osteomyelitis (OR 2.4; 95% CI 1.0 to 5.9; $p = .0473$), or elevated glycated hemoglobin (OR 1.2; 95% CI 1.0 to 1.4; $p = .0053$). Independent risk factors found to be statistically significant for major LEA in diabetic CN in the setting of osseous reconstruction must be mitigated for long-term prevention of major amputations.

The clinical, social, and economic implications of diabetes mellitus (DM)-related complications are well documented. The incidence rate for foot ulceration in this cohort is approximately 15% to 20% in a patient's lifetime (1). There are approximately 29.1 million cases of diabetes in the United States, with 1.4 million new cases annually with medical and surgical diabetes-related complications (2). As the prevalence worldwide is increasing with projections to 430 million persons with DM by 2030, more definitive evidence-based identification of those patients at highest risk for complications play more critical roles (1–3). Charcot neuroarthropathy (CN) is a rare but limb-threatening consequence of DM. The prevention, early detection, treatment, and surveillance of patients with diabetic CN deformities involve a thorough understanding and a systematic approach to management (4–6). Patients with CN are at the highest risk for multiple operative limb salvage procedures, as well as major and minor amputations (7–10). When the Charcot foot is complicated by infection of the soft tissue or bone, surgical management and osseous reconstruction become an important attempt toward limb salvage (11–13).

Uncontrolled DM, previous ulcerations or minor amputations, presence of peripheral polyneuropathy, and concomitant osteomyelitis (OM) are commonly associated risk factors for osseous reconstructive failure (14,15). Host factors such as advanced age, smoking history, impaired renal function, suboptimal nutrition, and a variety of other risk factors have an impact on outcomes (16,17). When it is determined that surgical osseous reconstruction is a viable option, all of these potential risk factors for failure must be considered. A functional, plantigrade, braceable foot, free of infection and ischemia, is the goal of successful limb salvage (18).

The authors of this article are part of a multidisciplinary team dedicated to limb salvage whose approach and care have been standardized

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and have developed a robust database of patients with CN. Our experience with comprehensive Charcot management has provided anecdotal successes; however, reconstruction failures do occur. The aim of this article was to determine which independent risk factors were associated with major lower extremity amputation (LEA) after osseous reconstruction in patients with CN.

Patients and Methods

After approval was provided by the Georgetown University Medical Center institutional review board, a retrospective review was performed on 331 patients with CN of the foot and ankle by querying the records of the senior author (C.E.A.) in a 16-year period (September 1997 to December 2013). All patients were admitted for the acute management of the foot and ankle that included lower extremity infection, complex Charcot foot or ankle deformity, and ischemic changes. Exclusion criteria included those without a known diagnosis of DM, patients < 18 years of age, < 1 year of postoperative follow-up, cases presenting with dry gangrene, and those treated with nonsurgical management. All osseous reconstructions were performed by a single surgeon (P.C.). Osseous reconstruction included the use of a combination of internal and external fixation techniques. Patients were offered reconstruction when their wound(s) had a high probability for nonhealing or recurrence as a result of biomechanical abnormalities. Two hundred eighty-five patients were included for evaluation. The following demographic data were collected: age, sex, and body mass index. Glycated hemoglobin (HbA1c), comorbidities including peripheral arterial disease (PAD) (defined as an ankle brachial index < 0.9, those who had monophasic arterial Doppler scans or had signals not detectable by Doppler scanning, and those who had < 3-vessel run-off on angiography), Eichenholz stage (19), location of Charcot collapse, type of surgical correction, and surgical outcomes including reulceration, infection, delayed healing (defined as nonhealing > 30 days), and nonunions were identified on plain radiographs and clinically correlated and defined as a visualized lack of osseous fusion with or without hardware failure, postoperative OM (diagnosed by histopathology, microbiology, and imaging), and minor and major LEA. We defined minor amputation as those distal to the tibiotalar joint and major LEA as below-knee amputations, knee disarticulations, and above-knee amputations.

All patients in this cohort were hospitalized at an urban university hospital and were under the care of a multidisciplinary team dedicated to limb salvage. Patients were evaluated by internal medicine, vascular surgery, orthopedic surgery, infectious disease, plastic surgery, physical therapy, and other consultations that were provided as needed. Patients who presented with clinical, systemic, or laboratory findings requiring emergency surgical decompression of an infected lower extremity were stabilized and urgently debrided in the operating room. In all other circumstances, comprehensive laboratory testing, imaging, vascular evaluation and treatment, and the medical management of other coexisting conditions were addressed before CN reconstruction.

Debridement of nonviable and infected soft tissue and wide resection of clinically infected bone was performed while obtaining deep postdebridement soft tissue and bone samples for culture. Antibiotic treatment was culture specific and monitored by infectious disease specialists. This often required external fixation to keep the remaining bones in place. Once eradication of infection was confirmed by culture and vascular disease optimized wherever necessary, osseous reconstruction and soft tissue closure/coverage were addressed. Reconstruction included bone fusion with internal and external fixation, depending on the defect and initial infection status. Adjunctive procedures and techniques such as tendo-Achilles lengthening, gastroc recession, and use of negative-pressure wound therapy were added when indicated. The postoperative protocol required strict non-weightbearing until radiographic evidence of osseous consolidation was confirmed. Removal of external fixation was dependent on clinical and host considerations.

Means and standard deviations with continuous variables, counts, and percentages have been presented for categorical variables. The p values were calculated with Fisher's exact test. Multivariate logistic regression was used to identify risk factors associated with major LEA. Significance was assessed at $p < .05$. Data for comparison were segregated into those who required a major LEA and those who did not.

Results

Three-hundred eleven unique patients with a diagnosis of CN were identified. Of those, 26 patients without diabetes were excluded, and the outcomes of the remaining 285 patients were analyzed. Overall descriptive statistics are presented in Table 1. All 285 patients had a history of diabetes complicated with peripheral polyneuropathy and CN requiring osseous reconstruction. There were 116 men (58.2%) and 119 women (41.8%) included. The mean age of patients at the CN osseous reconstruction was 63.9 (range 31.6 to 91.9) years. Patients in this population had a mean HbA1c of 8.6% (range 4.8 to 16.1). The mean body mass index was 33.36 (range 14.3 to 65.2) kg/m^2. There was a high prevalence of comorbidities, with hypertension, found in 204 patients, being the most common (71.3%). Other comorbidities included 92 patients with renal disease (defined as those with a glomerular filtration rate < 30 mL/min/1.73 m^2) (32.2%), 51 with PAD (17.8%), and 40 with a history of smoking (13.9%). Forty-nine patients (17.2%) required a major LEA, compared with those who had successful lower extremity salvage (n = 236 [82.8%]). The mean length of time to below-knee amputation was 20.7 (range 0.1 to 102.9) months. The mean length of time to above-knee amputation was 3.6 (range 1.9 to 5.3) months. Twenty-one patients had minor amputations (14 transmetatarsal amputations [4.9%], 2 Lisfranc amputations [0.7%], and 5 Chopart amputations [1.8%]). One hundred sixty-eight patients required external fixation (58.7%). The mean length of treatment with external fixation was 3.9 (range 0.5 to 31.5) months. The predominance of the patients in our cohort were Eichenholz stages 2 and 3 (76.5%). The mean follow-up time after reconstruction was 29.5 (range 12.1 to 124.4) months.

Table 1
Demographics (N = 285 patients)

Variable	N (%)
Sex	
Male	164 (57.5%)
Female	121 (42.5%)
Age (y)	
Mean	56.5
Range	14.3 to 65.2
Body mass index	
Mean	33.4
Range	14.3 to 65.2
Diabetes	285 (100%)
Charcot	285 (100%)
Hypertension	204 (71.3%)
Renal disease	92 (32.2%)
Peripheral arterial disease	51 (17.8%)
Smoker	40 (13.9%)
HbA1c	
Mean	8.8
Range	4.8 to 16.1
Eichenholz	
Stage 0	0 (0)
Stage 1	21 (7.4%)
Stage 2	53 (18.6%)
Stage 3	165 (57.9%)
TMA	14 (4.9%)
Lisfranc	2 (0.7%)
Chopart	5 (1.8%)
Symes	0 (0%)
BKA	46 (16.1%)
AKA	3 (1.1%)
Use of ExFix	168 (58.7%)
Length of ExFix (mo)	
Mean	3.9
Range	0.1 to 31.5
Time to BKA (mo)	
Mean	20.7
Range	0.1 to 102.9
Time to AKA (mo)	
Mean	3.6
Range	1.9 to 5.3
Follow-up (mo)	
Mean	29.5
Range	12.1 to 124.4

Abbreviations: AKA, above-knee amputation; BKA, below-knee amputation; Chopart, Chopart amputation; HbA1c, glycated hemoglobin; Lisfranc, Lisfranc amputation; Symes, Symes amputation; TMA, transmetatarsal amputation.

One hundred seventy-four patients (60.8%) had postoperative complications. The most common complications included delayed healing, soft tissue infection, OM, and recurrent ulceration. Postoperative delayed healing was defined as nonhealing at ≥ 30 days (79 [27.6%]). Postoperative wound infection was defined by positive cultures and clinical signs of infection 84 (29.4%). OM was diagnosed based on histopathology, microbiology, and imaging modalities. Postoperative OM

was diagnosed in 76 (26.5%) patients, and ulcer recurrence was found in 58 patients (20.3%) (Table 2).

In a univariate logistic regression, the risk factors comparing those who required a major LEA and those who had successful reconstruction in this cohort were PAD ($p = .0001$), renal disease ($p = .0051$), delayed postoperative healing ($p = .0001$), postoperative wound infection ($p = .0054$), postoperative OM ($p = .0001$), transfer ulceration ($p = .0497$), new site of Charcot collapse ($p = .018$), and postreconstruction nonunion ($p = .0048$). In the multivariate logistic regression, data revealed that the most significant risk factors associated with major LEA were PAD, renal disease, postoperative delayed healing (defined as nonhealing >30 days), postoperative OM, postreconstruction nonunions, the development of new CN sites, and increased HbA1c, when all other variables were made constant.

Table 2
Descriptive statistics for major amputation

Variable	Amputated (n = 49)	Nonamputated (n = 236)	*p* Value
Age (mean)	61.23	65.71	.0150
HbA1c (mean)	9.3 (2.6)	8.8 (2.5)	.2070
Body mass index (mean)	32.6 (7.0)	33.1 (7.0)	.5850
Peripheral arterial disease			<.0001
Yes	18 (36.7%)	33 (14.4%)	
No	31 (63.3%)	202 (85.6%)	
Smoker			.1856
Yes	10 (20.4%)	30 (13.1%)	
No	39 (79.6%)	205 (86.9%)	
Male sex			.2674
Yes	32 (65.3%)	132 (55.9%)	
No	17 (34.7%)	104 (44.1%)	
Renal disease			.0004
Yes	27 (55.1%)	65 (28.0%)	
No	22 (44.9%)	170 (72.0%)	
Hypertension			.1165
Yes	40 (81.6)	164 (96.5)	
No	9 (18.4)	72 (30.5)	
Preoperative soft tissue infection			.2526
Yes	14 (28.6)	48 (20.3)	
No	35 (71.4)	188 (79.7)	
Preoperative osteomyelitis			.2033
Yes	16 (32.7)	55 (23.3)	
No	33 (67.3)	181 (76.7)	
Postoperative delay in healing			.0002
Yes	25 (51.0)	54 (22.9)	
No	24 (49.0)	182 (77.1)	
Postoperative wound infection			.0054
Yes	23 (46.9)	61 (25.8)	
No	26 (53.1)	175 (74.2)	
Pin tract infection			.1265
Yes	6 (12.2)	14 (5.9)	
No	43 (87.8)	222 (94.1)	
Postoperative osteomyelitis			<.0001
Yes	26 (53.1)	50 (21.2)	
No	23 (46.9)	186 (78.8)	
Dehiscence			.1967
Yes	8 (16.3)	22 (9.3)	
No	41 (83.7)	214 (90.7)	
Transfer ulcer			.0497
Yes	5 (10.4)	8 (3.4)	
No	43 (89.6)	228 (96.6)	
Recurrent ulcer			.6983
Yes	11 (22.4)	47 (19.9)	
No	38 (77.6)	189 (80.1)	
Recurrent dislocation			.0732
Yes	4 (8.2)	6 (2.5)	
No	45 (91.8)	230 (97.5)	
New site of Charcot collapse			.0183
Yes	4 (8.2)	3 (1.3)	
No	45 (91,8)	233 (98.7)	
Malunion			.2753
Yes	2 (4.1)	4 (1.7)	
No	47 (95.9)	232 (98.3)	
Nonunion			.0049
Yes	8 (16.3)	10 (4.2)	
No	41 (83.7)	226 (95.8)	
Hardware failure			.1456
Yes	9 (18.4)	25	
No	40 (81.6)	211	

Abbreviation: HbA1c, glycated hemoglobin.

The location of Charcot collapse and the type of reconstructive construct were not statistically different between groups. The type of soft tissue closure was found to be different between those with major LEA and those without. More patients had secondary closures as compared with primary closures (Table 3.)

A total of 18 of 285 (6.3%) patients had nonunions. A multivariate logistic model showed that those patients who had nonunions were 8.5 times more likely to require a major LEA compared with patients who did not have nonunions (odds ratio [OR] 8.5; 95% confidence interval [CI] 2.2 to 33.5; $p = .0023$). A total of 7 of 285 (2.5%) patients had development of a new CN site. A multivariate logistic model showed that those patients who developed a new CN site were 8.2 times more likely to require a major LEA compared with patients who did not develop a new CN site (OR 8.2; 95% CI 1.1 to 62.9; $p = .0440$). There was a total of 51 of 285 (17.9%) patients with PAD. A multivariate logistic model demonstrated that patients who had PAD were 4.3 times more likely to require a major LEA compared with patients without PAD (OR 4.3; 95% CI 1.7 to 11.0; $p = .0020$). A total of 92 of 285 (32.3%) patients had renal disease. A multivariate logistic model showed that patients with renal disease were 3.7 times more likely to require a major LEA compared with patients without renal disease (OR 3.7; 95% CI 1.6 to 8.8; $p = .0025$). A total of 79 (27.7%) patients had delayed healing. In a multivariate logistic model, patients who had postoperative delayed healing >30 days were 2.6 times more likely to require a major LEA compared with patients who healed within 30 days (OR 2.6; 95% CI 1.1 to 6.5; $p = .0371$). A total of 76 (26.7%) patients developed postoperative OM. In a multivariate logistic model, patients who developed OM after surgery were 2.4 times more likely to require a major LEA compared with patients who did not develop postoperative OM (OR 2.4; 95% CI 1.0 to 5.9; $p = .0473$). The mean HbA1C in those who required a major amputation was 9.3% compared with a mean HbA1c of 8.8% in those who did not require a major LEA (OR 1.2; 95% CI 1.0 to 1.4; $p = .0053$) (Table 4).

Discussion

The diabetic Charcot foot has dramatic osseous changes that culminate in a repetitive cycle of worsening biomechanical high-pressure areas that predispose to ulceration, infection, and the need for repeated surgical interventions (20,21). In our cohort, multiple independent risk factors were identified. The risk factors with the highest statistical significance were postreconstructive nonunion, the development of a new CN site, and the presence of PAD. Other important risk factors were renal disease, delayed postoperative healing, development of postoperative OM, and elevated HbA1c.

Nonunion rates in patients with DM are higher than those without. The scientific literature unanimously agrees with the importance of more aggressive means of mitigating nonunions in this population. There are many factors that have an effect on fracture healing and arthrodesis outcomes. DM, PAD, and hypothyroidism have a direct effect on bone healing. The use of nonsteroidal antiinflammatory drugs and corticosteroids and history of smoking also have a direct deleterious effect on bone healing (22). For those with complicated DM, Wukich et al (22) in a 2011 study emphasize the increased risk of postoperative complications in this population. Nonunion rates also require more robust fixation, increased diligence toward anatomic alignment, and an increased postoperative period of immobilization (23). Schon et al (24)

Table 3
Descriptive analysis by Charcot location, type of reconstruction, and closure

	Amputated (n = 236)	Nonamputated (n = 49)	*p* Value
Location of Charcot collapse			
Forefoot			.6836
Yes	228 (96.6%)	47 (95.9%)	
No	8 (3.4%)	2 (4.1%)	
Midfoot			.2024
Yes	94 (39.8%)	25 (51.02%)	
No	142 (60.2%)	24 (48.98%)	
Transverse tarsal collapse			.3737
Yes	207 (87.7%)	40 (81.6%)	
No	29 (12.3%)	9 (18.4%)	
Subtalar joint			.6472
Yes	205 (86.9%)	41 (83.7%)	
No	31 (13.1%)	8 (16.3%)	
Ankle: Varus			.6515
Yes	204 (86.4)	41 (83.7%)	
No	32 (13.6)	8 (16.3%)	
Ankle: Vargus			.6515
Yes	204 (86.4)	41 (83.7%)	
No	32 (13.6)	8 (16.3%)	
Type of closure			
Primary			.0041
Yes	125 (53%)	37 (75.5%)	
No	111 (47%)	12 (24.5%)	
Secondary			0.0371
Yes	210 (89%)	38 (77.6%)	
No	26 (11%)	11 (22.4%)	
Delayed primary			1.0
Yes	189 (80.1%)	39 (79.6%)	
No	47 (19.9%)	10 (20.4%)	
Skin graft			.0964
Yes	199 (84.3%)	36 (73.5%)	
No	37 (15.7%)	13 (26.5%)	
Local flap			.7671
Yes	219 (92.8%)	45 (91.8%)	
No	17 (7.2%)	4 (8.2%)	
Free flap			.1017
Yes	228 (97%)	45 (91.8%)	
No	7 (3%)	4 (8.2%)	
Type of Charcot reconstruction			
Midfoot fusion			.0817
Yes	131 (55.5%)	34 (69.4%)	
No	105 (44.5%)	15 (30.6%)	
Subtalar joint arthrodesis			1.0
Yes	233 (98.7%)	49 (100%)	
No	3 (1.3%)	0 (0%)	
Triple arthrodesis			.743
Yes	223 (94.5%)	46 (93.9%)	
No	13 (5.5%)	3 (6.1%)	
Tibiotalocalcaneal arthrodesis			.7459
Yes	221 (93.6%)	47 (95.9%)	
No	15 (6.4%)	2 (4.1%)	
Talectomy			1.0
Yes	231 (97.9%)	48 (98%)	
No	5 (2.1%)	1 (2%)	
Tibiotalar arthrodesis			.1514
Yes	219 (92.8%)	42 (85.7%)	
No	17 (7.2%)	7 (14.3%)	
Pantalar arthrodesis			.1065
Yes	197 (83.5)	36 (73.5%)	
No	39 (16.5)	13 (26.5%)	

Table 4
Risk outcome on major amputations (N = 285 patients)

	OR	Lower CI	Upper CI	*p* Value
Intercept	0.100	0.004	2.584	.1654
Age	0.944	0.906	0.983	.0053
Hba1c	1.206	1.030	1.413	.0197
Body mass index	1.004	0.949	1.062	.8983
Peripheral arterial disease	4.340	1.706	11.036	.0020
Smoker	1.138	0.386	3.351	.8151
Male gender	1.136	0.500	2.578	.7607
Renal disease	3.734	1.591	8.765	.0025
Hypertension	1.471	0.492	4.398	.4901
Preoperative soft tissue infection	1.178	0.449	3.090	.7397
Preoperative osteomyelitis	0.989	0.384	2.545	.9811
Postoperative delay in healing	2.623	1.059	6.498	.0371
Postoperative wound infection	1.047	0.416	2.632	.9223
Pin tract infection	1.978	0.504	7.762	.3283
Postoperative osteomyelitis	2.438	1.011	5.879	.0473
Dehiscence	1.277	0.416	3.916	.6692
Transfer ulcer	2.970	0.627	14.071	.1702
Recurrent ulcer	0.772	0.283	2.108	.6133
Recurrent dislocation	2.185	0.385	12.399	.3776
Malunion	1.133	0.111	11.585	.9163
Nonunion	8.494	2.153	33.512	.0023
Hardware failure	1.451	0.515	4.088	.4814
New site of Charcot	8.156	1.057	62.917	.0440

Abbreviations: CI, Confidence interval; HbA1c, glycated hemoglobin; OR, odds ratio.

discussed the postoperative complications related to osseous healing in patients with CN, emphasizing the importance of addressing these factors for improved long-term success. Wukich and Kline (25) in a 2008 study report the importance and preference for rigid internal fixation in patients with neuropathy or vasculopathy for nonunion prevention (26).

The development of a new CN site in the reconstructed foot or ankle is a real threat and was a strong independent risk factor for a major amputation in our cohort. Surgical trauma can induce a new onset of acute CN. When this occurs, hardware from the previous surgical reconstruction can become infected because of delayed healing or new ulcer recurrence. Increased derangement of the foot and ankle essentially translates into increased infection of the soft tissue and bone. The data reveal a strong association between the development of a new CN joint after osseous reconstruction and major LEA. Interestingly, the location of CN collapse and the type of reconstruction was not found to be statistically significant. Intuitively, midfoot and hindfoot CN should confer worse prognosis. However, our study did not support this generally accepted notion. There are no published studies that discuss the risk of major amputation with respect to the location of CN collapse.

The prevalence of PAD in patients with CN and concomitant PAD is not well reported in the literature. Although the pathogenesis of CN has been elusive, one of the major theories supports increased vascular perfusion, which in turn induces osteopenia in CN. PAD is, however, strongly associated with DM and is a major risk factor for lower extremity complications. The sparse scientific literature implies a general lack of awareness of the important link between PAD and diabetic CN. Wukich et al (26) in 2016 published the only robust study to date on this topic, reporting a 40% prevalence rate of PAD in 85 patients with CN. This finding emphasizes the importance of carefully evaluating vascular integrity, initiating early attempts at lower extremity revascularization, and involving vascular surgeons in the care of patients with diabetic CN. It has been suggested that reperfusion should be attempted before reconstructive efforts (27,28). Tissue perfusion in patients with diabetes is compromised as a result of macrovascular and microvascular pathology. Endovascular and bypass procedures should be considered early in the CN limb salvage process when indicated (29).

The natural history of DM includes the unfortunate decline in renal function. Diabetic nephropathy should be aggressively screened in patients with early increases in creatinine. Microalbuminuria is an early indicator of the renal sequelae related to DM. Unfortunately, many patients with CN present with chronic renal disease and end-stage renal disease. The literature has been mixed relating to the significance of renal disease as it relates to lower extremity pathology and DM. It should be noted, however, that the tertiary nature of our center attracts

patients with complex comorbidities who, when operated on, have an average physical score by the American Society of Anesthesiologists of 3.4 out of 5. In our study, the presence of renal disease confers a 3.7-fold increased likelihood for a major LEA—a rate much higher than that reported in other studies.

Meticulous postoperative monitoring is required to optimize outcomes and provide appropriate patient counseling. General postoperative complication rates are high, and osseous nonunion is common (30). Although local surgical site complications such as infection, dehiscence, and hardware failure can be mitigated, these events can be predictive of eventual amputation. A delay in healing >30 days after index closure is associated with a 2.6 times increased likelihood of major amputation. Delayed healing can be attributed to a plethora of reasons, and it is difficult to decipher a more specific cause. Any patient with delayed healing will always be more prone to a major amputation. The development of postoperative OM imparts a 2.4-fold increased likelihood for a major amputation. The authors' institution places emphasis on eradication of OM with wide resection of questionable bone and subsequent clean cultures of the residual bone. Despite the best efforts to address OM surgically and with appropriate antibiotics, recurrence can occur. Wukich et al (31) published a comparative retrospective study on hospitalized patients with diabetic foot infections, comparing outcomes with those with OM. The authors report a 3.4 times higher likelihood for major amputation with the presence of OM. Although this study was not exclusive to CN, it exemplifies, as others have, the importance of OM as a risk factor for major LEA. To date, there are many questions and controversies regarding diagnosis, treatment, and surgical staging of OM and concomitant CN. Pinzur et al (32) report a 95.7% ambulation rate with single-stage CN reconstruction in patients with OM. The authors of this article, in similar fashion, performed a wide resection of clinically infected bone, followed by culture-driven parenteral antibiotic therapy.

HbA1c was found to be another predictor of major LEA in our cohort. The findings in our study support what others have reported. An elevation in HbA1c increases perioperative risks that include dehiscence, postoperative infection, delayed healing/ nonhealing, and nonunions. Although our study cannot comment on a specific HbA1c cutoff, it is clear that in our cohort, the patients who had major LEA had higher HbA1c levels than those who did not.

It is important to note that we aggressively advocate for below-knee amputations if a salvage attempt is not likely to result in the functional outcome that fits the patient's realistic functional goals. The more active the patient, the more likely the patient will require a functional foot. This is not necessarily a reflection of age but more of how well the patient has addressed his or her disease to preserve maximal function. It may be for this reason that advanced age in our cohort reflects decreased likelihood for a major amputation (OR <1). The authors of this study also believe that it is more difficult for some individuals, particularly those of advanced age, to ambulate in a prosthesis after a major LEA. Thus, limb salvage is more aggressively pursued in those patients who will use the limb for limited ambulation and activities of daily living (eg, transfers). Our study results support this notion because the odds for a major amputation are more likely to occur at an earlier age in patients who are physically very active and require a fully functional foot to carry out activities that would otherwise be impossible with a salvaged but biomechanically compromised foot or ankle.

Furthermore, the authors acknowledge that surgical intervention in patients with CN can be a complex endeavor that may not always be the best option. The risks and benefits of osseous reconstruction must be evaluated on a case-by-case basis. Conservative management of the CN foot can offer meaningful outcomes in select cases. There is no standardized or validated algorithm to support nonsurgical over surgical management. The results presented in this article demonstrate risk factors that lead to major LEA in patients who have been medically optimized and maximally vascularized. Despite such efforts, this patient population remains at high risk for postoperative complications, including major LEA when addressed surgically. Addressing the risk factors identified in this article and others may help decrease the risk of major LEA. Further studies are required to help stratify Charcot management between those who may benefit from conservative versus surgical interventions.

There are several important limitations to our study. CN is a process that occurs over time. In this study, we did not account for the duration of CN or the number of Charcot events for each patient. Furthermore, our population does not include elective reconstructions but is limited to patients who were acutely ill and were all evaluated and treated on an emergency basis. Additionally, we strongly advocate for major LEA when the likelihood for failed individualized functional salvage is high. For those with adequate functional reserve and an active lifestyle, a below-knee amputation is more likely to result in a patient who does well in a prosthetic limb.

In conclusion, our data reflect a highly compromised population that is at high risk for postoperative complications after CN reconstruction. Although there are many factors that can increase failed limb salvage rates, the results of this study highlight the importance of evaluating vascular status, something not well reported in the literature. Furthermore, patient counseling regarding possible long-term outcomes must include the possibility of a major amputation. Nonunion rates are common in this population, and our results show poor salvage outcomes when they occur. Because of the inherent fragility of this patient population, a strong multidisciplinary team approach can provide comprehensive management aimed at functional outcomes.

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