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Review Article

A Systematic Review of Current Surgical Interventions for Charcot Neuroarthropathy of the Midfoot

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ABSTRACT

Charcot neuroarthropathy of the foot, or Charcot foot, is a pathologic entity of the foot, associated with diabetes mellitus. Owing to the increase of diabetes mellitus in developed nations worldwide, the prevalence of Charcot foot has been increasing. The initial treatment of Charcot foot is often conservative, with methods including bracing, casting, and the use of customized orthopedic shoes. However, many cases of Charcot foot eventually require surgery, because the consequent destabilization of the foot associated with bone, joint, and nerve injury due to the pathology eventually leave patients unable to walk independently. The present systematic review analyzed the published data regarding surgical interventions for midfoot Charcot deformities and estimated the rates of common complications occurring with the surgical modalities studied. The main outcomes of interest analyzed in the present study were postoperative amputation and bony fusion. The included cohort of patients with Charcot foot was very heterogeneous in terms of the demographic and comorbid characteristics. However, even with this heterogeneity, the present study should provide useful information to surgeons in terms of the outcomes after some of the common surgical procedures for midfoot Charcot.

Charcot neuroarthropathy of the foot, or Charcot foot (CF), is a manifestation of the pathologic loss of nervous sensation in the foot that often presents in conjunction with compromised peripheral vasculature in patients with diabetes (1–5). The loss of sensation, coupled with repetitive microtrauma, to which the patients are insensate, leads to progressive neuroarthropathic and osseous degeneration of the foot. This, in turn, leads to disruption of the normal arches of the plantigrade foot (1–24). CF is becoming an increasingly pronounced issue as the number of diabetic patients increases worldwide (1–24). Although CF is most commonly observed in the current published data as a complication of late-stage diabetes (1–24). It is also observed as a consequence of chronic alcoholism, leprosy, syphilis, syringomyelia, spina bifida, meningomyelocele, or trauma (4,5,9,22,23).

The initial treatment of CF is often conservative and usually involves the use of bracing, casting, and custom orthopedic shoes. These interventions allow patients to functionally ambulate without the use of more invasive interventions (1,2,7,9–11,16,17,22). However, many patients will eventually require surgical treatment, because CF is often refractory to conservative care (1–24). The common long-term sequelae of failed conservative care of CF include plantar ulceration, superficial and deep tissue infection, osteomyelitis, and amputation (1–4,6–24). Owing to the heterogeneity of both the patients with this pathologic entity and their presentation, and the differing characteristics of their pathology, no standard protocol is available for the surgical treatment of CF.

The purpose of the present study was to review the data published within the previous 10 years regarding the surgical interventions used in the treatment of midfoot Charcot deformities. The operative interventions discussed in the present study were primarily intramedullary medial column bolt fusion and multilevel external fixation. The present study also aimed to analyze the occurrence of common outcomes associated with each intervention. We hope to inform surgeons about the current trends in the surgical treatment of CF and the complications associated with each such intervention.

Materials and Methods

The primary research studies reported from January 2006 to March 2016 were collected from the PubMed National Institutes of Health database. Only studies reporting the results of surgical interventions used to treat Charcot neuroarthropathy of the foot were examined, and only original research published in peer-reviewed journals with data from ≥3 subjects was included. We only considered studies written in English of human subjects. We conducted searches with the help of a professional librarian. The keywords

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used for the search included "Charcot," "arthropathy," "neurogenic," "surgery," "neuroarthropathy." The search protocol using PubMed is detailed in the Appendix.

Studies concerned with the treatment of Charcot deformities of the midfoot or the midfoot in conjunction with other areas were analyzed in the present study. For each study, we recorded the number of patients, total number of surgeries performed, mean patient age, and gender distribution. Patient characteristics such as body mass index and comorbidities such as diabetic status (type 1, type 2, or nondiabetic) were collected. The surgical procedure used in each study and any inclusion or exclusion criteria used for surgery were recorded. The method of postoperative management and the average follow-up period were recorded. Finally, in terms of the surgical outcomes, we recorded the postoperative ambulatory status of the patients and the incidence of bolt or screw migration and wire, pin, or bolt breakage, bony fusion (the desired outcome for all procedures), subsequent amputation, pin track infection, and preoperative and postoperative ulcers. The ability to ambulate was recorded on a per patient basis. Because some patients had required >1 surgery, we recorded the complications on a per surgery basis. Some information on these outcomes was missing; thus, the ambulation and complication rates are reported for those patients for whom the data were available.

Studies were only included if data regarding these parameters had been reported separately for all the patients in the study. If the studies had included patients who had received treatment for deformities not including the midfoot, such was the case for some studies regarding multilevel external fixation, only the data for the procedures involving the midfoot were included in the meta-analysis. If such a study had not included separate results for each patient (ie, reported the total number of amputations for all patients in the study without including separate data for each patient), the study was excluded. The studies were also required to have a minimum of 3 patients undergoing treatment of midfoot deformities to be included in the meta-analysis.

The main procedures included in the present review were medial column fusion and multilevel external fixation, because most of the studies identified in the data search had included these procedures. Data concerning the outcomes of these studies are listed in the Table (5,7,9,11,12,15,18,21,22).

Statistical Analysis

We performed a meta-analysis of our data. Random effects models were built to estimate the rates of postoperative amputation and bony fusion to estimate the rates of complications while accounting for heterogeneity. Forest plots and funnel plots were drawn for each outcome, and heterogeneity was assessed and described using Cochran's Q and I^2. The variance between studies was estimated using the random effects model. All statistical analysis was performed using the R statistical package (R Developmental Core Team; R: A Language and Environment for Statistical Computing, 2009; available at: http://www.R-project.org). Cochrane's online resources details the guidelines for performing meta-analyses (available at: http://handbook.cochrane.org).

Results

The search yielded 136 reports. All abstracts were examined, and 111 were discarded, either because they were not primary studies of Charcot neuroarthropathy of the foot or because they had not exclusively included patients with CF. The remaining 25 full texts were read, and 3 were discarded because they had included patients who had not undergone surgery for Charcot neuroarthropathy and had not provided separate results for the Charcot patients receiving surgery. Of the 22 studies, 9 were included in the outcome analysis for review. These were case studies with data regarding surgical correction of midfoot deformities. The remaining studies did not have data available for analysis. Intramedullary medial column bolt fusion and multilevel external fixation were the most commonly cited procedures. Studies concerning other procedures such as combined internal and external fixation were identified; however, fewer studies of these procedures were identified in our literature search. All included studies were case series with a level of evidence of 4, and the goal of all the studies was to fix the foot in the neutral plantigrade position.

The most common comorbidity among the patients across all the studies was diabetes mellitus, with 59% to 100% having either type 1 or 2 diabetes. The percentage of male patients ranged from 33% to 100%, and the average patient age ranged from 30 to 65 years. The reported percentage of patients with peripheral vascular disease and peripheral neuropathy ranged from 0% to 30% and 6% to 100%, respectively. The average follow-up period for these studies ranged from 12 to 63 months.

The estimated rate of subsequent amputation after surgical treatment of midfoot CF was 6% (95% confidence interval 2% to 10%; Fig. 1) (5,7,9,11,12,15,20–22). Subsequent ipsilateral amputation included any below-the-knee or transtibial amputation after surgery and occurring within the follow-up period of the given study. No other types of amputation performed after the initial surgical treatment for CF were reported in the studies analyzed in the present review (1,2,4,7,9,12,14,15,18,21,22).

The rate of postoperative amputation was relatively uniform, with the only exception in the study by Eschler et al (12) (Fig. 1). A high rate of amputation (43%) was seen in their study (12), although the other 2 studies that performed retrograde intramedullary medial column fusion reported amputation rates similar to those of the studies in the other surgical groups. In contrast to the other 2 studies in this surgical group, Eschler et al (12) used medial column bolt fusion as a stand-alone implant. Cullen et al (7) and Wiewiorski et al (22) both performed medial column fusion simultaneously with other procedures such as lateral column fusion and reported no amputations as a complication of any of their procedures. These results support the assertion by Eschler et al (12) that medial column fusion should not be used as a stand-alone implant owing to its limited rotational stability during the prolonged healing period associated with the CF (Fig. 1).

The estimated rate of bony fusion after surgical treatment of midfoot CF was 91% (95% confidence interval 86% to 96%; Fig. 2). Bony fusion was determined radiographically in all the studies and was typically defined as bony consolidation at the site of the deformity after surgical correction. Most studies used either 2 or 3 views to confirm radiographic fusion. The rate of successful bony fusion was notably lower in the study by Eschler et al (12) at 29% (Fig. 2) (5,7,9,11,12,15,20,21).

The secondary outcomes of interest included postoperative ambulation, pin track infection, and hardware complications (Table). Postoperative ambulation was defined as a patient's ability to begin walking with or without the use of mechanical assistance such as a cane, cast, brace, customized shoes, or customized orthosis during the

Table
Study outcomes

Investigator	Surgical Procedure	Surgeries Analyzed (n)	Patients Analyzed (n)	Amputation (n)	Bony Fusion (n)	Ambulation (n)	Pin Track Infection (n)	Hardware Complications (n)
Lamm et al (5), 2010	Combination	11	8	0	11	NA	11	4
Siebachmeyer et al (21), 2015	MCB	4	4	0	3	4	NA	3
Mittlmeier et al (15), 2010	Internal Fixation	9	8	0	9	8	NA	NA
Cullen et al (7), 2013	MCB	4	4	0	4	NA	NA	1
Wiewiorski et al (22), 2013	MCB	8	8	0	NA	8	NA	3
Eschler et al (12), 2014	MCB	7	7	3	2	NA	NA	2
Pinzur (18), 2007	MEF	25	25	1	24	24	NA	NA
Dalla Paola et al (9), 2009	MEF	45	45	4	39	39	0	0
El-Gafary et al (11), 2009	MEF	9	9	0	9	NA	NA	NA

Abbreviations: MCB, medial column bolt fusion; MEF, multilevel external fixation; NA, not available.
All studies were case series with level of evidence of 4; the purpose of all the studies was to fix the foot in the neutral plantigrade position.