NORTHERN OHIO FOOT & ANKLE FOUNDATION

The Northern Ohio Foot and Ankle Journal *Official Publication of the NOFA Foundation*

Peri-operative Management of the Diabetic Patient with Charcot Neuroarthropathy

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The Northern Ohio Foot and Ankle Journal 1 (1): 1

Abstract: Charcot Neuroarthropathy in the diabetic patient is a complex disease process with significant morbidity. There has been considerable debate in the literature regarding optimal surgical management with a large bias toward conservative treatment due, in part, to the high rate of operative complications in this patient population. When surgical intervention is elected, appropriate and aggressive peri-operative management must be undertaken to unsure satisfactory patient outcomes. This consists of optimization of intrinsic and extrinsic factors. The following review seeks to present the available literature regarding the peri-operative management of this difficult patient cohort and an overview of commonly utilized operative treatments.

Key words: Charcot Neuroarthropathy, Diabetes, Peri-operative management

Accepted: October, 2014 **Published:** November, 2014

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Surgical management of Charcot Neuroarthropathy in the diabetic patient is a challenging undertaking for even the most experienced foot and ankle surgeon. This is due in part to the lack of established protocol or consensus regarding the optimal treatment. Variance exists in the literature regarding not only the optimal surgical intervention and method of fixation but the timing of surgery and peri-operative management. This patient population has an inherent increased risk of complications when managed even non-operatively. This risk increases significantly when operative intervention is undertaken. The following review seeks to present the available literature on peri-operative management of the diabetic patient with Charcot neuroarthropathy.

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In order to understand the management of Charcot, we must first define the goals for management. Patients who develop Charcot are challenging patients with multiple comorbidities and the resulting poor metabolic potential. Amputation rates have been sited at 7% if no ulceration is present on initial evaluation and 28% if an ulceration is present[1]. Thus we must be realistic in our goals for this difficult patient population. These patients will likely never be able to return to normal foot architecture and gait. Instead our focus should be on creating a braceable foot. This is done by achieving osseous stability, maintaining a plantigrade foot and preventing ulceration. If these goals are accomplished, patients will be at significantly decreased risk of infection, loss of limb or loss of life.

These goals are achieved in the majority of patients with conservative means alone. Conservative measures aim to offload the affected extremity. This is accomplished with total contact casting and Charcot restraint orthotic walkers (CROW). Bracing in ankle foot orthoses may also be utilized in chronic Charcot and for patients with mild to moderate deformities. A study performed by Saltzmann identified a 2.7% annual rate of amputation in diabetic Charcot patients treated with structured, nonoperative treatment[1]. The avoidance of surgery in this patient population with a known increased risk of healing as well as infectious complications is advisable as an operation itself subjects these patients to significant morbidity.

In cases in which surgery is considered, there is a lack of consensus regarding timing or method of surgical intervention with evidence being primarily retrospective Level IV and V, and based on small patient populations. There has been no study to date comparing surgical correction versus non-operative management or amputation[2]. That being said, surgery is often undertaken. Indications for surgical intervention include patients with ulceration or those that are at high risk for ulceration due to foot structure or plantar prominence, patients with gross instability of the foot and/or ankle as well as those with active infection.

The optimal time of surgical intervention is highly debated regarding Charcot patients but the available literature is insufficient for an absolute conclusion. Historically, surgical intervention in acute Charcot was not recommended due to reports of increased risk of wound healing complications, failure of bone fixation due to bone fragmentation as well as increased risk of infection[3]. Two studies to date have been performed investigating the outcomes of surgical management in acute Charcot[4,5]. The first performed by Simon examined fourteen patients all in acute, stage 1 Charcot with an average 41 month follow up[5]. Arthrodesis of the midfoot joint complex was performed for these patients. Simon reported no complications in this patient cohort with 100% union rate and no recurrence of ulceration. The second study, performed by Mittlmeier, investigated primary surgical intervention for patients with Charcot affecting the midfoot or hindfoot in all stages of Charcot, including four patients in stage 1 and seven patients in stage 2 charcot[4]. Surgical intervention consisted of midfoot fusion, triple arthrodesis or ankle and STJ fusion, dictated by affected joints. He reported achievement of plantigrade foot without recurrence of ulceration in 100% of patients and significant improvements in AOFAS scores. Of these patients, six where found to have incomplete boney union, four of which required revisional surgery for instability. Five additional patients required revisional surgery for evacuation of hematoma formation. Although these studies are encouraging, further research into the subject is needed before a consensus can be drawn.

In order to insure the best possible surgical outcomes, peri-operative management is crucial. As important as the surgery itself is managing patient expectations. This starts at the patient's initial visit. The patient needs to understand that Charcot is a limb threatening disease and our goal is limb salvage. Success will be determined by the ability to create a braceable foot. In order to accomplish this goal, the patient needs to be optimized both prior to and after surgery. This requires a team approach. Medical optimization of these patients is not easy nor is it always possible especially in cases of infection where emergent surgical intervention is required. Peri-operative optimization can be divided into two main categories: intrinsic factors and extrinsic factors.

The optimization of intrinsic factors begins with identification and treatment of patient's comorbidities. Diabetics are at increased risk of cardiovascular and renal disease; with a 2-4 times increased risk of cardiovascular disease[6] and 50% of all diabetics suffering from renal disease[7]. Diseases affecting these body systems increase risk of post-operative complications[6,8,9]. Specifically renal disease which is associated with increased rates of infection, delayed or nonhealing of skin and bone, post-operative renal failure, hyperkalemia and volume overload. These complications not only increase risk to our operative outcomes, but also increase patient hospital stays and ultimately patient mortality[8]. Thorough evaluation by patient's respective physicians to insure that these issues have been optimized is paramount in optimizing the surgical outcome.

Charcot neuroarthropathy in and of itself is not typically thought to be associated with arterial disease. Though the combination of the neuro-ischemic foot has been reported in the literature[10,11]. Recognition of this morbid combination is essential for appropriate treatment and should not be overlooked. Appropriate pre-operative screening with ankle-brachial indices/toe-brachial indices, pulse volume recordings, and/or transcutaneous oxygen measurements should be evaluated. When suspected, the concomitant evaluation by a vascular surgeon is required.

Hyperglycemia has been linked to an increase in nosocomial infections in diabetics. The mechanism is thought to be due to a decrease in adherence, chemotaxis, phagocytosis and bacteriocidal activity of the polymorphonuclear leukocytes in diabetics[12]. Latham et al studied post-operative glycemic control in diabetic and non-diabetic patients following coronary bypass surgery or valve replacement. In his study, hyperglycemia was defined as blood glucose level > 200mg/dL. He found that diabetics had a 2.7x increase in infection rate. Hyperglycemia in the immediate post-operative period correlated with the greatest risk of SSI and identified hyperglycemia as an independent risk factor for infection in patients with and without DM. Schroeder advocated the delay in elective surgery in patients with HbA1c levels higher than 8% in order to optimize control and reduce risk for complications[7].

Malnourishment contributes to the development of wound healing complications and the resulting increased rates of surgical site infections. This is due to its negative affect on normal immune function[13,14]. Malnutrition is generally a laboratory diagnosis, with total lymphocyte count less than 1200 cells/µl , a serum albumin level less than 3.4g/dl, a prealbumin level less than 15mg/dl, or serum transferring less than 200mg/dl (Table 1). Infection rates have been shown to increase 7 times in patients with preoperative malnutrition[13], while nutritional support has been shown to decrease the incidence of surgical site infections[14].

Vitamin D has significant importance in bone metabolism. Studies by Yoho et al have shown decreased levels of vitamin D in patients with diabetes, especially those with concomitant renal disease[15]. Low levels perpetuate a decrease in calcium absorption leading to a decrease in bone density. This may have significant implications in the bone healing and remodeling that is required after surgical treatment of Charcot. Perioperative supplementation may be beneficial to ensure optimal outcomes in this high risk group. Calcium supplementation may also be utilized in patients with vitamin D deficiency or for whom osteoporosis is of concern. Caution needs to be exercised in patients with concomitant kidney disease as excess levels can lead to increased arterial calcifications and cardiovascular disease.

	Normal Range	Malnutrition
Serum Albumin	3.4-5.4 g/dl	< 3.4 g/dl
Prealbumin	15-30 mg/dl	< 15 mg/dl
Serum Transferrin	160-370 mg/dl	< 200 mg/dl
Total Lymphocyte Count	3900-10,000 cells/µl	< 1200 cells/µl

Table 1: Laboratory indicators for diagnosis of malnutrition

Smoking cessation is imperative prior to surgical intervention in these high risk patients. The vasoconstrictive effects of smoking are well known. Smoking has also been shown to delay of the proliferative healing response with alteration of collagen metabolism, attenuation of the inflammatory healing response and impairment of oxidative bacterial killing mechanisms[16,17]. All of these effects lead to the increased rates of wound and bone healing complications as well as increases in surgical site infection that are seen in smokers. Recent meta-analyses across multiple surgical specialties have highlighted the risks of smoking and the beneficial effects of preoperative smoking cessation[16, 17]. A meta-analysis by Sorensen demonstrated a 2 times higher risk for delayed wound healing, wound complications or infection in smokers with a decrease in the incidence of surgical site infections by greater than 50% following smoking cessation[16]. Wong et al evaluated the timing of smoking cessation on the infection risk. He found that patients who quit at least 4 weeks prior to surgery had a similar risk of wound healing complications as nonsmokers[17].

Adjunctive bone stimulators have been shown to accelerate bone healing in diabetic patients with improvements in growth factor expression, cartilage formation and neovascularization[18]. The utilization of this device in patients with Charcot has shown significant promise with reduction in consolidation times in both the acute phase as well as following reconstruction[3,19,20,21].

The use of pharmacologic therapy as adjunctive treatment for Charcot has been investigated. The most common agents for this have been the bisphosphonates and calcitonin though new drugs, including Receptor Activator of Nuclear Factor Kappa B ligand (RANKL) antagonists and tumor necrosis factor (TNF) alpha antagonists, are on the horizon. To date, these agents have been advocated for use in the acute phases of Charcot and not in the peri-operative period as the majority of current data in surgical intervention focuses on the chronic stages of Charcot and not the acute phase. That being said, these drugs have demonstrated a clear decrease in serum bone turnover markers though the clinical significance of this is undetermined[22].

Pre-operative physical therapy consultation for non-weightbearing training is fundamental for the achievement of patient compliance. These patients are often overweight and being non-weightbearing is a difficult task. Training patients the techniques of non-weightbearing prior to surgery allows for assessment of patients ability to comply prior to the surgery and thus allows for better post-operative planning and possible placement in skilled nursing facility if needed. The post-operative course in patients with Charcot reconstructions must by tailored to give the patient the best chance at compliance. Evaluation of patient's support system is the first step in this process. These are large surgeries with long and difficult post-operative courses. Patients who live alone without significant help are often times forced into non-compliance due to functional needs, known as "social or economic noncompliance". Long term care facilities may be utilized in these instances to allow for compliance with non-weightbearing instructions. As established, the goal of surgery in these cases is to create a braceable plantigrade foot. Bracing including CROW boots may be used in transition from non-weightbearing to weightbearing. Long term bracing may be accomplished with CROW boots, solid ankle foot orthoses or short articulated ankle foot orthoses depending on severity of deformity.

When surgical intervention is elected, multiple procedure and fixation options are available. Procedure choice and fixation should be based on degree and instability of deformity, anatomic location of deformity, presence or absence of osteomyelitis, stage of disease, patient's health and comorbidities and patient's goals. A systematic review performed by Lowery in 2012 looking at all surgical treatment for Charcot neuropathy identified the midfoot as being the most common site for surgical intervention, making up 59.5% of all procedures for Charcot reconstruction[2]. This should be a surprise to no one as it is also the most common anatomic location of occurrence. This was followed by the ankle, 29.3%, and finally the hindfoot, 11.1%[2].

Available procedures include soft tissue procedures, exostectomies, fusions with internal fixation or external fixators and amputations.

The use of soft tissue procedures, most notably Achilles tendon lengthening or soft tissue flaps or advanced are used in conjunction with boney procedures in the surgical intervention of Charcot. The lack of dorsiflexion seen in equinus deformity has shown to be directly correlated to increased peak plantar pressure, increasing pressure by three fold[23]. An association has also been shown with Charcot neuroarthropathy suggesting that increased peak planar pressures may predispose the neurologically impaired patients to the development of charcot[24]. Achilles tendon lengthening procedures have been shown to release the equinus deformity therefore decreasing peak plantar pressures[25]. Local skin flaps and advancements may be utilized to close ulceration sites and are most common following exostectomies. It is important to remember that these should only be used in cases clear of infection and with viable blood flow. Referral to plastic surgeon can be beneficial in large defects where a pedicle or free flap may be optimal.

Exostectomies eliminate plantar prominences that are currently contributing to or may lead to ulceration. They can be very beneficial with a smaller degree of risk due to smaller incision size as well as potentially decreased time for post-operative gait restrictions and periods of non-weightbearing. This technique is utilized primarily for the prevention or treatment of ulceration and in conjunction with Achilles tendon lengthening to decreased stress across the midfoot in cases of concomitant equinus deformity. Healing rates of 74-90% have been demonstrated with used for treatment of midfoot ulcerations. Though this technique appears to be more reliable in medially located ulcerations in comparison to laterally located[26,27,28]. Adjunctive skin flaps or advancements may also be utilized in cases of uninfected open ulcerations.

Arthrodesis of joints affected by Charcot seeks to create a biomechanically stable foot by eliminating motion and reducing deformity. A systematic review performed by Lowery identified 43 studies investigating arthrodesis as a treatment option for charcot[2]. Fusion rates averaged 76% with a 1.2% rate of amputation following attempted fusion. A nonunion rate of 22.8% was noted though it is important to remember that not all of these nonunions are symptomatic though this was not discussed in the article. Sites of joint fusion are dependent on site of Charcot and vary from the tarsometatarsal joint to the hindfoot to the ankle. Planing is often required, especially in midfoot Charcot, as a significant rockerbottom deformity often results. In these cases wedge resections, most commonly dorsomedial based wedges are taken to allow for realignment arthrodesis and ultimately a plantigrade foot[29]. A resultant shortening of the foot should be expected. Computer programs based on pre-op computer tomography scans are available to aide in surgical reconstruction and planning. Method of fusion varies greatly and is largely dependent on surgeon preference as one method not proven to be superior to another. Options for fixation include internal fixation and/or external fixators and are often a combination of these devices.

External fixators have multiple uses in the treatment of Charcot neuroarthropathy. Most common utilization include: primary fusion, static frame as adjunct to internal fixation, or as a mean of offloading for difficult to offload wounds. The use of external fixation for primary fusion is especially beneficial in patients in which infection has been in question and the use of internal fixation should be avoided. The advantage to use of external fixation include ability to access open wounds, surgical flaps or incisions to allow for continued wound care as well as the ability to allow for early mobilization in this patient population in which non-weightbearing is of significant challenge. Diabetic patients are notorious for their poor soft tissue envelope and increased infection potential. 80-100% of DM patients treated with external fixation will have at least 1 complication[30].

Amputation is a viable and functional option for patients with severe deformity predisposing them to recurrent wounds and infection. Amputation may allow for earlier return to weightbearing and participation in activities of daily living. That being said, amputation is not without risk. Energy consumption is increased 10-40% with unilateral below the knee amputation and 50-70% with unilateral above the knee amputation and is directly proportional to the number of functional joints remaining and inversely proportional to the length of the remaining limb[31, 32].

Proper peri-operative management of these complex patients is paramount to decrease surgical risks. Comorbidities such as renal and cardiovascular disease need to be fully evaluated prior to undertaking any surgical intervention. Operative treatment has powerful limb salvage potential but both intrinsic and extrinsic factors must be optimized as limb salvage is the primary objective. Long-term adjunct conservative care consisting of bracing and custom offloading are necessary to maintain positive surgical outcomes.

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