Exostectomy for Charcot Arthropathy

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Introduction

Charcot arthropathy (CN) is a destructive process of the bones and joints. In developed countries, this is most commonly seen in the diabetic population. The primary goal in the treatment of CN is to preserve or achieve, and then maintain, a stable and plantigrade foot that is shoeable and ulcer-free. Exostectomy of bony prominences is a viable treatment option for the stable Charcot foot, presenting with an ulcer or impending ulceration [1–4]. When indicated, an exostectomy has the potential to cure dangerous ulcerations while avoiding the morbidity and complications that can be seen after performing reconstructions and fusions in the foot and ankle [1–4]. The primary concerns with this procedure are an inadequate resolution of ulceration and iatrogenic destabilization of a previously stable foot, through overly aggressive bony resection. (Fig. 12.1a, b)

The midfoot)is the area most commonly affected by CN and is likewise the area of the foot most commonly treated with surgical measures [1–6]. The hindfoot is the second most commonly affected and the ankle third [5]. The ankle, though, is operated on more frequently than the hindfoot [6]. Given that the midfoot is the area most commonly affected, when discussing exostectomy exclusively, it is overwhelmingly the most common area treated [1–4, 6]. We present a discussion on indications and how to use an exostectomy in the treatment of Charcot neuroarthropathy.

Etiology

The etiology of)bony prominences arises from complete bone displacement after joint subluxations/dislocations, displacement of a bone fragment, or excessive bony formation during the healing and consolidation phases. These bony prominences are most commonly unfractured bones, which are malpositioned, due to collapse of the foot, rather than displaced fractures or new bone formation [1]. In our experience, there is often a combination of these etiologies, where bone fragmentation and subsequent healing creates a bone bridge between fractured and

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D. Herscovici, Jr. (ed.), *The Surgical Management of the Diabetic Foot and Ankle*,
DOI 10.1007/978-3-319-27623-6_12

Fig. 12.1 (**a**) Plantar foot ulcer overlying a plantarly subluxed medial cuneiform. (**b**) Lateral X-ray demonstrating the exostosis, a subluxed medial cuneiform and the suggested level (line) of where the exostectomy should be performed

unfractured bones. This creates a large, inflexible bony mass, which is often malpositioned plantarly. Soft-tissue calcifications may also be noted. While they are not true exostoses, they do contribute to ulcer formation by limiting skin flexibility and blood supply.

Staging

The two most commonly used classification systems for Charcot arthropathy are the Eichenholz system and the Brodsky classification. The Eichenholz classification is a temporal classification system that discusses Charcot arthropathy as it progresses through three stages: Stage 1 (dissolution/fragmentation), Stage 2 (coalescent/healing), and Stage 3 (resolution/consolidation) [7]. Stage 0 has been added and is used to describe an early charcot reaction where the foot is red, hot, and swollen, but without any fragmentation [8].

The Brodsky classification organizes the arthropathy by anatomic location. Type 1 is located in the midfoot (tarsometatarsal or naviculocuneiform). Type 2 affects the hind foot (subtalar and/or Chopart joint). Type 3A involves the ankle joint and type 3B affects the posterior tuberosity of the calcaneus [5]. This classification has been modified by Trepman et al. to include type 4 (combination of areas) and type 5(the forefoot), respectively [9].

Indications/Contraindications

A conservative approach should be the initial treatment for any patient presenting with Charcot arthropathy. This should consist of temporary immobilization and off-loading techniques such as total contact casting or Charcot Restraint Orthotic Walking (CROW) boot, until the arthropathy has stabilized (Eichenholtz stage 2 or 3). The patient should then be fitted for protective shoe wear with accommodative orthotics or braces. In addition, an Achilles tendon stretching program should be instituted, either with a physical therapist or at home with appropriate education and guidance. If an ulcer develops, conservative treatments such as total contact casting and custom off-loading braces (Charcot Restraint Orthotic Walker(CROW)) should be utilized. Antibiotics should be instituted if an infection is identified or subsequently develops. Broad spectrum oral antibiotics are acceptable for superficial infections. If osteomyelitis is suspected, broad spectrum or bone culture-specific IV antibiotics should be instituted with assistance from an Infectious Disease specialist. If these measures fail to prevent or resolve the ulceration, surgical options should be considered.

When the problematic deformities are stable and shoeable and/or braceable, reconstruction and/or arthrodesis may not be necessary. An

exostectomy of the offending bony prominences should be considered for these patients. This procedure can eliminate a prominence causing the ulcer with limited morbidity and minimal risks [1–4].

Another indication for an exostectomy is an unstable Charcot arthropathy in a patient with ulceration over a bony prominence and underling osteomyelitis, which has not resolved with appropriate antibiotic and off-loading treatments. In this circumstance, a reconstruction is not advised due to the high risk of developing a postoperative infection or a subsequent infected nonunion. The purpose of the exostectomy is to relieve pressure by reducing the size of the prominence, but also to remove any necrotic or infected bone which may be recalcitrant to antibiotic treatment. The goal is to heal the ulcer and clear the infection, allowing for later reconstruction of the foot to a stable, plantigrade position. Advanced imaging, including magnetic resonance imaging (MRI) and/or white blood cell (WBC) bone scan, should be performed prior to any surgery to document the extent of the infection and to guide the bony resection. Exostectomies should also be considered in an unstable Charcot foot which would be best treated with reconstruction or fusion, in cases where the patient is medically unstable or is at too high a risk for postoperative complications. In these circumstances, chronic ulceration can lead to osteomyelitis and ultimately amputation. While an exostectomy will not correct the instability of the foot, it may help resolve any chronic or impending ulceration and thus lower the risk of amputation.

The only absolute contraindication to exostectomy is in a foot that presents during Eichenholz stage 1, with bony edema and fragmentation. Clinically, edema, warmth, and erythema should first be resolved and radiographically, bone healing and stability should be evident. Relative contraindications include instability (subluxation or dislocation which would worsen if the offending bone were excised), severe peripheral vascular disease and an unbraceable/unshoeable deformity that cannot be resolved with exostectomy, who are medically stable.

Preoperative Evaluation

The preoperative decision making should always begin with a basic history and clinical examination. The history should identify the patient's symptoms (onset, history of trauma, sensation changes, discoloration, deformity, pain, swelling, discharge, previous episodes), how long the symptoms have been present and what previous treatments have been employed. Additionally, the surgeon should gain an understanding for the patient's satisfaction with the foot (Does it fit in regular shoes or braces? Are they able to ambulate effectively? Are they able to examine the foot daily and manage minor problems such as calluses and skin abrasions?). Any patient comorbidities should also be discussed, evaluated, and managed by their medical doctor preoperatively and postoperatively.

The clinical examination should evaluate the structure and stability of the foot, as well as searching for signs of active Charcot arthropathy or infection. As stated above, instability, active charcot, and nonplantigrade foot are contraindications to exostectomy. Instability is defined as a deformity which is dynamic and progressive over serial X-rays, or as a deformity which will recur or worsen after the exostosis is removed. An example of the latter is a lateral plantar ulcer, often the cuboid being forced plantarly. If there are no bone bridges fusing the cuboid to surrounding bones, resection of the plantar bone will only lead to the remaining cuboid subluxing further plantar and creating the same pressure to the plantar lateral skin. Resection of the entire cuboid will destabilize the lateral column of the foot. If the patient presents with findings suggestive of a superficial or deep infection, advanced imaging modalities and appropriate lab values are necessary to evaluate the exact extent of infection. If osteomyelitis is present, a surgical debridement should be performed and samples of affected bone should be sent for gram stain and culture with sensitivity to guide antibiotic treatment. Without concern for infection, surgery should be delayed in order to allow for the patient's medical doctors to stabilize the patient's comorbidities and optimize the chances for a good outcome.

Vascularity of the extremity should also be carefully evaluated. If there are any signs of vascular

compromise, such as diminished pulses, temperature changes, or cyanosis of the toes, a vascular surgery consult should be obtained in order to determine the viability of the affected area. If blood flow is compromised, restorative procedures should be performed prior to performing any bony surgical interventions.

Imaging of the foot and ankle should begin with basic weight-bearing radiographs. Bony coalescence and sclerosis should be identified and any bony prominences seen on the radiographs should correlate clinically with areas of ulceration. Computed Tomography (CT) should also be considered to more accurately correlate bony protuberances with skin ulcerations.

Superficial and deep infections should be fully investigated prior to performing an exostectomy. If bone can be easily identified at the base of the ulcer, a working diagnosis of osteomyelitis is assumed to be present and MRI should be performed to determine the extent of infection [10, 11]. Without exposed bone, a WBC-labeled bone scan or combined bone scans may be more specific and sensitive than MRI for ruling out osteomyelitis [11, 12]. Swabbing the ulcer for cultured yields unreliable information is not recommended, but deep tissue samples may provide more accurate culture and sensitivity results. Superficial infections and ulcerations can be expected to resolve with oral or IV antibiotics once the pressure causing prominence is removed. The use of oral versus IV antibiotics has many factors, such as the virulence of the suspected organism (history of MRSA?) and the vascularity of the foot. An infectious disease expert should be involved to guide this aspect of the treatment. A deep infection may require multiple debridements with possible bulk resection of deep tissues, including bone in patients with osteomyelitis.

Surgical Approaches

General Considerations

Incisions should be planned so that they avoid the plantar surface and the ulcerated skin, while providing good access to the bony prominence. Dissection should be full-thickness, avoiding any undermining of the skin and subcutaneous tissues. Excising a plantar ulcer should only be considered for small lesions with no evidence of infection. (Figs. 12.2 and 12.3) Once removed, the bony prominence should be sent to pathology to evaluate for osteomyelitis. If a superficial or deep infection is present, deep tissue and/or bone cultures should also be obtained. Swabbing the ulcer is likely to lead to misleading culture results, and thus is not recommended. Great care must be taken to avoid excessive bony resection, which can subsequently result in iatrogenic destabilization of a stable foot. Lengthening the achilles tendon should always be considered for plantar or heel ulcerations. This has been shown to lower peak pressures on the plantar foot during ambulation, and likewise may lower the risk of recurrent ulceration [13].

Forefoot

The metatarsophalangeal (MTP) joints are the area most commonly affected in the forefoot. The destruction seen at these joints may not be secondary to the same unique Charcot disease process that is noted in the midfoot, hindfoot, and ankle. Rather, the problem is often believed to be from chronic overloading of the forefoot and subsequent bone and joint destruction. In addition, there is often an associated deep infection. Most patients present neuropathy producing an insensate forefoot along with an equinus contracture, both of which causes an overload of the forefoot. Either due to excessive pressure, infection, or a combination of both, one can often see bone destruction and subsequent bone growth during repair. This combination of bony overgrowth and excessive loading of the forefoot can lead to ulceration of the plantar skin over the MTP joints.

For the second- third- and fourth metatarsals, there are two available approaches: dorsal and plantar. A dorsal approach is preferable, as ulcerations are typically plantar, it is best to place incisions away from the ulceration, and an exostectomy of a plantar bony prominence is

Fig. 12.2 Lateral X-ray demonstrating another level of exostectomy (line) how much bone should be excised for bony problems at the level of Chopart Joint

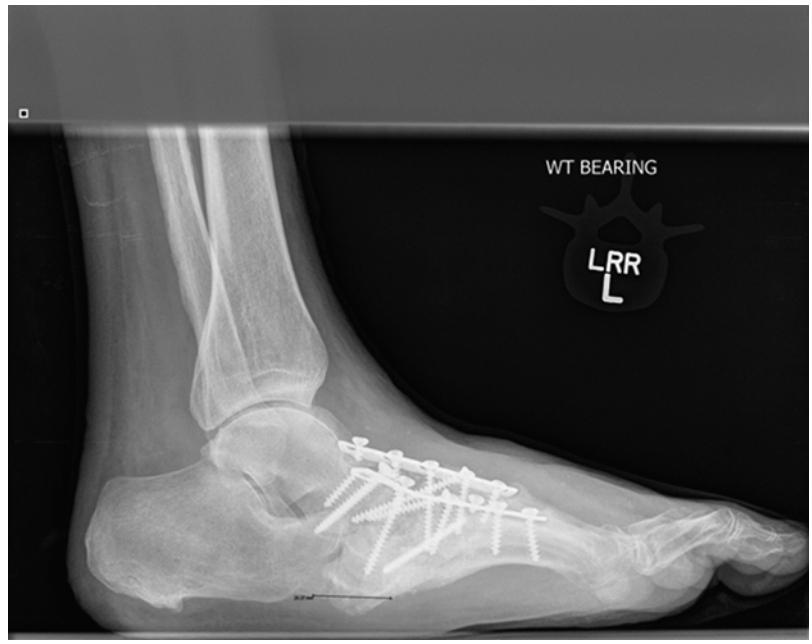

Fig. 12.3 Lateral X-ray demonstrating an exostosis that has developed after fixation of the midfoot and the proposed (line) exostectomy

technically difficult. There is no clinical research to guide decision making but the authors prefer a complete metatarsal head resection for ulcers greater than 1 cm which are recurrent or have failed to resolve with conservative care for 3 months. For impending ulcerations or smaller ulcers with no signs of infection, a plantar approach, excising the affected area, can be performed provided there is adequate healthy skin to close without tension. When approaching the first or fifth metatarsals, a medial incision for the first or lateral incision for the fifth may also be utilized, respectively.

In addition to the exostectomy, irrigation and debridement of necrotic tissues should be performed and a percutaneus achilles tendon lengthening should also be considered. Lengthening the achilles tendon has been shown to lower peak pressures on the plantar forefoot during ambulation, and likewise may lower the risk of ulceration [13].

Midfoot

The midfoot is the area of the foot most commonly affected by CN [1]. The most common problematic bony prominences in this area are the plantarly displaced medial cuneiform and first metatarsal base [1], often presenting in conjunction with a plantar ulcer. Other problematic protuberances are seen arising from plantar displacement of the other cuneiforms, occurring on the medial side of the medial cuneiform or navicular as a result of severe planovalgus, the development of dorsal osteophytes around the TMT joints, and exostoses that occur at the base of the fifth metatarsal or cuboid laterally [1–4].

For plantarmedial exostoses, the authors' preferred approach is through a longitudinal incision on the medial border of the foot, dorsal to the ulcer. Since the ulcer is typically on the plantar surface, the incision will allow for a direct access to the midportion of the subluxed cuneiform. A small oscillating saw is then used to cut through the bone, from medial to lateral, removing all of the offending plantar prominence. A bone rasp is then used to smooth down any rough edges.

Dorsal exostoses typically result in smaller ulcerations, since they are not located on the weight-bearing surface of the foot. The bony prominences are often due to the development of osteophytes or as a result of dorsally displaced metatarsal bases. For these exostoses the approach is to perform an elliptical incision, beyond the ulceration, which excises the ulcerated skin and the underlying exostosis together.

Laterally, the plantar surface of the cuboid or the lateral surface of the fifth metatarsal base can be problematic to treat. The approach for these lateral ulcers is preferred on the lateral border of the foot, performing a full-thickness approach to the exostosis (Fig. 12.4a–e). The longitudinal incision used is dorsal to the ulceration will allow complete exposure of the bone through healthy skin and allow removal of the exostoses. One should be cognizant that there may be a higher risk of ulcer recurrence with lateral exostectomy, as compared to treatment of medial exostoses [2]. An achilles tendon lengthening procedure should be considered when treating plantar ulcers of the midfoot if an equinus contracture is present.

Hindfoot

The hind foot rarely requires surgical intervention for CN. In the authors' experience, displacement of the posterior tuberosity of the calcaneus is often the cause for most problematic bony protuberances. This can result in ulcerations developing medially, laterally, or posteriorly. Similar to the dorsal midfoot, these ulcerations are not located on any weight-bearing surfaces. Rather, they occur secondary to friction produced from the patient's shoes or braces rubbing against the bony protuberance. An exostectomy can often be performed directly over the exostosis, with an elliptical incision, again excising both the ulcer and the bony prominence. If the ulcer is too large for an elliptical incision to be closed without tension, or if there are signs of deep infection, an alternate incision should be used through healthy skin. Additionally, a percutaneous release of the Achilles tendon should be considered in these patients to remove the excessive proximal pull of the Achilles on the calcaneal tuberosity.

Ankle

The ankle is least commonly affected area in terms of patients presenting with CN. However, the ankle is frequently managed surgically because the collapse that occurs is often so devastating that it frequently affects the anatomic alignment of the other structures in the foot. The development of osteophytes or displaced bony fragments can occur anywhere. These most commonly occur medially or laterally, can cause anterior or posterior impingement, or result in ulcerations anywhere about the ankle.

The ulcerations that occur are not overweight-bearing surfaces. Most often they occur secondary to pressure necrosis or abrasion from shoes and braces. For these patients, an exostectomy should be as minimal as possible in order to avoid iatrogenic instability. In particular, surgeons should be careful not to detach the origins of the deltoid or lateral ligaments with overly aggressive bony resection. Incisions should be longitudinal and away from the ulceration in an area which is anatomically safe and allows for access to the exosto-

Fig. 12.4 (**a**) Plantar foot ulcer that has developed overlying a subluxed cuboid and lateral cuneiform. (**b**) Preoperative lateral X-ray demonstrating the subluxed cuboid and lateral cuneiform. (**c**) Surgical incision used to approach and perform the exostectomy. (**d**) Postoperative lateral X-ray demonstrating resection of the exostoses. (**e**) Resolved plantar ulcer status post exostectomy

sis. Patients presenting with displaced bony fragments also frequently present with impingement of the soft tissues and limited motion around the ankle. If a large posterior exostoses is identified, it should be removed, if it causes any decrease in motion, produces impending skin problems, or has already resulted in the development of an ulcer. When patients are identified with either anterior tibial and talar osteophytes, they often demonstrate difficulty in dorsiflexing the ankle along increased pressures to the plantar forefoot and midfoot, and often develop secondary arthritic

changes to the ankle joint. When an exostectomy about the ankle is performed, an Achilles tendon release should also be considered, in order to increase dorsiflexion at the ankle and lower plantar peak pressures.

Postoperative

All patients should be immobilized postoperatively and made non-weight-bearing for 2 weeks in a carefully molded splint or cast to keep pressure off the foot. If there was concomitant osteomyelitis, antibiotics should be continued under the guidance of an infectious disease expert. If the ulcer and exostosis were in a non-weight-bearing area, then weight-bearing as tolerated in accommodative shoe wear may begin as soon as the incision is healed. For plantar ulcers, weight-bearing is withheld in a cast or boot (CROW, CAM) until the ulcer has resolved. Once the ulcer has healed, the patient may begin weight-bearing in custom-modified plastazote orthotics and extra-depth shoes with specific recessions to keep pressure off of the affected area. Achilles tendon stretching should be emphasized. The authors prefer patient education and a home exercise regimen, but a referral to physical therapy can also be utilized.

Outcomes

There are few studies which have investigated the use of exostectomy as a means to surgically relieve ulcerations secondary to bony prominences in Charcot Arthropathy of the foot and ankle. Brodsky and Rouse [1] reported on 12 patients with problematic plantar bony prominences. One patient had a problem affecting the hindfoot and the remaining eleven had arthropathy affecting the midfoot. Eight involved the medial foot and four were lateral. Eleven of the twelve patients remained free of ulceration throughout the follow-up period. Catanzariti, et al. [2], reported on 20 patients (27 ft) who underwent exostectomy for the treatment of midfoot ulcers secondary to arch collapse caused by CN. They reported a 74 % healing rate, with medial ulcers healing more reliably than lateral ulcers. Seventeen of 18 ft presenting a medial ulcer healed without further surgery, while 6 of 9 ft presenting lateral ulcers failed to heal after the initial surgery. Rosenblum, et al. [4], reported similar findings when investigating patients presenting with plantar ulcerations to the lateral column of the foot. Only 21 of 32 ft healed uneventfully after the initial exostectomy. However, after revision surgery, including flap coverage, 29 of the 32 ft remained healed and functional throughout the follow-up period (20.8 months). Lastly, Laurinaviciene, et al. [3], reported on 19 patients (20 ft) who underwent exostectomy. They also found excellent overall results with wound healing in 90 % of patients, but again noted the difficulty in managing patients who presented with lateral ulcerations. Nine ulcerations were plantar to the medial column, nine were plantar to the lateral column and two were central. In feet with that initially presented with a lateral column ulcer, 6 of the 9 recurred, 5 of which required a second surgery.

Conclusion

An exostectomy is a proven minimally invasive technique that can be used to treat ulcers resulting from impinging bony prominences that result from Charcot Neuroarthropathy. When indicated, this approach can provide the same benefits of much more involved procedures and can result in excellent outcomes, while producing fewer complications. Incisions should be made away from the ulcer but in small ulcers an excision of both the ulcer and exostosis can be combined. It appears however, that that lateral ulcers are more difficult to heal than medial ulcers. At the time of surgery, consideration should also be given to performing an Achilles lengthening in these patients in order to improve ankle dorsiflexion while limiting the plantar peak pressures that occur in the mid- and forefoot region.

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