Beaming for Charcot Foot Reconstruction

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Abstract
Charcot arthropathy commonly affects the midfoot and is often an extremely difficult and challenging surgical problem. Operative treatment with medial column arthrodesis using large intramedullary bolts or screws is an evolving and increasingly popular technique called “beaming.” The technique is described here.

Keywords: Charcot foot, beaming, arthrodesis

Charcot arthropathy, first described by the French neurologist Jean-Martin Charcot, is a progressively destructive, noninfectious inflammatory process that affects weight-bearing joints in individuals with peripheral neuropathy.2 The exact etiology is unclear, but cytokines have been implicated in the pathophysiology.3 The midfoot is a commonly affected area of the lower extremity and is the focus of the technique described here.

The goal of treatment for Charcot arthropathy is to maintain and/or obtain a stable and plantigrade foot from the time of presentation through the consolidation phase of the Charcot process. Ideally, this can be accomplished nonoperatively.4 Unfortunately, even with appropriate treatment, instability and deformity may lead to ulceration, deep infection, and limb loss.6 Total contact casting and bracing were the gold standard treatment for midfoot Charcot for decades and remain an important part of the management algorithm. However, if the midfoot is persistently unstable or painful or if it progresses to a nonplantigrade posture at risk for or with ulceration, then operative intervention may be necessary.4 Multiple internal and external fixation constructs have been described, with variable levels of success.4

“Beaming” is a relatively new technique used to achieve medial column stability and arthrodesis.5 Long solid or cannulated bolts or screws are typically placed retrograde through the first metatarsal, bridging the medial column to the talus. Advantages include restoration of sagittal and axial plane alignment, minimally invasive application, intrasosseous hardware, compression for arthrodesis, and long-term stability. The description of the technique for beaming, which continues to evolve, is presented here.

Indications
Midfoot arthrodesis for Charcot arthropathy is primarily indicated for (1) plantigrade foot with painful instability despite prolonged immobilization and (2) the nonplantigrade foot with or without active ulceration. Beaming is an excellent choice for fixation, particularly for the ulcer-free and noninfected foot.

Patients that present in Eichenholtz stage I (fragmentation) are usually managed with a nonweightbearing total contact cast for 8 to 10 weeks.4 Compliance with weight-bearing is inconsistent. If the midfoot fails to consolidate into a stable position, arthrodesis may be indicated. The nonplantigrade foot with progressive deformity that is at high risk for ulceration is an excellent indication for midfoot osteotomy/arthrodesis and internal fixation with the “beaming” technique.

There are no specific radiographic deformity parameters for operative indications. The decision for surgery is based on a combination of clinical and radiographic assessments, as outlined above. Deformity on weightbearing plain radiographs, areas of bony prominence (particularly plantar) on clinical examination, gross instability, skin breakdown or recurrent ulceration, and problems with modified shoe wear are additional reasons to consider realignment arthrodesis (Table 1).

Contraindications
If deep infection is evident or suspected, internal fixation with beams or bolts is contraindicated. Surgery may still be indicated, but external fixation is preferred. Superficial ulceration without infection is not necessarily a contraindication to beaming, but care must be taken to avoid cross-contamination.

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between the wound and the surgical site. Also, if the metatarsal diameters are unusually small, beaming may not be feasible.

Patients that are unable to maintain nonweightbearing restrictions are not ideal candidates for beaming alone. Internal fixation supplemented with plate application and/or external fixation is preferred in this situation. Additionally, patients with poorly controlled diabetes are at high risk for complication, and surgery is contraindicated until appropriate glucose levels are consistently maintained.

Technique

1. Midfoot beaming is performed under general anesthesia with a thigh tourniquet and the patient positioned supine.
2. Occlusive dressings are placed over any open wounds or ulcerations prior to incision.
3. Through 3 stab incisions, a triple hemisection Achilles lengthening is performed. Alternatively, the gastrocnemius tendon may be lengthened. In the rare situation that there is not an equinus contracture, a heel cord lengthening is not necessary.
4. The most common deformity is abduction through the midfoot with a rocker bottom in the sagittal plane (Figures 1 and 2). An incision is made along the medial aspect of the mid/hindfoot extending from the talar head to the base of the first metatarsal (Figure 3).
5. The anterior tibial tendon is identified, mobilized, and protected so that bone preparation can be performed beneath or adjacent to it without causing laceration (Figure 4). Alternatively, the tendon may be detached from its insertion and tagged for later repair.
6. Based on clinical and fluoroscopic inspection, the apex of the deformity is identified. A biplanar cut is typically utilized to establish a plantigrade foot. The cut typically resects portions of the naviculocuneiform and/or tarsometatarsal joints. For an abducted deformity, the cut converges laterally, and the limbs of the osteotomy are perpendicular to the long axes of the talus and first metatarsal, respectively (Figures 5 and 6).
7. If the deformity is relatively mobile through the midfoot articulations, in situ joint preparation without osteotomy may be sufficient. All of the medial column joints are prepared, including the talonavicular, naviculocuneiform, and tarsometatarsal joints.
8. The talonavicular articulation is exposed, and a joint distractor is placed. The joint is prepared for arthrodesis by removing all remaining cartilage with curettes and osteotomes (Figure 7).
9. Exposed bone surfaces at the level of the wedge resection and prepared articulations are fenestrated with a small drill bit. Autograft or allograft may be utilized for any defects but is often not necessary,
particularly at the site of osteotomy where resection planes should have excellent bone apposition.

10. After the deformity is corrected and the arthrodesis sites are prepared, a large Steinmann pin is placed for provisional fixation. Multiple-view fluoroscopy is utilized to confirm a colinear relationship, in all planes, between the talus and the first metatarsal. If this has been achieved, the foot position should be plantigrade.

11. A dorsal incision is made over the hallux metatarsophalangeal joint. The extensor hallucis longus is retracted laterally and the capsule is incised and reflected. The hallux is plantar flexed, and the first metatarsal head is fully exposed.

12. A guide pin for a 6.5- or 7.0-mm solid or cannulated screw is advanced, under fluoroscopic guidance, retrograde through the center of the first metatarsal head across the osteotomy and arthrodesis sites into the talus (Figure 8). It is critical that the pin is
located within the talar body on all fluoroscopic views (Figures 9 and 10).

13. The pin is measured and then overdrilled to the level of the talar head (Figure 11). A headless cannulated 7.0-mm compression screw is then placed and seated below the level of the articular cartilage of the metatarsal head (Figures 12 and 13). If the surgeon chooses to use a solid screw, the pin is removed, and the bolt is inserted in similar fashion.

14. For most Charcot cases, a second beam is placed in retrograde fashion through one of the lesser metatarsals (Figures 14 and 15). The choice of metatarsal for the second bolt depends on the size of the bone and its orientation to the osteotomy and target spot (ie, talus or calcaneus). The third and fourth metatarsals are the most commonly used, and a 5.0-mm solid bolt typically fits well. The bolt is inserted through the metatarsal head, which is exposed through a dorsal metatarsophalangeal capsular approach as described above.

15. Adjunctive fixation (ie, locked plate, thin wire fixator) may be added at this point if indicated per surgeon’s preference.

16. The incision is closed in a layered fashion with 2-0 PDS suture in the deep tissues and 3-0 nylon suture in the skin. A well-padded short-leg plaster splint is applied with the foot and ankle in a neutral position, and the tourniquet is deflated.
See Tables 2 and 3 for technical pearls and pitfalls.

**Postoperative Protocol**

*0-2 weeks*: The postoperative splint remains in place until follow-up and the patient is nonweightbearing. Elevation and limited activity are encouraged to control swelling and facilitate wound healing. Sutures are removed 2 to 3 weeks after surgery. Baseline radiographs

**Figure 11.** The guide pin is over drilled to level of talar head.

**Figure 12.** The medial column bolt is countersunk into first metatarsal head.

**Figure 13.** Anteroposterior fluoroscopic image of medial column bolt across midfoot osteotomy and talonavicular arthrodesis into talar body.

**Figure 14.** Anteroposterior fluoroscopic image of addition of second solid bolt placed retrograde through third metatarsal into talus.
are obtained (anteroposterior ankle and 3 views of the foot) at the first postoperative visit.

2-10 weeks: A total contact cast is applied, and the patient remains nonweightbearing until 10 weeks postoperatively. The cast is changed every 2 to 3 weeks to monitor the skin and soft tissues. A knee walker or wheelchair is typically utilized to maximize compliance.

10-14 weeks: Weightbearing is permitted in a tall walker boot or CROW (Charcot restraint orthotic walker), assuming that the radiographs demonstrate appropriate consolidation. Physical therapy may be necessary for gait training and strengthening.

14 weeks–lifelong: The patient is transitioned into an in-depth shoe with rocker sole modification and steel shank reinforcement with diabetic-type insole.

Complications

The inherent complications of surgery are particularly concerning with this high-risk patient population: wound dehiscence and infection may occur in the immediate postoperative period. Careful patient selection and appropriate diabetic control (if applicable) are critical to limit wound-healing problems. Nonunion or incomplete union is not uncommon, which may be associated with broken hardware. If a stable fibrous union occurs and the foot remains planigrade, then the clinical outcome may still be successful, particularly with the adjunctive treatment of modified shoe wear or braces.

Another surgical concern is the exposure of the anterior tibial tendon as it crosses directly across the surgical field and is at high risk for laceration. It should be exposed and mobilized for protection. If a large exposure is needed, the tendon can be detached from its insertion and repaired at the end of the procedure. The dorsal neurovascular bundle is also at risk, particularly if a wide medial-to-lateral osteotomy and wedge resection are performed. Large Hohman retractors placed dorsally and plantarly before making any bone cuts are protective.

To ensure that the deformity is fully corrected and that the first beam is placed in the correct position, the guide pin must be centered in the first metatarsal and the talus. The osteotomy or arthrodesis may have to be adjusted to ensure that the pin enters the talus appropriately. There is a tendency for the pin to be placed too far medial and miss the talus entirely. Some surgeons insert the pin retrograde from the tarsometatarsal joint, out the metatarsal head, then antegrade into the talus.

Lastly, an oversized beam may inadvertently split a smaller-diameter metatarsal. If there is reasonable purchase distal and proximal to the iatrogenic fracture, it is best to leave the screw in place. Replacing the beam with a smaller screw often results in even less stability at both the osteotomy and the fracture site.

Results and Discussion

The beaming technique is relatively new and continues to evolve. There is only a small number of short-term follow-up series in the literature. Assal and Stern reported on 15 patients with midfoot deformity secondary to diabetic neuropathy treated with extended fusion using an 8-mm cannulated medial column screw inserted antegrade from the posterior talus into the first metatarsal. At mean follow-up of 42, there were no recurrent ulcerations. One patient developed a deep infection that required amputation. There
were 4 nonunions with a broken screw, but only 1 of these had a substantial loss of correction that required revision reconstruction.1

More recently, Wiewiorski et al7 reported on the use of a solid 6.5-mm medial column bolt for midfoot Charcot arthropathy in 8 patients. At mean follow-up of 27 months, there was only an average loss of correction of Meary’s line of 7°, and there were no cases of recurrent ulceration. No screw breakage of the solid bolt occurred, but 3 migrated and required removal. Interestingly, in all 3 cases with a migrated screw, the joints were left unprepared, and this may have contributed to excessive motion and implant loosening.

There are currently 2 midfoot fusion “beaming” systems available in the United States. One of the systems solely consists of solid stainless-steel 6.5-mm bolts of variable lengths. The other system—designed and indicated by the Food and Drug Administration specifically for Charcot arthropathy—includes solid titanium alloy 6.5- and 5.0-mm bolts and a cannulated 7.0-mm beam.

A solid bolt is preferred over a cannulated screw because of the superior biomechanical properties. However, our experience has suggested that exchanging the guide wire for a solid screw can result in loss of fixation and alignment, even when other provisional fixation methods are utilized. For these reasons, even though our preference is to utilize a solid 6.5-mm bolt in the medial column, some surgeons may prefer to use a large cannulated screw. It is strongly suggested that this cannulated screw be at least 7.0 mm in diameter. A solid 5.0-mm bolt is preferred in the lateral (usually third or fourth) metatarsals. Larger sizes are unlikely to fit within the canal.

Anecdotally, the number of wound problems and infections has decreased substantially when beaming versus large- or multiple-plate fixation techniques are utilized. The exposure required for beaming is much less, and there is essentially no hardware irritation on the soft tissues at the time of closure. Longer-term follow-up will be necessary to determine union rates, ability to maintain corrected alignment, and efficacy of ulcer prevention.

**Summary**

Midfoot Charcot arthropathy that progresses to instability with or without deformity is a very difficult problem to treat. Beaming is a powerful technique that provides stability, compression, and improved alignment with minimally invasive intraosseous fixation.

**Declaraction of Conflicting Interests**

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Carroll P. Jones, MD, is a consultant and designer for Wright Medical Technologies, which has a Charcot reconstruction product line, including a “beaming” system, on the market.

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**References**