Midfoot Charcot Arthropathy: Overview and Surgical Management

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ABSTRACT
Midfoot Charcot arthropathy is a progressive deforming condition characterized by recurrent ulceration leading to high morbidity and amputation with lack of timely intervention. Non-operative treatment is largely reserved for acute phase disease. Recent trend in management is early surgical interventions which could alter deforming forces and prevent deformity progression, as well as surgeries which provide osseously stable plantigrade foot. However, there are no clear-cut evidence-based guidelines regarding timing of interventions and method of techniques in surgical stabilization. This study discusses about surgical technique in the management of midfoot Charcot.

Keywords: Early surgery, External fixation, Fusion bolts, Internal fixation, Midfoot charcot.

INTRODUCTION
Charcot neuroarthropathy (CNA) is a chronic debilitating limb-threatening condition affecting musculoskeletal system characterized by progressive joint dislocation, pathological fractures, deformities, ulcer formation and leads to disability and even amputation.1,2 Midfoot CNA leads to collapse of the arch, rocker bottom deformity, which alters weight distribution causing point loading over plantar bony prominence resulting in ulcer formation.3 Charcot neuroarthropathy profoundly reduces the quality of life and is associated with premature mortality.4,5 Conservative management of CNA consisting of total contact cast and off-loading was advocated as the first line treatment till recently. But conservative method prolongs treatment duration, reduces quality of life, and carries recurrent ulceration rates up to 30 to 50% and extremities with ulcers carry high-risk for amputation with reported annual limb amputation rate of 1 to 5%.6-12 Current trend is early diagnosis of foot at risk and surgical stabilization aiming to improve quality of life by not only salvaging the foot, but also by providing stable plantigrade, infection-free, ulcer-free foot, which can allow independent ambulation.13,14 Studies have shown that complication rate after early surgery is comparable to those after failed conservative method, i.e., secondary surgery.1 This study intends to provide details about current surgical indications and various surgical methods for midfoot CNA.

EPIDEMIOLOGY AND PATHOGENESIS
Jordan15 first described CNA in relation to diabetes mellitus. Diabetes mellitus is the commonest cause in developing world and other causes are peripheral neuropathy due to leprosy, syringomyelia, alcohol abuse, and denervated limb.16 Usually, this disease occurs in 4th to 5th decade, many years after the onset of diabetes mellitus.17 Overall incidence among diabetic patients is 0.3 to 2.5%,18 and it is as high as 13% in patients attending high-risk diabetic foot clinic.17,19 Incidence in patients with diabetic neuropathy is 16% and bilateral involvement is reported in 30% of patients.20,21 Pathogenesis of CNA is poorly understood and various theories put forward are deficiencies in spinal trophic centers by Jean Martin Charcot (French theory), neuro-traumatic theory by Volkmann and Virchow (German theory), and neurovascular theory by Finsterbush and Friedman.22-25 But, now it is generally thought to be due to combination of neurotraumatic and neurovascular theories wherein autonomic neuropathy leads to increase in blood flow, osteopenia, and weak bones. Motor neuropathy leads to muscle imbalance and abnormal stress on weak bones which remains unrecognized due to sensory neuropathy leading to fractures, dislocations, deformities, and ulcer progression which sets vicious cycle by further increasing the blood flow.26-28

PREDILECTION FOR MIDTARSAL JOINTS
Charcot neuroarthropathy commonly involves midfoot joints that are mainly supported by ligaments, due to combination of multiple factors. The most important factor is equinus contracture. Patients with CNA show high plantar pressures in metatarsophalangeal joints due to equinus contracture.
contracture, with forefoot acting as a lever which results in midfoot collapse on weightbearing.\(^{29,30}\) Another factor is the motor neuropathy, which leads to unopposed action of plantarflexors especially tendoachilles in comparison to dorsiflexors. This causes heel to remain off-the-ground during stance phase as well as, it alters ligament integrity. So, on transmitting whole body weight across midtarsal joints, the resultant shearing forces and weak ligaments cause midtarsal joint subluxation, fractures, and dislocation. The other factors, such as low bone mineral density seen on these patients’ lead to CNA.\(^{31}\)

**CLASSIFICATION**

### Modified Eichenholtz Classification\(^{27}\) (Table 1)

It describes the stages of progression of disease based on clinical and radiological findings. It is useful for treatment decision-making.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Clinical findings</th>
<th>Radiological findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Loss of protective sensation with erythema, swelling, clinical instability</td>
<td>Normal</td>
</tr>
<tr>
<td>1 Acute (fragmentation) stage</td>
<td>Increased ligamentous laxity and swelling</td>
<td>Osteopenia, periarticular fragmentation, fracture, and subluxation</td>
</tr>
<tr>
<td>2 Quiescent (coalescence) stage</td>
<td>Reduced warmth and swelling</td>
<td>Absorption of debris, early fusion, and sclerosis</td>
</tr>
<tr>
<td>3 Resolution stage (consolidation)</td>
<td>Absence of inflammation</td>
<td>Joint arthrosis, osteophytes, subchondral sclerosis</td>
</tr>
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</table>

### Sanders and Frykberg Anatomical Classification\(^{16}\) (Table 2)

This classification is more useful clinically as complications and healing depend on site of involvement.

<table>
<thead>
<tr>
<th>Type</th>
<th>Site of involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Forefoot – Metatarsophalangeal, interphalangeal</td>
</tr>
<tr>
<td>II</td>
<td>Tarso metatarsal joint – Most common</td>
</tr>
<tr>
<td>III</td>
<td>Midtarsal joint</td>
</tr>
<tr>
<td>IV</td>
<td>Ankle and subtalar joints</td>
</tr>
<tr>
<td>V</td>
<td>Calcaneum</td>
</tr>
</tbody>
</table>

**RADIOGRAPHIC FEATURES OF CNA**

Early-stage radiograph may be normal. The first radiographic features of Charcot foot are diffuse osteopenia, disorganized joints, and soft tissue calcification. Radiograph often shows two patterns: Atrophic pattern where bones are thin with minimal new bone and osteophyte formation. Hypertrophic pattern shows extensive fragmentation, huge haphazard osteophytes, and callus formation with foot taking the form of bag of bone appearance.\(^{37}\) Radiological parameters used to assess severity of deformity are talometatarsal angle in lateral and dorsoplantar views, calcaneo – 5th metatarsal angles in lateral view. Comparison of angles pre- and postoperatively helps to know the adequacy of deformity correction.\(^{38}\)

**MANAGEMENT OF MIDFOOT CNA**

The best treatment is early diagnosis and identification of foot at risk, followed by proper immobilization till acute phase settles. Pakarinen et al\(^{39}\) analyzed long-term effects of Charcot foot on patient’s lives and found that the need for surgical interventions tends to increase 4 years post diagnosis of Charcots foot and delaying diagnosis by 3 months leads to poor functional outcome. Method of management is largely based on Eichenholtz stages of disease and location of disease radiologically.\(^{1}\) Goal of treatment as proposed by Pinzur is to create osseous stable, plantigrade foot, prevention of ulcer and to create foot which can support ambulation with permanent footwear.\(^{6,12}\)

**Nonoperative Treatment**

Armstrong et al\(^{19}\) reported that 75% of CNA patients can be treated with nonoperative method and surgery is indicated only in 25% cases with 2/3rd requiring exostectomy and 1/3rd requiring arthrodesis. Nonoperative treatment is
the mainstay of treatment for acute phase CNA. The aim of nonoperative treatment is to reduce stress on midfoot area, immobilization of joints, and prevention of deformity progression. It consists of immobilization of foot in total contact cast (TCC) and encouraging weightbearing walking to prevent stress fractures, ulceration in contralateral foot, even though reported prevalence of bilateral CNA varies from 9% to 2/3rd of cases in some series. Total contact cast should be changed every 2 weeks to accommodate for the change in volume of foot and to be continued till quiescent stage, indicated by reduced swelling, temperature, erythema, and radiological evidence of bridging trabeculae. Duration of TCC varies with location of disease, with forefoot CNA having faster healing rates compared to other sites and mean duration of immobilization being 86 days. Mean duration of immobilization for midfoot Charcot is 4 months (4–6 months) but some may require up to 12 months. Once the quiescent stage sets, TCC is replaced with removal walking cast and finally, permanent therapeutic footwear applied. Studies have reported 60% successful outcome with TCC for midfoot CNA with mean duration of treatment varying 4 to 6 months, with faster healing rates in forefoot followed by ankle > midfoot > hindfoot.

**Drawbacks of Conservative Treatment**

Failure of conservative treatment leads to progressive deformity, recurrent ulceration, osteomyelitis, and amputation. This two-stage approach is associated with increased duration of treatment, high morbidity, cost, and reduced quality of life. Studies have reported recurrent ulceration up to 30% in patients who are on TCC. Some studies reported 40 to 50% of patients who are on TCC may need secondary surgery. Total contact cast in obese patients with insensitive foot is difficult as it carries high morbidity and increased risk of ulceration.

**SURGICAL MANAGEMENT OF CNA OF MIDFOOT**

Surgical management guidelines for midfoot CNA are lacking due to insufficient evidence and lack of prospective randomized studies. The surgical procedures done commonly for midfoot CNA are: (1) Arthrodesis, (2) exostectomy, and (3) gastrocnemius or tendoachilles lengthening. Evidence on timing of these surgical interventions and ideal fixation methods is lacking.

In a systemic review by Schneekloth et al., 30 studies consisting of 860 CNA patients who had surgical interventions were analyzed. Surgeries included arthrodesis, exostectomy, debridement of ulcers, drainage of infections, and amputation (8.9%). They concluded that timing of surgery and methods of fixation still remain inconclusive.

The basic principles to be followed while performing surgery for CNA are: Surgery should be avoided in acute phase till edema and swelling subside; till then TCC is used; and start of quiescent stage should be confirmed by clinical and radiological evaluation. Arthrodesis should be performed with proper technique using rigid internal fixation, autogenous bone grafting, and operated limb should be immobilized for adequate period allowing limited weightbearing till radiological evidence of healing.

Early vs late surgery: Failure to initiate early treatment carries risk of foot instability, ulceration, and infection. Patients with instability, early Charcot, nonplantigrade foot, impending, or formed ulcer should undergo early surgery as it is found to increase quality of life and reduce cost of treatment. Early surgery also provides long-standing functional outcome without recurrent ulceration or instability and gives walking independence with permanent footwear. Mittlmeier et al.53 stated that early surgical intervention helps in timely restoration of plantigrade foot, improves quality of life, and carries complications rates comparable to that after secondary surgery. Eschler et al.50 found that even late corrective arthrodesis for patients with nonplantigrade foot provides reasonable reconstruction of foot but carries high chance of reoperations and complications related to soft tissues (76%) and hardware (43%).

Preoperative workup should include assessing vascularity of limb by palpation of peripheral pulses, foot swelling should be investigated with Doppler to rule out venous thrombosis, routine weightbearing radiographs, and computed tomography in selected patients with severe deformity is needed for surgical planning.

**SURGICAL RECONSTRUCTIVE ARTHRODESIS PROCEDURES (TABLE 3)**

The goal of surgical treatment is not merely salvaging the foot but providing infection-free, ulcer-free, plantigrade osseous stable foot which can accommodate depth inlay therapeutic footwear and provide independent walking. Most of the patients have low physical demand and salvage of foot leads to satisfactory results. Reconstructive procedures of foot are challenging due to poor bone quality, comorbidities, sensory, vascular, and immunity impairment. But even with advances in fixation devices arthrodesis procedure carries complication rate varying from 10 to 30% such as implant failure, infection, loss of reduction, hardware failure, nonunion, and wound-healing problems.

**INDICATIONS AND CONTRAINDICATIONS**

*Indications* are: (1) Nonplantigrade foot, (2) impending or established ulceration, (3) severe foot deformity which cannot be accommodated in footwear, (4) early Charcots...
after acute phase, and (5) CNA with instability.\textsuperscript{1,2,13,49,54} Contraindications\textsuperscript{55} are: (1) High-risk patient for anesthesia due to multiple comorbidities, (2) technically nonreconstructible deformity due to severe bone loss, (3) peripheral vascular disease, (4) high-grade infections and osteomyelitis, and (5) patients who are not willing for extended period of inactivity.

Arthrodesis should be done at both medial and lateral column of foot.\textsuperscript{56,57} Eschler et al\textsuperscript{58} studied patients who had undergone medial column fusion with standalone fusion bolt and it resulted in need for revision surgery in 6 out of 7 cases. The authors concluded the use of medial fusion bolt as a standalone technique carries high-risk of complications and failure of union due to poor stability. So, they recommended the use of additional angular stable plates for medial column and lateral column stabilization for foot at the time of first surgery.

Choice of Implant

There is no clear evidence regarding ideal implant for internal or external fixation but decision should be based on multiple factors. The commonly used implants are 6.5 mm long fusion bolts of varying sizes and designs, combination of plate and screws, external fixators, and combination of internal and external skeletal stabilization. Pinzur and Sostak\textsuperscript{13} proposed criteria for implant selection and stated patients with nonplantigrade foot with large bone deformity, longstanding ulcer, infected bone, osteopenia, obesity, or immunocompromised state were found to have more complications and he recommended percutaneous deformity correction and ring external fixators for these patients. Those patients without ulcers, infection, good bone quality, less comorbidities, without obesity carry low-risk of complications and are to be managed with open stabilization and internal fixation. Eschler et al\textsuperscript{59} found based on above criteria that mean complication in patients with less than two risk factors is 1.3 in comparison to 2.8 in patients with more risk factors.

Midfoot Fusion Bolts

Charcot neuroarthropathy patients encounter difficulty in limiting weightbearing on operated limb and they are at risk for early implant failure. To overcome this, solid 6.5 mm intramedullary bolt was designed. These bolts were found to withstand higher load and have reduced risk of implant failure in comparison to plates.\textsuperscript{1,2} Jones\textsuperscript{58} has described midfoot fusion with the use of large intramedullary locking bolts called “beaming,” Richter et al\textsuperscript{57} in their study reported the use of midfoot fusion bolts for realignment and fixation of severe midfoot CNA in 47 cases. He stated midfoot fusion bolts provide stable fixation, high union rates (98\%) with minimal loss of correction. They had complications like wound-healing problems in 21\% cases, recurrent ulceration in 13\%, major amputations in 4\%, minor amputations in 6\%, and 6\% required revision surgery due to loss of correction. They found complications were more when only one fusion bolt is used and when Gastrocnemius was not lengthened. Waldecker\textsuperscript{59} performed midfoot fusion using screws and bone grafting in 12 patients (six with ulcer rest without ulcer) and were followed up till 2.4 years. Ten patients achieved osseous union by mean of 4.3 months, one patient had infection, one had unstable nonunion and recurrence of deformity, and all were ambulant by 7 months. Author concluded that midfoot fusion with open reduction and arthrodesis with screws provides good results. Butt et al\textsuperscript{60} studied 6 mm Synthes midfoot fusion bolt for medial column fusion in nine cases and found high-rate complications like screw migration, loosening, and finally concluded that 6 mm Synthes bolt fails to provide adequate stability for midfoot fusion and advised against routine use of it (Figs 1A to G).

### Surgical Technique (Figs 2A to J)

Surgery is performed in supine position under aseptic precautions and tourniquet control. Initially, gastrocnemius or tendoachilles lengthening done in patients found to have equinus contracture with separate incision at musculotendinous junction of gastrocnemius or by percutaneous method for tendoachilles lengthening respectively. Two incisions dorsomedial and dorsolateral are employed for medial and lateral column exposure and fusion. Dorsomedial incision starts from medial malleolus to first metatarsophalangeal joint. Interval

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of patients</th>
<th>Mean follow-up (months)</th>
<th>Recurrent ulceration</th>
<th>Revision surgery</th>
<th>Infection</th>
<th>Nonunion</th>
<th>Amputation</th>
<th>Function AOFAS</th>
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<td>32</td>
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<td>4</td>
<td>1</td>
<td>6</td>
<td>0</td>
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<td>41</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>30</td>
<td>48</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>Community walker</td>
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<tr>
<td>Pinzur and Sostak (2007)\textsuperscript{13}</td>
<td>51</td>
<td>33</td>
<td>3</td>
<td>8</td>
<td>–</td>
<td>–</td>
<td>3</td>
<td>–</td>
</tr>
<tr>
<td>Sammarco et al (2009)\textsuperscript{97}</td>
<td>22</td>
<td>52</td>
<td>3</td>
<td>9</td>
<td>1</td>
<td>6</td>
<td>0</td>
<td>All ambulant</td>
</tr>
<tr>
<td>Richter et al (2015)\textsuperscript{97}</td>
<td>48</td>
<td>12</td>
<td>6</td>
<td>3</td>
<td>8</td>
<td>1</td>
<td>5</td>
<td>94% success</td>
</tr>
<tr>
<td>Assal and Stern (2009)\textsuperscript{82}</td>
<td>15</td>
<td>42</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>14/15 ambulant</td>
</tr>
</tbody>
</table>

Table 3: Outcomes of case series of midfoot CNA treated with arthrodesis procedures
developed between tibialis anterior medially and extensor hallucis longus laterally to expose talonavicular joint, naviculocuneiform joint, and cuneiform-first metatarsal joint. Dorsolateral incision starts in front of lateral malleolus ending at base of 4th and 5th metatarsal bone. Here calcaneocuboid, cuboid 4th and 5th metatarsal joints, 2nd to 3rd tarsometatarsal joints were exposed. Synovium, cartilage, sclerotic bone excised to create healthy bleeding surface of bones. Usually, midfoot CNA presents as rocker bottom deformity and forefoot abduction with apex of deformity at plantar and medial aspect respectively. Osteotomizing and excision of more bone at apex of deformity followed by plantar aspect ligament release aids in deformity correction. If there is extensive bone loss after debridement, tricortical iliac crest bone grafts were used to bridge and maintain length of foot. Midfoot collapse and forefoot abduction are corrected by plantarflexion and adduction of metatarsal bones so as to align with corresponding tarsal bones. Final fixation is carried out with intramedullary 6.5 mm fusion bolts with or without additional low profile plates and screws. Stab incision made at head of 1st metatarsal bone, using curved hemostat metatarsal head reached by bluntly spreading the soft tissues. Holding the foot in alignment, a 2 mm guide pin is passed in antegrade manner through plantar aspect of head of first metatarsus along first metatarsus, medial cuneiform, Navicula (or strut grafts when used), and talar body under image intensifier control. Through 2nd stab incision, a 2nd guide pin passed through plantar aspect of head of 4th metatarsus across 4th metatarsus, cuboid, and calcaneum. The position of guide pin confirmed with anteroposterior, lateral, oblique, and axial images of image intensifier. Reaming done over guide pin using 4.5 mm cannulated reamer and appropriate size 6.5 mm AO long, cannulated, short-threaded compression screws are inserted to achieve compression in plantigrade position. Threaded portion of screws should cross talus or calcaneum completely to achieve good compression. If fixation is not stable enough, additional 6.5 mm AO screw was passed across 2nd metatarsus through intermediate cuneiform, navicular, and talus or low-profile plates are used to augment medial column. Rest of gaps were packed with iliac crest bone grafts. Closure done over suction drain, and below the knee Plaster of Paris cast was applied.

**Postoperative Protocol**

Postsurgery, antibiotic therapy should be continued for 3 days and nonweightbearing is allowed with foot immobilized in cast for 6 to 8 weeks till swelling reduces, later partial weightbearing with removable cast walker for up to 3 months is advised, followed by full weightbearing with permanent footwear.

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**Figs 1A to G:** Case example: (A & B) Plain radiographs showing Eichenholtz grade I charcot arthropathy in 58 years male involving midtarsal joints of right foot with midtarsal collapse; (C & D) radiographs at 6 months following medial and lateral column fusion with 6.5 mm AO cannulated screws, additional medial column plate and screws at lateral column showing well consolidated arthrodesis; and (E to G) clinical picture at 6 months follow-up showing plantigrade right foot with well corrected rocker bottom deformity.
Arthrodesis with Plates

Garchar et al.\(^{61}\) studied the use of plating in plantar surface of medial column in Lisfranc fracture dislocations secondary to CNA in 24 patients. At average follow-up of 38 months union was achieved in 24 of 25 feet and average time to ambulation was 11.68 weeks and the author concluded that the use of plantar plate provides sturdy construct for arthrodesis and ambulation. Nasser et al.\(^{62}\) described medial column fusion for various indications with anatomical distal fibular locking plates and stated that technique provides rigid fixation for at risk bone.

Hybrid Fixation

Sometimes it may be useful to use both internal and external fixation methods to provide stable construct. Smith and Moore\(^{63}\) described hybrid fixation consisting of medial column fusion with plate and protection of construct and correction with external ring fixator. Matsumoto and Parekh\(^{53}\) described the use of multiaxial correction monolateral external fixation with or without plate for midfoot Charcot arthropathy correction. Out of 11 cases, all cases went onto union without amputation, all were ambulant, and no pin site infections occurred.
The authors concluded that monolateral external fixator is an easy and acceptable method. Hegewald et al\textsuperscript{64} reported the use of both external and internal fixation in management of 22 cases of CNA. During mean follow-up 58.6 months foot was salvaged in 20 cases (90.91%) with satisfactory radiographic alignment and 2 cases underwent amputation (9.09%). Complications like wound dehiscence – 36.36%, pin tract infection – 45.45%, and superficial infection – 40.91% were reported. The authors concluded that limb salvage rate in CNA is improving due to newer developments in internal and external fixation.

### Minimally Invasive Surgical Procedures

Open major reconstructive surgeries involve excision of bone, deformity correction, and internal fixation which carries risk of delayed wound healing, shortening of foot, incomplete correction of deformity, implant failure, infection, and need for cast or brace for longer periods with complications ranging from 10 to 30%.\textsuperscript{13,14} To minimize these complications, Delhey et al\textsuperscript{65} described closed reposition and circular fixator stabilization treatment for midfoot CNA. Lamm et al\textsuperscript{66} described deformity correction by distraction using Taylor spatial frame, followed by arthrodesis with minimally invasive internal fixation. Among 11 feet in their study all had satisfactory radiological outcomes; no patient had deep infection, screw failure, recurrent ulceration, and amputation. The most common complication in their series was pin tract infection –11, pin and ring breakage, and need for readjustment of frame.

### Arthrodesis of Midfoot CNA associated with Ulcer or Infection

Surgical reconstruction in the presence of ulcers is often feared due to risk of infection. Some series recommended postponing of surgery till ulcer heals or advocated external fixators to reduce complications.\textsuperscript{49,67} This complicated scenario demands stepwise approach aiming at eradication of infection, deformity correction, and wound coverage.\textsuperscript{68} Managing ulcers of CNA require multidisciplinary approach; Sinkin et al\textsuperscript{69} managed 314 wounds in 259 diabetic patients with various methods like primary closure (15%), delayed primary closure (18.01%), bioengineered tissues (31.6%), skin grafts (21.2%), local flaps (7.8%), and free flaps (2.6%). They found that 65.1% wound healed in time and 35.6% required amputations and finally concluded that despite multidisciplinary approach most of patients are at risk of major or partial foot amputations with more proximal wounds are at highest risk. External fixators are indicated when CNA is associated with infection. Capobianco and Zgonis\textsuperscript{68} described local muscle flap of abductor hallucis for wound coverage and use of ring external fixators for stabilization of foot. Pinzur et al\textsuperscript{70} managed 73 cases of CNA with infection by single-stage radical excision of infected tissue, deformity correction, and maintenance of correction with circular ring external fixators followed by parenteral antibiotics as per the culture sensitivity. Fixators were retained for 8 to 12 weeks, later TCC was applied for 4 to 6 weeks. They reported 95.7% of limb salvage with ability to ambulate in therapeutic footwears. Farber et al\textsuperscript{71} managed CNA of midfoot with associated ulcer with debridement, corrective osteotomy, external skeletal stabilization, and culture-specific antibiotics. They reported that all patients were able to wear footwear by 12 to 49 months follow-up. In another study by Pinzur\textsuperscript{49} CNA with infection was managed with tendoachilles lengthening, excision of infected tissue, deformity correction, and stabilization with three-level ring fixator followed by antibiotic therapy. They reported all patients were ulcer-free, infection-free and were ambulant. Dalla Paola et al\textsuperscript{72} managed 45 cases of CNA with infection by debridement and external skeletal stabilization and the authors reported that 39 cases had no infection and foot salvaged. In one study, it was concluded that the site of disease and grade of osteomyelitis has no bearing on limb salvagability.\textsuperscript{73}

But some studies have reported good outcome with internal fixation in the presence of ulcer. In a series by Mittlmeier et al\textsuperscript{1} one-third of patients had ulcers preoperatively and all ulcers healed postsurgery using plates or screws without any major complications. Altindas et al\textsuperscript{74} described two-stage Boyd operation (talectomy and tibiocalcaneal nail fusion) for complicated infected CNA of foot, where 11 patients were managed with this method and all attained ulcer-free ankylosed foot at mean follow-up of 2.1 ± 0.8 years.

### Tendoachilles or Gastrocnemius Lengthening

Boffeli and Tabatt\textsuperscript{75} described the use of simple less-invasive surgical procedures in the form of tendoachilles lengthening, plantar fasciotomy, tendon transfers in early-stage CNA before the development of rigid deformed foot. The principles of these interventions are to eliminate deforming forces acting across the joint. The goal is to provide braceable foot, halting development of deformities, and avoiding possible need for major reconstructive surgeries. Equinus contracture is the most important factor responsible for increased plantar pressures, plantar ulceration, and progression to midfoot collapse.\textsuperscript{29,30,76} Lengthening of gastrocnemius or tendoachilles reduces shearing forces passing through the midfoot, thereby may prevent midfoot collapse. Surgery is based on Silfverskiold test wherein dorsiflexion at ankle joint is
tested with knee in extension and flexion. Positive test is when dorsiflexion improves with knee flexion, suggesting tightness of gastrocnemius. Here gastrocnemius is transected transversely at muscle tendon junction using 3 cm incision over posteromedial aspect of leg. Later, suture was placed at tendon stump to stabilize the tendon in correct length.57 In patients with negative Silfverskiöld test, tendoachilles was lengthened by percutaneous method.1

Exostectomy
Midfoot collapse in CNA foot leads to rocker bottom deformity, with apex of deformity being plantarward. This causes skin breakage and ulceration.3 Surgeries addressing plantar bone prominence like exostectomy aids in ulcer healing. Laurinaviciene et al77 described exostectomy for chronic midfoot ulcers with Charcot deformities. Pakeriene et al79 found in his study that exostectomy resulted in successful ulcer healing in 62% of cases.

Predictors of Good Outcome after Surgery
Use of more than 1 fusion bolts is associated with lower failure rates and minimal loss of correction.56 Richter et al57 reported the use of three fusion bolts: One in medial column, one in lateral column, and one for subtalar joint, has least complications. Gastrocnemius or tendoachilles lengthening is associated with lower failure rates as it eliminated deforming force on foot.28

Complications of Surgery: Summary in Table 3
Richter et al57 reported 63.8% adverse events in patients undergoing surgery for CNA, indicating morbidity associated with the pathology. Hartig et al59 in a systemic review concluded even with strict aseptic precautions and vast experience complications can occur with CNA. The authors concluded early diagnosis of CNA, timely intervention before ulceration, and optimal treatment of comorbidities help to reduce the complications. The common complications are:

- Wound-healing problems, recurrent ulceration.
- Loss of correction – Can lead to nonunion and ulceration. Literature as reported loss of correction ranging from 16 to 60%.1,2,67 But with the use of intramedullary solid fusion bolts the reported rate of loss of correction is 6%.57
- Hardware failure – Mertinus Richter reported revision surgery due to instability and loss of correction in 6% of cases.
- Deep infection – reported rate is up to 30%.
- Nonunion – reported rate is up to 30% and it often coincides with hardware failure.
- Fibrous union – if stable does not require revision.

Amputation
Amputation is indicated in cases where CNA is complicated with osteomyelitis with threatening sepsis. Dalla Paola et al73 stated in his study that even in CNA with osteomyelitis single- or double-stage arthrodesis, with the use of external fixation provides good outcome and is a reasonable alternative to below knee amputation. Evans et al80 analyzed outcomes in diabetic patients undergoing amputation and found that mortality and morbidity in patients undergoing proximal forefoot and midfoot amputation is less in comparison to below knee amputation. Authors suggested aggressive efforts to salvage the limb with proximal forefoot and midfoot amputation first, before considering high-level limb amputations (below knee amputation).

CONCLUSION
Charcot neuropathy of midfoot is most debilitating orthopedic condition which warrants early diagnosis, aggressive immobilization, and timely reconstructive procedures to reduce ulceration and to restore stable plantigrade foot for independent ambulation.

REFERENCES
Midfoot Charcot Arthropathy: Overview and Surgical Management


