Managing Severe Foot and Ankle Deformities in Global Humanitarian Programs

Shuyuan Li, MD, PhD, Mark S. Myerson, MD*

INTRODUCTION

This article presents a variety of severe deformities that the authors have encountered in Steps2Walk humanitarian programs globally. Many of these deformities are not seen routinely in the Western world today and provide unique challenges for treatment and correction.¹ There are differences in the expectations of the patients whom the authors treat compared with those in the Western world; the latter have different goals, some of which may be quite unrealistic in these programs. Many of the deformities discussed have been present since birth, whereas others are caused by systemic disease, neuromuscular disorders, trauma, and so forth. In many parts of the world,
there is an acceptance of these deformities due to patients’ financial problems or the limited availability of orthopedic foot and ankle surgery in the local areas. Most patients have learned to live with a deformity and accept the disability, until the authors have been able to provide treatment through humanitarian projects. In treating these patients, in addition to careful systematic clinical assessment, a thorough communication with the patient and the family, with a good understanding of the local culture and the patient’s background, can never be overemphasized. For a majority of these patients, a plantigrade foot always is desirable, but for some, the ability to wear a shoe is more important than obtaining a perfectly shaped and aligned foot, which may be not only unnecessary but also unrealistic given the equipment that the authors are working with. Having said this, the authors always attempt to obtain the best possible correction so that the patient is able to ambulate and wear a shoe.

As always, treatment should include both bony alignment correction and soft tissue balance whenever necessary. For flexible pediatric, in particular congenital, deformities, osteotomies are preferable, even for severe deformities. Arthrodesis usually is reserved for severe rigid deformities in adults. There often are exceptions, however, where the authors are forced to perform a hindfoot arthrodesis or takedown in a child with severe rigid deformity. The authors have to take into consideration the recovery, the ability of the patient to obtain rehabilitation, their ability to return for follow-up visits, and how they will cope if bilateral surgery is performed. For many of these patients, bilateral surgery is preferable, but many of them live in rural areas where ambulation even with crutches is difficult on uneven terrain, and it is difficult to obtain a wheelchair for them. Family resources must be taken into consideration when planning these surgeries.

During the surgeries, the authors often are confronted with a lack of resources, mostly with respect to implants and power equipment, which are taken for granted in day-to-day practice in the Western world. The authors frequently use solely Kirschner wires of various diameters to maintain stability after deformity correction. In some countries, the authors have been fortunate to have corporate support for the use of plates and screws, which make the recovery a little easier. The authors have found, however, that wires work extraordinarily well both for children and adults. Although external fixation with staged correction may be ideal for severe deformities to avoid potential wound and neurovascular complications, which are higher in 1-stage correction, it is not preferred in patients from rural areas, where postoperative medical care is limited. In such cases, 1-stage careful aggressive correction is ideal to obtain definite outcome and avoid complications as much as possible. Sometimes, surgeons need to accept that a functional foot with some minor residual deformities is more realistic than perfect alignment with procedures that carry a higher risk of complications.

**UNTREATED CLUBFOOT**

Clubfoot deformity refers to a variety and range of deformities that cause continuing disability of the hindfoot and ankle and, in the most severe cases, patients are load bearing on 1 side of the foot and ankle. There are several subcategories of deformity, including equinus, calcaneus, varus, valgus, adductus, and abductus. The etiology of these varied deformities can be congenital, caused by multiple vascular deficiencies, position in utero, abnormal congenital muscle insertion, and genetic factors, or be associated with neuromuscular disorders, such as poliomyelitis, cerebral palsy, arthrogryposis, and spinal bifida. Neglected or untreated clubfoot deformities are common in developing countries and regions where there are limited pediatric
orthopedic resources and a high rate of recurrent deformity due to recidivism and inability to return for follow-up treatments. van Wijicke and colleagues\textsuperscript{12} did a qualitative and partly quantitative study with semistructured interviews in 4 countries—the Netherlands, South Africa, Argentina, and Indonesia—with both caregivers, mostly parents of children with clubfoot, and practitioners treating clubfoot. They found that poverty, long travel duration, and beliefs of supernatural were the most common causes for the delay of treatment of clubfeet. It was proposed by the investigators that accessible clinics in rural areas could be good alternatives to highly specialized hospitals in large cities.\textsuperscript{12} This is exactly the goal of the global humanitarian educational projects of Steps2Walk. The authors are coordinating global orthopedic foot and ankle surgery resources to deliver professional education to local orthopedic surgeons and medical care to patients.

In neglected clubfoot cases, usually there is severe stiffness caused by long-standing soft tissue contracture or even arthritis. Therefore, surgeries usually are indicated, including soft tissue release, Achilles tendon lengthening, tenotomies, tendon transfer, triple arthrodesis, and talcetomy with or without tibiocalcaneal arthrodesis.\textsuperscript{13–15} Soft tissue procedures alone usually do not provide adequate correction; therefore, bony procedures usually are needed to sustain the correction.\textsuperscript{15} Ghali and colleagues\textsuperscript{16} reviewed 125 patients with 194 feet affected by congenital talipes equinovarus deformity treated during the period 1959 to 1980. In the early group of 70 patients, who presented within 4 weeks of birth, the investigators reported excellent or good results in 94\% of feet treated conservatively and 82\% of feet that required pantalar release. In the late group of 55 patients who presented after 4 weeks of birth, satisfactory results were achieved in 75\% of cases. The investigators found there was no statistical correlation between early soft tissue release and a good final outcome, but there was a positive statistical correlation between good clinical results and a high talocalcaneal index. The external fixation technique has the ability to correct all deformity components of rigid deformity at the same time without bone resection or limb shortening. Complications, however, such as pin tract infection, early consolidation, and articular subluxation, all are concerns, in particular among patients from areas without adequate medical care and where sequential postoperative follow-up is unavailable.\textsuperscript{13,17,18} Among bony procedures, triple arthrodesis is an option for skeletally mature patients with rigid clubfoot deformity. There is a high incidence of complications, however, with long-term follow-up, including residual deformities, degenerative osteoarthritis, and nonunion.\textsuperscript{19,20} There also are opinions claiming that triple arthrodesis is not the first choice for patients with a neurologic foot deformity, because of the dangers of joint degeneration and skin ulceration caused by the stiffness of the foot.\textsuperscript{21}

Talcetomy has been used to treat clubfoot since the seventeenth century.\textsuperscript{22} More recently it has been widely used when reduction of the deformity is extremely difficult or when the talus is very deformed.\textsuperscript{23} It is stated that talcetomy could provide sufficient laxity for the hindfoot deformity to be corrected without tension. The tibiocalcaneal pseudoarthrosis that is created remains stable and relatively congruous with a plantigrade foot with little tendency to relapse due to the stable position and the absence of medial tension.\textsuperscript{14} According to El-Sherbini and Omran,\textsuperscript{15} in a 10-year prospective observational study, talcetomy is a relatively straightforward technique, which allows early mobilization of the operated extremity, and an effective procedure for correction of severe rigid equinovarus feet with significant effect, provided the talus is completely removed and the calcaneus can be aligned in the ankle mortise. Cooper and colleagues followed a series of 26 talcetomy cases who had the surgery at an average age of 10.25 years for an average of 20 years. The results were good with obtaining
stable and painless plantigrade feet, regardless of the preoperative deformities. They believed that talcetomy is indicated only in rigid and severe deformed feet, whereas other less radical approaches are not recommended for various reasons.²⁴

The authors present a 28-year old woman with untreated bilateral club foot deformities. There was no movement of either foot whatsoever, and the ankle also was extremely rigid. The options for treatment included a talcetomy combined with a tibiocalcaneal arthrodesis, a talcetomy without an arthrodesis, or correction of the feet gradually with an external fixator, which, however, was not available in this location. If a talcetomy is selected as treatment, it is preferable to perform this bilaterally so as to maintain equal limb length. Although it may be preferable to perform simultaneous bilateral talcetomy, this decision always depends on the ability of the patient to manage non–weight bearing for a prolonged period of time. The family and social circumstances of the patient and their resources in planning this type of surgery have to be considered.

With the magnitude of this deformity, a talcetomy may not be sufficient for correction of the hindfoot, and performing additional procedures in order to decompress the hindfoot has to be considered (Fig. 1A–C). Also, in Fig. 1C the contracture of the metatarsophalangeal (MP) joints, in particular, the hallux, can be seen. Generally, the flex contracture of the hallux corrects after bone decompression posteriorly but additional procedures on the toes to restore a neutral and mobile MP joint have to be anticipated. The authors have found that a transfibular approach to the talcetomy is preferable to an approach anteriorly, which removes the talus piecemeal. After the lateral incision, the distal fibula is removed completely to expose the talus. There are 2 options for

![Fig. 1](image_url)

**Fig. 1.** (A) A 28-year-old woman presented with untreated bilateral club foot deformities. Both the feet (B) and the ankles (C) were in extremely rigid equinovarus. (C) The contracture of the MP joints, in particular, the hallux. (D) On the left foot, a transfibular approach to the talcetomy was performed. In this case, after the talcetomy, a very large lateral based wedge was removed at the level of the calcaneocuboid joint to address the residual adduction deformity through the transverse tarsal joint. (E) A very satisfactory correction of the deformity was achieved intraoperatively.
managing the fibula, that includes discarding it, and, in the other procedure, the fibular is peeled back posteriorly, the talus removed, and then the fibula fixed with a plate to improve stability of the calcaneus in the ankle mortise. An osteotome is inserted into the ankle joint, which is gradually opened, and the talus slowly mobilized from its soft tissue attachments. It generally is easy to disarticulate the talus from the ankle joint but not as easy to remove it off the calcaneus until the interosseous ligament has been cut. In this case, after the talectomy, the hindfoot did not correct. There was persistent adduction deformity through the transverse tarsal joint, and further resection had to be performed at the level of the calcaneocuboid joint, where a very large wedge was removed (Fig. 1D). No attempt was made to perform an arthrodesis of the tibia to the calcaneus. The authors and other investigators, as discussed previously, have found that it generally is not necessary, and, provided the hindfoot is stable after immobilization, most patients tolerate this very well. It is believed that in talectomy cases, maintaining a correct position of the calcaneus is a key factor of the surgical outcome.22,24,25

At this stage, the most important aspect of the procedure is to ensure that there is adequate circulation to the foot. The tourniquet should be released routinely after bone removal before the foot is fixed in its final position. In this case, ischemia of the foot was present. In the presence of ischemia, the most important treatment is to wait and see what happens to the circulation after a few minutes leaving the foot hanging over the edge of the table. Warm moist sponges can be used, and, if the circulation still does not improve, a tunnel release must be performed. It is useful to have a Doppler ultrasound available to be able to map out the vessels, which may be compressed or twisted, in particular, the anterior tibial artery at the level of the ankle. The other alternative is to use nitroglycerin paste, which produces vasodilatation and may improve perfusion. The authors applied this paste liberally to the foot and 5 minutes later circulation had been restored completely. The final correction of the deformity intraoperatively is indicated in Fig. 1E.

RECURRENT CLUBFOOT

A recurrent clubfoot can develop either from failed serial stretching and casting treatment, including the Ponseti method, or from previous surgical treatment. Both surgeons and patients need to accept that due to complicated teratologic, neurologic, or even patients’ personal circumstances, residual deformities and recurrence of the deformities are quite normal.26 According to the literature, there is approximately 20% to 30% recurrence associated with idiopathic clubfoot, and 20% of clubfeet may require further surgical correction to address residual deformities even after a successful conservative treatment.27 As long as the foot is asymptomatic, plantigrade, and functional, however, even with the assistance of orthotics or splints, no further surgical intervention is necessary. Revision surgery should be considered only to improve function and reduce symptoms.

Residual or recurrent deformities or even overcorrection may lead to equinus, varus, valgus, cavus, supination, and adduction. As with the mechanism of primary deformities of clubfeet, recurrent deformities usually are caused by soft tissue imbalance, which can be unbalanced muscle strength, static soft tissue contracture, or both. In the midfoot, the anterior tibial and the peroneal longus tendons keep the first ray in plantar flexion and dorsal flexion balance. The Achilles tendon and the anterior tibial tendon are a pair maintaining the foot in plantar flexion and dorsiflexion balance, and, with the posterior tibial tendon (PTT) and the peroneal brevis tendon, keep the foot in inversion and eversion balance. A relatively strong...
Achilles tendon pulls the hindfoot into equinus if an Achilles tenotomy has not been done when it is necessary. Unbalanced relative strong posterior tibial and anterior tibial muscles force the foot into varus, whereas an overacting anterior tibial muscle drives the forefoot into adduction and the first ray into elevation. The secondary effect of this is to cause hallux rigidus with a plantar flexion contracture of the first MP joint, which also known is as a dorsal bunion. Plantar fascia contracture, a relatively strong peroneal longus muscle, and a weak anterior tibial muscle all can contribute to a midfoot cavus deformity. Vice versa, contracted soft tissue on the lateral side and a relatively tight or strong peroneal brevis from either an undercorrection or an overcorrection cause a valgus deformity in the midfoot or hindfoot.\textsuperscript{26,28–31} Therefore, the need to address any potential static or dynamic soft tissue imbalance with soft tissue releases and tendon transfers, where necessary, always should be borne in mind. Claw toes usually are caused by soft tissue imbalance either from the primary deformity, which includes weakness of the intrinsic muscles, dysfunctional anterior tibial muscle, and overaction of the extensor longus muscles, with contracture of the plantar fascia and extensor brevis muscles, and flexor muscles, or from a corrective surgery of the hindfoot. As is known, in bringing the ankle from an equinus contracture to the neutral position, the flexor tendons are put under greater tension, which can cause a claw toe deformity. For a primary claw toe deformity, treatment options include tenotomy of the extensor brevis tendons, lengthening of the longus extensor tendons, excision of the flexor longus tendons, release of dorsal and lateral soft tissue of the MP joint, and arthroplasty or arthrodesis of the proximal phalangeal joint. The approach to correction depends on the flexibility of the toe, which should be reassessed after each step. For a secondary claw toe deformity, which is caused by correction of a severe equinus ankle, the treatment may be postponed as a staged surgery to avoid ischemic complications, particularly in cases where extensive bony and soft tissue procedures already have been done in the midfoot and hindfoot. With severe equinus, as the foot is brought up to a neutral position, both the short and long flexors are contracted. It is easy to correct the contracture of the long flexors with tenotomy but not the short flexors. These may elongate slightly after the plantar fascia release but may remain contracted, limiting dorsiflexion of the MP joints. This is difficult to treat, and the only way to increase dorsiflexion is to either remove the metatarsal heads in severe cases or shorten the metatarsals with a distal osteotomy to relieve the flexion contracture.

The authors present a 23-year-old patient who had been treated for a club foot deformity during early childhood and operated on twice with recurrence of deformity. Note the severity of the unilateral deformity, which was not entirely rigid (Fig. 2A, B). Intraoperatively, the foot was examined and noted to have mobility in the ankle, albeit slightly limited due to a flat top talus. Limited correction of this deformity with manipulation (Fig. 2C, D) can be appreciated. Based on the mobility of the ankle, it was decided to preserve the ankle joint and perform only a triple arthrodesis with a medial soft tissue releases, including a percutaneous posterior tibial tenotomy with incision of the spring ligament, which made the foot slightly more mobile. The rest of the procedure was performed through an extensile lateral incision. Commencing with the subtalar joint, a lateral wedge was removed from the joint using a sharp osteotome until the hindfoot could be corrected into slight valgus (Fig. 2E, F). The majority of the correction was performed through the transverse tarsal joint by resecting a large biplanar wedge commencing at the calcaneocuboid joint and entering into the talonavicular joint. The first cut was made on the calcaneus and talus (Fig. 2G), followed by removal of a larger wedge from the cuboid and navicular (Fig. 2H). At the completion of the joint
preparation, the foot easily could be manipulated into a neutral hindfoot position (Fig. 2I). Further work was performed on the toes, which were contracted preoperatively and slightly more so after the hindfoot correction.

CALCANEovalgUS

Congenital calcaneovalgus deformity, also known as reverse clubfoot,\textsuperscript{32,33} is a type of deformity that is seen far less commonly than equinovarus. According to a study of the Edinburgh Register of the Newborn 1964 to 1968, including 52,029 births in the city during the 4.5 years, there were only 22 cases of talipes calcaneovalgus.\textsuperscript{34} The congenital calcaneovalgus deformity, which must be differentiated from a congenital vertical talus,\textsuperscript{35,36} is characterized by calcaneus at the ankle and valgus at the subtalar joint.\textsuperscript{32,35–38} Dislocation of the peroneal tendons on the lateral side and contracture of the Achilles tendon posteriorly and anterior tibial tendon anteriorly have been
considered as part of both the etiology and result of the deformity. The Edinburgh Newborn Register study showed that there was an incidence of developmental dysplasia of the hip of 0.6%. Westberry and colleagues reported an incidence of 0.28% of developmental dysplasia of the hip with congenital talipes calcaneovalgus. Paton and Choudry’s 11-year prospective longitudinal observational study of the relationship between neonatal deformities of the foot and the presence of ultrasonographic developmental dysplasia of the hip showed an overall risk of 1:5.2 of ultrasonographic dysplasia or instability in congenital talipes calcaneovalgus. Muscle imbalance caused by muscular neurologic disorders, such as spina bifida, polio, and cerebral palsy, are additional causes of calcaneovalgus deformities. There can be a wide variety of combined congenital and acquired deformities, such as contracture or dislocation of the hip, contracture or valgus/varus deformities of the knee, and rotation of lower limbs. In those circumstances, treating the proximal deformities of the limb other than focusing only on the foot and ankle and balancing the lower limb muscle strength are the key points for a satisfactory outcome. Treatment includes early splinting and serial casting for primary flexible deformities and surgeries for severe, rigid, or residual deformities and deformities with muscle strength imbalance.

The authors present a severely disabled 15-year old child, who was unable to wear shoes. She had a profound calcaneovalgus deformity, which was markedly unstable (Fig. 3A). The foot could be dislocated and was extremely unstable at the level of the ankle (Fig. 3B), most likely due to a ball-and-socket ankle. The foot could be straightened with manipulation (Fig. 3C) but the peroneal tendons and Achilles tendon were extremely contracted. With the hindfoot held in a relatively neutral position, the forefoot was markedly supinated with instability present in the midfoot. This child had difficulty ambulating, and an ideal goal for her was simultaneous bilateral correction. Despite her age, she weighed very little, and her mother felt that she would be able to cope with lifting her and moving her around the home. Therefore, bilateral surgery was performed. There were many procedures that could be considered for correction, but, due to the profound instability as well as the contraction post-erolaterally, a tibiotalocalcaneal (TTC) arthrodesis was chosen, despite her age. The procedure was performed through a lateral incision and a transfibular approach used to address both the ankle and subtalar joints. A tenotomy of the Achilles tendon and peroneal tendons then were performed. When performing an Achilles tenotomy, the authors recommend that the incision is made from the inside rather than percutaneously to avoid gapping of the skin after correction.

The authors find that it is easier to begin with the subtalar joint while the ankle joint is still relatively stable. At this age, the articular surface can be scraped using a fine osteotome; however, care must be taken not to remove more of the articular surface laterally in either the subtalar or ankle joint, which would produce a valgus malunion. The ankle then is dislocated medially so that the entire articular surface is visible. This makes it easier to make the surface preparation of the ankle joint and identify the source of instability (Fig. 3D). The joint can be prepared either using a sharp osteotome or, in this case, using a fine saw to cut the joint surface, as seen in Fig. 3E.

Fixation of the TTC arthrodesis was straightforward, using 2.5-mm pins. In Fig. 3F, the hindfoot is well aligned with respect to the tibia but there is marked forefoot supination present. This likely was the result of a contracture of the anterior tibial tendon, which was now unmasked as a result of correction of the hindfoot. In addition to the supination of the forefoot, there also was abduction instability noted in the midfoot, and a closing wedge arthrodesis of the naviculocuneiform joints also was performed. The final appearance of the foot with the midfoot arthrodesis and the lateral transfer of
Fixation of the anterior tibial tendon transfer was performed using a rubber stopper taken from a 20-mL syringe. The syringe is taken apart, and the rubber stopper is removed and perforated with a small hemostat clamp through which the 2 sutures from the tendon are now passed. The rubber stopper then is used as a type of button over thick gauze padding on the plantar surface of the foot. The authors find that this is much safer than using a button because it is less rigid and less likely to cause skin necrosis (Fig. 3H).

**TARSAL COALITION BALL-AND-SOCKETANKLE JOINT**

Tarsal coalitions include talocalcaneal, calcaneonavicular, and, less commonly, the talonavicular joint. As a result of failure of segmentation of the primitive mesenchyme...
during development, tarsal coalitions cause failure of formation of the involved joint. For a symptomatic tarsal coalition with sufficient hindfoot flexibility and no obvious degeneration of adjacent joints, a coalition resection with other supplementary procedures usually are performed to restore the hindfoot alignment and stability, such as a medial displacement calcaneal osteotomy, a calcaneus stop procedure, or a cotton osteotomy. For a tarsal coalition case with a very rigid hindfoot or significant joint arthritis, a subtalar joint fusion or a double or triple arthrodesis is used. Due to the abnormal restriction of motion in the foot from an early age, more severe coalitions, in particular the talonavicular, sometimes lead to a spherical malformation of the ankle joint, that is, a ball-and-socket joint.44,45

Mechanical structures of a ball-and-socket ankle involve a shortened fibula, a spherical shape of the tibial plafond, and a valgus ankle and hindfoot deformity. All of these plus increased hindfoot rigidity caused by the tarsal coalition lead to decreased ankle stability.46 For a ball-and-socket ankle presenting in a young age or even in adults without evidence of ankle arthritis, a supramalleolar osteotomy can be performed to restore the shape of the ankle. Although, for an adult patient with advanced arthritis of the ankle due to long-term uneven loading and instability of the joint, an ankle arthrodesis is a more appropriate treatment.46,47

The authors present a 16-year-old girl with a severe rigid flatfoot deformity. The hindfoot was in marked valgus, and there was extreme rigidity of the foot. The ankle, however, was very mobile, indicating the possibility of ankle instability associated with that ball-and-socket ankle (Fig. 4A, B). Radiographs and a CT scan confirmed the presence of the tarsal coalition and a severe deformity of the talonavicular joint (Fig. 4C–F). The CT scan of the ankle was highly unusual, with a varus ankle deformity in the presence of such severe hindfoot valgus. In addition, there were cystic changes on the lateral aspect of the distal tibia, indicating a lateral overload of the ankle joint. This confirmed that there was marked valgus overload of the ankle in addition to the valgus deformity of the hindfoot.

Given the severity of the valgus deformity all of the ankle joint, a medial closing wedge supramalleolar osteotomy was performed first (Fig. 4G). It is important when performing this osteotomy that it is planned according to the size of the plate that is to be used for fixation, which should be approximately 4 cm proximal to the tibiotalar joint surface. In a situation like this, it rarely is necessary to perform a simultaneous fibular osteotomy. A small wedge should be commenced with and then slightly more bone removed as needed until the ankle is in a neutral position (Fig. 4H). At the completion of the tibial osteotomy, the ankle was well aligned and planning of the hindfoot correction can be begun. Due to the severity of the deformity, a medial approach to correction was planned by performing a medial double arthrodesis (talonavicular and subtalar joints). Prior to commencing with the arthrodesis, a percutaneous tenotomy of the peroneus brevis was performed laterally (Fig. 4I). Without this, it is unlikely that the severe valgus deformity could be corrected. The approach to the subtalar and talonavicular joints began with exposure of the flexor tendons. By retracting the flexor digitorum longus dorsally and the flexor hallucis longus (FHL) inferiorly, the subtalar joint can be identified, simultaneously protecting the neurovascular bundle behind the FHL (Fig. 4J). The authors found that it was not necessary to completely expose the entire subtalar joint. Although the subtalar joint was exposed and debrided, the bone cut was made through the calcaneus as close to the joint as possible in order to medially translate the tuberosity (Fig. 4K). A small bialar wedge was removed from the talonavicular joint, permitting adduction and slight plantar flexion of the foot through the talonavicular joint (Fig. 4L). The intraoperative
Fig. 4. A 16-year-old girl presented with a severe bilateral rigid flatfoot deformity. Note the profound bilateral hindfoot valgus both from the anterior (A) and posterior views (B). A decision to treat the right foot first was made. Lateral (C) and anteroposterior (D) radiographs, and sagittal (E) and coronal (F) plane CT scan showed the presence of a tarsal coalition and a severe deformity of the talonavicular joint. A medial closing wedge supramalleolar osteotomy was performed first to correct the marked valgus deformity of the ankle joint (G) and a plate applied (H). To correct the hindfoot valgus, a percutaneous tenotomy of the peroneus brevis was performed laterally (I), and then a double arthrodesis of the talonavicular and subtalar joints was done through a medial approach. While doing the subtalar joint arthrodesis through a medial approach, by retracting the FDL dorsally and the FHL inferiorly (J), the subtalar joint can be identified easily with protecting the neurovascular bundle behind the FHL (K). A small biplanar wedge was removed from the talonavicular joint permitting adduction and slight plantar flexion of the foot through the talonavicular joint (L). Intraoperative radiographs showed the ankle was in a neutral positions (M). The slight rounding of the edges of the talus and medial malleolus can be appreciated, confirming the presence of a slight ball-and-socket ankle joint (M). The final lateral radiograph at 8 weeks after surgery showed very good correction, arthrodesis, and restoration of the arch. Note the markedly improved talar declination angle as well as the calcaneal pitch angle (N).
radiographs of the ankle are presented with the ankle in a neutral position. The slight rounding of the edges of the talus and medial malleolus confirming the presence of a slight ball-and-socket ankle joint (Fig. 4M) can be appreciated. The final lateral radiograph at 8 weeks after surgery is presented, noting very good correction, arthrodesis, and restoration of the arch. Note the plantar translation of the calcaneus tuberosity, which markedly improved the talar declination angle as well as the calcaneal pitch angle (Fig. 4N).

EQUINUS DEFORMITY

The patient in Fig. 5 was a young man who suffered a knee injury and a complete peroneal nerve palsy with a resulting foot drop and eventual fixed contracture of the entire foot 6 months later. The authors had the opportunity to treat him 9 months after his injury and he was unable to ambulate, stand, or wear a shoe (Fig. 5A, B). On examination, there was no movement in the ankle whatsoever, and it was not clear on examination if there was any function of the deep posterior compartment of the lower leg. In a case like this, where there is no movement whatsoever, it is difficult to determine if there is any function of the posterior tibial muscle or if the tendon and or muscle is scarred. In other circumstances, an MRI of the leg may be able to be obtained and the muscle evaluated for fatty infiltration and atrophy, but these were not possible in this location. Therefore, the authors had to anticipate numerous alternative procedures for correction, which would include a TTC arthrodesis, a talectomy and tibiocalcaneal arthrodesis, or, if sufficient elongation was present after lengthening of the Achilles tendon, restoration of dorsiflexion function with tendon transfers. If a PTT transfer were performed, it could function either as a dynamic transfer or as a tenodesis to maintain the position of the foot. In this case, ultimately there was mobility of the PTT and it had to be assumed that some muscle function would be present and a PTT transfer through the interosseous membrane was performed.

At surgery, a posterolateral incision was used, which was versatile enough to be changed to any of the procedures discussed previously. An Achilles tendon lengthening was performed rather than a tenotomy. The reason for this choice was that in the event that a neutral foot was attained, after a PTT transfer to the dorsum of the foot, overactivity of dorsiflexion could occur and, in the presence of an absent gastrocnemius, it would cause a calcaneus deformity. It was not necessary to perform a posterior ankle capsulotomy. After the Achilles tendon release, however, a neutral foot was attained, which produced severe contractures of the hallux and lesser toes, as seen in Fig. 5C. The contractures were only in the long flexor tendons and not associated with contractures of the MP joints, that is, the short flexors and intrinsic muscles. Therefore, simple tenotomies of the tendons were performed percutaneously under the interphalangeal joints. Once a neutral foot had been obtained, mobility of the PTT was checked. There was no scarring of the tendon and some mobility was noted, and the authors assumed that some muscle function remained, but as discussed previously, it was difficult to determine preoperatively. A PTT transfer then was performed through the interosseous membrane (Fig. 5D). Despite the flexor tenotomies, there was still a slight lag at the MP joints as a result of the weakness of the toe extensor muscles. For this reason, a transfer of all of the long toe extensors (a Hibbs procedure) was performed to the midfoot (Fig. 5E) but only to serve as a tenodesis to help prevent the toes from dropping in flexion. The outcome of the procedure can be seen in Figs. 5F and 5G at 6 weeks after the surgery, and the patient was walking at 3 months with a plantigrade foot and managing well without a brace (Fig. 5H).
An active tendon transfer is used when there is sufficient muscle strength to use which is at least grade 4, so that the tendon can be placed in a new location to strengthen the weak/dysfunction muscle. Moreover, this is also based on the flexibility of the involved joint(s). In the presence of a flaccid paralysis of the limb, where the muscle function is not present, the authors can use the muscle and the tendon as a static sling structure by doing a tenodesis to help with maintaining a plantigrade foot. Although in the long run a tenodesis may fail due to stretching, it does have some role of preventing a drop foot.

CAVOEQUINUS

Equinus deformity refers to excessive fixed plantarflexion of the ankle beyond a neutral position and can be caused by a weak anterior tibial muscle, bony factors such as a vertical talus, or overactive triceps surae or for iatrogenic reasons, such
as malposition of an ankle or tibialtalocalcaneal fusion. If it is a real equinus deformity at the level of the ankle, is a cavus deformity, or is both needs to be differentiated, because the equinus may exist only in the forefoot with a neutral hindfoot and ankle, for example, after a TTC arthrodesis. Lateral radiographs of the ankle and foot are more helpful in diagnosis than judging only from physical examination because the apex of the deformity rarely can be appreciated clinically. Sometimes even radiographs, however, also are misleading. One way to determine the apex of the deformity and differentiate a cavus from an equinus is to evaluate the deformity by covering the hindfoot, midfoot, and forefoot separately (Fig. 6).

The authors present a 52-year-old woman with a severe cavoequinus deformity, the result of poliomyelitis. The predominant deformity is of course the equinus contracture, but a severe midfoot cavus also is present (Fig. 7A–D). This type of deformity poses significant challenges for planning correction. The equinus contracture was completely rigid, and the possibility of performing a TTC arthrodesis, a talarctomy and tibiocalcaneal arthrodesis, or other procedures as necessary to correct the equinus deformity had to be anticipated. Due to the magnitude of the contracture, it was not possible to determine if there were any functioning muscles present in the lower extremity. For this reason, combining the ankle realignment with a dynamic tendon transfer could not be planned. The goal, therefore, had to be skeletal realignment, which had to focus not only on correction of the equinus deformity but also on the midfoot cavus and the hyperextension of the toe MP joints.

Because position of the foot after tenotomy of the Achilles tendon and other flexor tendons could not be anticipated, a transfibular approach was used to the ankle and subtalar joint as well as the soft tissues posteriorly. In Fig. 7E, that there is no incision posteriorly over the Achilles tendon. This is consistent with the authors’ approach for managing severe equinus deformity with the tendon cut from inside to avoid any gapping of the skin with correction of the deformity. After the Achilles tenotomy,
the remaining tendons, including the peroneals, posterior tibial, FHL, and flexor digitorum longus, were cut percutaneously. The subtalar joint was prepared using a sharp osteotome, and the ankle joint using a saw followed by realignment of the hind foot and ankle and intramedullary fixation. This corrected the equinus deformity very well, but the midfoot cavus remained, and this was addressed using an anterior and central incision over the midfoot, where a midfoot wedge was removed from the navicular cuneiform joint. The final clinical appearance of the foot is indicated in Fig. 7F. It is curious that in this case, after correction of the deformity, there was no significant contracture of the flexor tendons causing a fixed claw toe deformity. This most likely was due to the hyperextension that existed preoperatively from chronic weight bearing on the forefoot with hyperextension of the MP joints. On the radiographs (Fig. 7G, H), the talus has been intentionally translated anteriorly. If the talus had been centered directly under the tibia, the intramedullary rod would
be inserted far anteriorly in the neck of the calcaneus, which could cause difficulties with fixation into the calcaneus. The appearance of the foot at 3 months after surgery is shown in Fig. 7I and J. She had a stable arthrodesis of both the hindfoot ankle and midfoot, had very nicely aligned toes, and was able to ambulate quite comfortably in a shoe, here barefoot.

**VALGUS DISLOCATION OF THE HINDFOOT**

A 62-year-old patient with rheumatoid arthritis had previously undergone a TTC arthrodesis. Although an arthrodesis of the ankle had been obtained, a nonunion with a complete dislocation of the subtalar joint as well as the talonavicular joint was present (Fig. 8A, B). The rod was protruding inferiorly and the patient bearing weight on the medial aspect of the foot, which was extremely painful. The foot was markedly deformed and fairly rigid (Fig. 8C). The decision making was how to approach restoration of the alignment of the foot given the rigidity of the deformity, the condition of the skin medially and laterally, and the potential for wound-healing problems if a lateral approach was used. A decision, therefore, was made to use an all medial approach to correction of the deformity, as demonstrated in Fig. 8D. Once the rod had been removed, it was easy to demonstrate the subtalar dislocation and the mobility of the subtalar joint into valgus, as seen in Fig. 7E. Using the medial approach to the subtalar joint, débridement and preparation of the joint were performed until the heel was in a neutral position (Fig. 8F). From here, there was the ability to focus on the talonavicular dislocation by removing a large wedge from the talonavicular joint medially using a saw (Fig. 8G). The foot was now quite plantigrade and in a neutral position both in the hindfoot and midfoot (Fig. 8H, I). Fixation of the TTC and the talonavicular arthrodesis was accomplished the use of a combination of screws and 3-mm pins (Fig. 8J).

In such a case of severe hindfoot valgus deformities, preoperative surgical approach planning to get access to subtalar joint is critical to the success of the surgery. Surgeons must realize that the conventional lateral approach limits the capability of deformity correction and can add the risk of wound-healing problems. Using the single medial approach is a much safer and an easier option for preparing both the subtalar joint and the talonavicular joint and taking out a medially based wedge in order to correct severe midfoot abduction.49–53 According to extensive literature reports, the medial approach has been used successfully in patients with high risk of wound complications, such as diabetes, rheumatoid arthritis, a severe deformity with contracted lateral skin, and soft tissue.54–56

Concerns with regard to the single medial approach for double or triple arthrodesis include the ability of exposing the subtalar joints, the union rate, possible risk of medial tendons and ligaments injury, vascular disruption of the talus and subsequent talar osteonecrosis, and so forth. Widnall and colleagues57 modified the approach described previously by Jeng and colleagues.51 Through an incision parallel to and just above the PTT running from just posterior to the medial malleolus to just distal to the navicular bone, using the sustentaculum tali as a bony landmark, access to both the middle and the posterior facets of the subtalar joint and the talonavicular joint could be achieved with retention of the PTT, the tibiocalcaneal ligament, and the spring ligament. A cadaveric study demonstrated that the medial neurovascular bundle was 21 mm from the medial approach.58,59 Another cadaveric investigation found that both the single medial incision approach and the traditional 2-incision approach could result in substantial disruption of the main blood supply to the talus. Necrosis of the talus has not been reported, however, in medial incision–approached
Jeng and colleagues\textsuperscript{50} reported that in performing a triple arthrodesis through the single medial incision, more than 90% of both subtalar and talonavicular joints could be prepared, and even 90% of the calcaneocuboid joint also could be accessed, which was comparable to the standard 2-incision approach for a triple arthrodesis. According to Brilhault’s\textsuperscript{55} cohort study in 14 feet with very high risk of lateral wound breakdown, at an average of 20 months’ follow-up, the investigators had found significant radiographic correction and no wound complications. The literature also reported comparable union rate\textsuperscript{52,60} and deformity correction capability\textsuperscript{61} of the double arthrodesis through a medial approach to a hindfoot fusion.\textsuperscript{60}

Fig. 8. A 62-year-old patient with rheumatoid arthritis presented with a nonunion with a complete dislocation of the talonavicular joint (A) as well as the subtalar joint (B) after an attempted previous TTC arthrodesis. Note the rod was protruding inferiorly (B). The foot was markedly deformed, and fairly rigid (C). Given the rigidity of the deformity and the potential for wound-healing problems, if a lateral approach was used, an all medial approach was chosen to correct the deformity (D). Using the medial approach to the subtalar joint (E), the débridement and preparation of the joint were performed until the heel was in a neutral position (F). Then, the talonavicular dislocation was addressed by removing a large wedge medially using a saw (G). The foot was now quite plantigrade (H), and in a neutral position both in the hindfoot and midfoot (I). Fixation was accomplished by the use of a combination of screws and 3-mm pins (J).
SUMMARY

The severe foot and ankle deformities that the authors’ organization has encountered in different humanitarian programs worldwide are much more complicated than those surgeons treat in their daily practice in developed countries. In a humanitarian program, various factors, including the severity of the deformity, the patients’ economic limitations, patients’ expectations and realistic needs in life, availability of surgical instrumentation, the local team’s understanding of foot and ankle surgery and their ability to do continuous consultation for patients postoperatively, and compliance of the patients all account for the success of the surgery. Detailed communication with the local orthopedic team, patients and their families, and within the medical care delivery team is critical. Because most of the surgeon volunteers themselves are from many parts of the world, however, the huge cultural differences between the surgeons and the patients always make the surgery more challenging than just a deformity correction. Under these circumstances, following basic rules of deformity correction, such as always addressing both soft tissue imbalance and bony malalignment whenever necessary and choosing classic surgeries, such as arthrodesis with high reliability, are the key points. On the one hand, successful treatment always is incredibly rewarding for both the caregivers and the patients. On the other hand, regardless of how much effort surgeons have made, complications and recurrence still occur, in particular among the patients treated when essential continuous follow-up is limited for various reasons. Therefore, educating and training the local surgeons to take over the future medical care are the most important goals of the authors’ global humanitarian programs.

REFERENCES


