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The Neglected Clubfoot

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Summary: The neglected clubfoot deformity is a major disabler of children and adults in developing nations. The bones and joints of the foot deform into fixed equinus, adductus, cavus, and supination as patients walk on the side or dorsum of the foot. There is severe obliquity of the calcaneocuboid joint, which must be corrected in most cases. An algorithmic surgical approach, using peritalar soft tissue release and selected midfoot osteotomies, corrects most deformities. In severe cases, a specific form of modified Lambrinudi triple arthrodesis is required, excising large bone wedges from the anterior process of the calcaneus. The Ponseti method of serial casting is proving applicable to developing countries in reducing the burden of disability. In developing nations, combining surgical outreach with existing community-based rehabilitation programs will improve outcomes. **Key Words:** Clubfoot—Triple arthrodesis—Ponseti—Calcaneo-cuboid joint.

The neglected clubfoot deformity is a problem of poorer developing countries. It is the most common congenital problem leading to locomotor disability. Approximately 80% of children born with a clubfoot deformity are born in the developing world, and the large majority of these do not have access to appropriate medical care. The obstacles of poverty, lack of awareness, and lack of appropriate medical resources in accessible locations mean that treatment is either not initiated or incompletely performed.

The orthopaedic literature on clubfoot deformity focuses on early intervention in a resource-rich environment, with numerous surgical options outlined for both primary treatment and treatment of the relapsed clubfoot.[7,9] There is very little literature available on treatment of the neglected clubfoot with major texts providing little more than anecdotal reference to triple arthrodesis as a salvage.

Orthopaedic surgeons visiting countries in the developing world for volunteer or teaching assignments cannot help but be struck by the large numbers of children seen, the product of high birth rates in most developing countries, and the large numbers of children with neglected clubfoot deformities presenting to outreach clinics. Deciding how to manage and treat these children, therefore, becomes a significant challenge. The purpose of this article is to provide a practical algorithmic approach developed by the author over a 6-year span of full-time work in Uganda, East Africa, while developing a Children's Orthopaedic Rehabilitation Project. During this time, more than 500 surgical procedures were performed for neglected clubfoot deformities. Most of the surgical procedures can be accomplished with basic surgical instruments in the low-technology environment of the developing world.

RELAPSED VERSUS NEGLECTED CLUBFEET

The Western literature focuses its attention on the treatment of relapsed clubfeet.[9] These are feet that have had early intervention, usually just after birth, with serial casting or surgery. Relapses may then occur as a result of incomplete initial correction or inadequate attention to long-term splinting. Relapses may also occur during growth spurts. In all relapsed clubfeet, a large degree of initial correction is achieved and subsequent deformity tends not to be as severe as in neglected clubfeet. Usually, the child is still walking on the sole of the foot and is able to wear shoes, although deforming them out of shape. There may be associated iatrogenic deformities.

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FIG. 1. Bursa and thickened skin over the weightbearing dorsolateral side of the foot.

The neglected clubfoot, however, is one in which there has been no initial treatment or perhaps very inadequate and incomplete initial treatment. The deformity is made worse at the time the child starts to walk because weightbearing takes place on the side or dorsum of the foot, exaggerating the abnormal shape and causing further deformation. The contracted soft tissues on the medial side of the foot are encouraged to contract further. The bones are compressed unnaturally at a time when they are plastic and deform into abnormal shapes. Bones that normally support the arch of the midfoot now bear axial load, which they were never intended to do. The sole of the foot never experiences proper weightbearing, and it is impossible to wear normal shoes. A thickened callous and large bursa develop over the prominent weightbearing head of the talus on the dorsolateral side of the foot, often associated with deep fissures, which are vulnerable to breakdown and infection (Fig. 1).

PATHOLOGIC ANATOMY

The primary contractile forces of the soft tissues in clubfoot deformity result in progressive bony deformity. These primary soft tissue and bony deformities have been well described in the dissections of Ponseti [28] and in the magnetic resonance imaging studies of Pirani.[27] The neck of the talus develops a medial angulation and the head of the talus becomes conical in shape. The navicular bone articulates with the medial aspect of the head of the talus and becomes wedge-shaped. The calcaneocuboid joint becomes oblique with medial subluxation of the cuboid on the calcaneus. The subtalar joint is held in its maximal position of supination (plantar flexion, inversion, and adduction). Early manipulation and cast treatment using the Ponseti technique shows cartilage remodeling back toward a normal anatomic appearance.[27] If the deformity persists as a neglected clubfoot, bony deformity becomes more entrenched because there is progressively less ability to remodel. Therefore, the neglected clubfoot shows all of the neonatal elements reflected in the osseous structure. There is significant bony deformity in the neck and head of the talus, shape of the navicular, subluxation of the cuboid, and dramatic obliquity of the calcaneocuboid joint (Fig. 2). Soft tissue release alone cannot fully restore bony anatomy, and the relapse rate in the older child with a neglected clubfoot will be high because of the tendency of the bones to revert to their deformed position. Of particular importance is the obliquity of the calcaneocuboid joint, and surgical procedures on the neglected clubfoot must address this bony incongruency as a primary consideration (Figs. 3 and 13B)

FIG. 2. Anterior–posterior radiograph of the ankle and foot showing marked obliquity at the calcaneocuboid joint, subluxation of the navicular on the head of the talus, and wedge-shaped head of talus.

FIG. 3. Coronal three-dimensional computed tomography scan in an 8-year-old boy with neglected clubfoot. Note the calcaneocuboid obliquity.

PATTERNS OF DEFORMITY

There is a spectrum of severity of clubfoot deformity right from birth. Although all the elements of equinus, rearfoot varus, cavus, and forefoot adductus are present, each of these will contribute variably to the deformity; this results in numerous combinations and degrees of deformity and stiffness. These patterns will be reflected as the foot grows. Even after many years of neglected deformity, degrees of flexibility can be retained in the foot. The more the intrinsic flexibility, the less severe the ultimate deformity. A basic clinical classification can be used based on physical examination:

1. Moderately flexible: The foot can be considerably corrected in some cases to neutral position.
2. Moderately stiff: There is some correctability, but not to neutral position and with moderately severe deformity persisting.
3. Rigid: There is almost no correction possible with severe deformity persisting.

These clinical features can be applied both to the midfoot and the rearfoot. In younger infants, the clinical classification systems of Dimeglio or Pirani are useful for this assessment.[8,26]

The degree of fixed cavus will determine how the child walks. If the cavus is not severe, or is flexible, the child will tend to walk on the lateral border of the foot with the forefoot still facing forward (Fig. 4). With large degrees of fixed cavus deformity, the foot may face backward (Fig. 5). In both clinical scenarios, the degree of equinus of the rearfoot is not readily apparent when standing but becomes obvious when the forefoot adductus is corrected. Dramatic and fixed equinus remains the most problematic of the clubfoot deformities to correct at all ages and degrees of neglected deformity (Figs. 6 and 13A).

THE DISABILITY OF NEGLECTED CLUBFOOT DEFORMITY

Children with a neglected clubfoot deformity do learn to walk without the use of crutches or walking aids. They can often run over short distances. Is it warranted, therefore, to consider surgical intervention in these children? Qualitative research in Uganda indicated that the neglected clubfoot deformity was indeed a significant disability for village children, preventing access to education and other social activity.[24] The stigma is a very obvious one and children are often considered cursed or unworthy of advancement in education or social status. There is pain and difficulty with locomotion over longer distances. The pain occurs primarily in the skin and subcutaneous tissues on the dorsum of the foot. There is also abnormal pressure distribution across the midtarsal joints and through the malaligned ankle joint causing pain. Recurrent skin breakdown with infections is not uncommon in the skin bearing weight on the dorsal and

FIG. 4. A moderately flexible forefoot results in the child walking on the lateral side of the foot.

FIG. 5. A rigid foot with significant cavus results in the child walking on the dorsum of the foot.

FIG. 6. Lateral radiograph of the ankle and foot showing marked rearfoot equinus and midfoot cavus.

lateral aspect of the foot. Severe ulceration in adults can lead to amputation. There is an inability to wear footwear, which aggravates all of the previously stated problems. The objective of obtaining a plantigrade foot that can fit shoes is worthwhile even if feet do not have normal mobility or shape, or have some degree of residual pain. Success of treatment of the neglected clubfoot can be evaluated by two primary indicators: weightbearing on the skin of the sole of the foot and the ability to wear normal shoes. Yadav has reported 87% acceptable results using these criteria.[34]

THE PONSETI METHOD OF CLUBFOOT TREATMENT IN DEVELOPING COUNTRIES

Since 1996, the Ponseti method of serial casting has gained dramatic popularity in developed countries and has been shown to be effective in treating all components of clubfoot deformity in more than 90% of babies. [6,14] As experience with the technique has grown, its applicability to treating late presenting or neglected clubfeet has been considered. The Ponseti method is a very specific method of clubfoot manipulation and casting, percutaneous tenotomy of the Achilles tendon, and a specific and prolonged follow-up program with a foot abduction brace. The technique is well described elsewhere.[28,31] Because it does not require significant technology or surgical expertise, this technique would seem very appropriate for underdeveloped nations. Extensive trials of the technique have been undertaken in Uganda and Malawi and have been shown to be successful where patients have completed the treatment program.[31] These trials have been accompanied by a national public health awareness campaign, which increases awareness of the clubfoot deformity and encourages early treatment. The problem of long-term inexpensive foot abduction bracing has been solved by developing low-cost braces fabricated using locally available materials and by training artisans in their fabrication.[31,32] Moreover, the technique has been proven successful in the hands of nonphysicians. Training programs in these two African countries have targeted orthopaedic officers, specialized clinical assistants who staff regional and upcountry hospitals in closer proximity to rural populations than the specialized centers. More than 150 have been trained to date. A significant component in the success of the clubfoot early intervention program has been community-based rehabilitation (CBR).[25] CBR projects are well suited to case finding, awareness raising, mobilization, and follow up of children with clubfeet and other physical disabilities.

Widespread implementation of the Ponseti technique in countries of the developing world has the potential to dramatically impact the incidence of neglected clubfoot deformity in their populations. Although Uganda and Malawi are the only countries to date who have implemented national strategies, training programs have been undertaken in numerous countries in Africa, Central and South America, and Asia.

There are anecdotal reports of children with neglected clubfeet up to 2 years of age, or even older, who have been corrected by the conservative means of the Ponseti technique.[22] The upper age of usefulness of the technique is not known, but it is likely that the technique is particularly useful in children who have a more flexible clubfoot deformity with considerable osseous remodeling potential. As the technique has taken hold in Africa, the need for open soft tissue release has diminished dramatically in children under 2 years of age. Percutaneous tenotomy of the tendo-Achilles under local anesthesia is the only operative intervention required. Sengupta, in Calcutta, has reported on the use of isolated percutaneous Achilles tendon and plantar fascia release

followed by serial casting in large numbers of children up to walking age having neglected clubfeet.[30]

There is obviously a significant role for corrective casting in newborns and young infants with clubfeet. In Uganda, it was found useful to apply serial casts before surgical correction in *all* children up to age 12 with clubfeet. Casting allowed for stretching of the contracted tissues and skin on the medial side of the foot, reducing the risk of postoperative skin necrosis. Some correction of the bony deformity was achieved, minimizing surgical resections. Protecting the skin in casts allowed for healing of ulcers and fissures in the callus on the dorsolateral side of the foot. Preliminary casting, however, requires supervision in rehabilitation facilities. This is often not possible in rural upcountry outreach surgical situations.

GENERAL CONSIDERATIONS

The treatment of the neglected clubfoot is largely surgical. The dilemma in the developing world is the large number of cases presenting with an extreme shortage of skilled surgeons. These surgeries are difficult and time-consuming; postoperative care is prolonged and requires access to bracing. There are difficulties with limited anesthesia technology. It is preferable to delay surgery until a child is at least 9 months of age because anesthesia is safer. It is also better to avoid prone positioning on the operating table to make anesthetic monitoring easier. Malnutrition, anemia, and chronic diseases such as malaria are common. Children live in unhygienic circumstances and the skin of the foot is often ulcerated or infested with parasites. A preliminary admission to hospital or a rehabilitation unit is useful to allow for nutrition priming and treatment of skin lesions. Children are kept bedbound for 24 hours before surgery and washed frequently to ensure cleanliness of the skin. In bilateral cases, it is usually best to do both feet at one sitting as a result of transportation and follow up difficulties in rural environments. This might be the child's only opportunity for correction. The use of pins and internal fixation devices in upcountry outreach situations may be compromised because of concerns for infection and pin care after the surgeons have left. CBR projects offer the best support in postoperative care and follow up.

ALGORITHMIC APPROACH TO SURGICAL TREATMENT OF THE NEGLECTED CLUBFOOT

There is no single surgical procedure that can resolve all clubfoot scenarios. A full armamentarium of procedures must be at the ready. What is presented here is an algorithmic approach to the neglected clubfoot that has proved useful in the low-technology environment of East Africa (Fig. 7). Depending on age, severity and degree of flexibility, there is a progression from soft tissue surgery alone through soft tissue release combined with midfoot osteotomies to osteotomy and arthrodesis in isolation. Many times, decisions have to be made in the operating room during the case. Age is not necessarily a predictor of the type of surgery; pattern of deformity and intrinsic flexibility are more important.

Soft Tissue Release

This is the most common surgical procedure in younger children up to approximately 4 years of age. In children older than this, osteotomies are often required as well. Soft tissue releases follow established guidelines in standard orthopaedic publications and are well described.[7] The pathologic contracted connective tissues on the medial, posterior, and lateral sides of the foot and ankle are released or lengthened. Occasionally, with the use of preoperative serial casting, only a posterior release is required in more flexible feet. Posterior release involves release of the posterior capsule of the ankle and subtalar joint as well as open Achilles tendon lengthening.

More resistant cases with midfoot adduction and cavus require medial lengthening as well. The initial landmarks for the dissection are the Achilles tendon posteriorly and the abductor hallucis anteriorly, with the neurovascular bundle between. The neurovascular bundle must be carefully exposed and protected throughout the subsequent dissection. This usually consists of complete release of the posterior and medial subtalar joint capsule (leaving the interosseous ligaments intact), talonavicular joint capsulotomy (including the spring ligament and bifurcate Y ligament), medial calcaneocuboid joint capsulotomy, release of the knot of Henry, sectioning of the abductor hallucis, and lengthening of posterior tibial tendon. The flexor hallucis longus and flexor digitorum longus can usually be left because they will stretch postoperatively, but occasionally these need lengthening as well. The lateral tether should be sectioned, releasing the lateral subtalar joint capsule, peroneal tendon sheath, and calcaneofibular ligament. The plantar fascia should be sectioned in the interval behind the lateral branch of the posterior tibial nerve to treat any residual cavus.

This surgical procedure can be carried out through the Cincinnati incision or by a two-incision technique. In the more severely involved foot with significant equinus, the Cincinnati incision has its limitations in that closure of the posterior incision will not be possible, or if closed, the foot will have to be left in an uncorrected position and followed up with remanipulation. It has been shown,

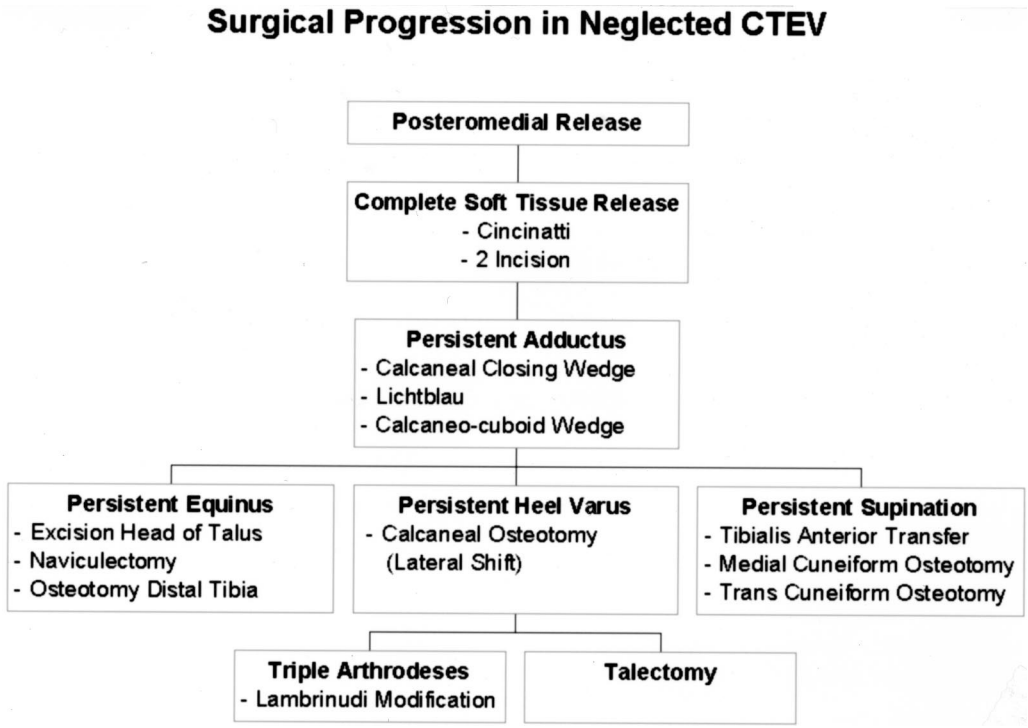

FIG. 7. Algorithm of neglected clubfoot surgery.

however, that clubfoot incisions left widely open do epithelialize successfully without the need for secondary wound closure or skin grafting.[13] In resource-poor environments, the prone positioning necessary for the Cincinnati technique creates potential anesthetic difficulties with inability to adequately control the airway when patients are not intubated, the predominant form of anesthesia being intramuscular ketamine. The preference in Uganda was a two-incision technique, with the medial incision being a straight oblique incision from the first metatarsal, across the medial malleolus to the Achilles tendon (Fig. 8). A second short, straight lateral incision was made along the lateral subtalar joint above the peroneal tendons and just in front of the distal fibula. By extending this incision a small amount, the distal calcaneus and calcaneocuboid joint is easily exposed if lateral shortening osteotomy is found necessary (Fig. 9).

The talonavicular joint, often with the subtalar joint, is routinely pinned with a K-wire in most descriptions of complete subtalar joint release. Where adequate supervision is available, the use of pins does allow for postoperative splinting in an undercorrected position to allow the skin to heal without relapse of bony position. In most operations performed in Uganda, we did not use pins. Often they were not available and there were concerns regarding pin care postoperatively in upcountry locations where surgeons were not necessarily available for follow up. Intraoperative radiographic confirmation of position was not available. We relied instead on careful postoperative cast management to maintain position. In a small comparative study performed in Uganda, no difference could be found at follow up between patients pinned and not pinned. There was, however, a higher incidence of

FIG. 8. A straight medial incision gives wide exposure. A complete soft tissue release has been performed, exposing the subtalar joint but leaving the talocalcaneal interosseous ligaments intact.

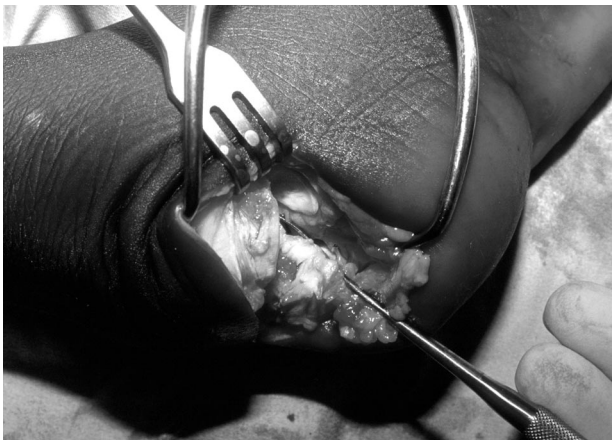

FIG. 9. Straight lateral incision gives exposure to the lateral tether, head of the talus, subtalar joint, and calcaneocuboid joint. The probe is in the oblique calcaneocuboid joint.

wound complications, specifically medial wound breakdown, in the unpinned group indicating excessive stretching of skin in corrective plasters.[3]

Lateral transfer of the tibialis anterior tendon is usually reserved for relapse after corrective cast management, usually after age 2 years once the lateral cuneiform has begun to ossify.[31] Because many children in poorer environments present for soft tissue release at an older age, consideration should be given to tibialis anterior transfer at the index procedure. This helps control any residual forefoot supination. It might also reduce the risk of relapse and dependency on lengthy postoperative abduction bracing protocols. The tibialis anterior tendon attachment to the first metatarsal and medial cuneiform is easily accessible through the standard medial incision used for soft tissue release. A proximal incision is not necessary. A separate small incision is necessary over the lateral (third) cuneiform. The tendon is implanted into a drill hole with sutures tied over a button on the sole of the foot.

Correcting Residual Adductus

Soft tissue release alone may not fully correct the deformity because of secondary bony deformity. If this is not addressed at surgery, the foot will not only be left incompletely corrected, but will relapse. The combination of this soft tissue release with midfoot osteotomy is usually required in children between approximately 4 and 12 years of age with neglected clubfeet. The bony lateral column is longer than the medial column, resulting in midfoot adductus. Shortening osteotomy through the lateral column is required and should occur through the calcaneus or calcaneocuboid joint. The primary bony pathology is obliquity of the calcaneocuboid joint and relative lengthening of the lateral portion of the anterior process of the calcaneus. Shortening should therefore occur through the distal calcaneus with an attempt to make the calcaneocuboid joint transverse. Alternatives include closing wedge osteotomy through the anterior process of the calcaneus leaving the articular surface intact, excision of the anterior process of calcaneus (Lichtblau procedure), or calcaneocuboid wedge resection (Dilwynn-Evans procedure).[12,21] Correction through the cuboid is not indicated because this does not address the primary pathology. In younger children, the Lichtblau procedure adequately shortens the lateral column and allows for a pseudoarthrosis to develop after remodeling. This potentially allows for more subtalar joint and midfoot motion than a calcaneocuboid arthrodesis. In older children, more correction can be achieved by doing a calcaneocuboid wedge excision, and the arthrodesis so performed may act as an epiphysiodesis to improve foot position with growth. Arthrodesis of this joint also potentially reduces the risk of relapse by providing a permanent solution but is associated with more potential stiffness of the subtalar and midfoot articulations. Where calcaneocuboid wedge excision is done, internal fixation may or may not be performed, depending on availability and surgeon preference.

The combination of radical soft tissue release and calcaneal shortening osteotomy is the most common operative procedure required in children between ages 4 and 11, giving satisfactory results in the majority of cases (Fig. 10).

Correcting Residual Equinus

It is not uncommon to perform a full soft tissue release in younger children only to find that the equinus deformity is not fully corrected. In this circumstance, the first thing to check is adequacy of release of the lateral tether, consisting of the posterolateral subtalar joint capsule, peroneal tendon sheath, and the calcaneofibular ligament. These structures have been shown to be critical to obtaining dorsiflexion.[29] If equinus deformity persists, the next step is lateral column shortening. Calcaneal shortening is usually recommended to correct midfoot adductus and the bean-shaped foot. Occasionally, however, it is required to correct equinus. Lateral column shortening allows a little more dorsiflexion through the midtarsal joint, although it does so by creating a mild rocker-bottom foot. In very severe cases, even these steps may not allow adequate dorsiflexion. This is usually the result of impingement of the navicular against the head of the talus. Consideration must then be given to excision of a portion of the head of the talus or to

FIG. 10. (**A** and **B**) Good result after soft tissue release and calcaneocuboid wedge excision.

naviculectomy. These procedures are seldom required but on occasion become necessary. Excision of the head of the talus, although helping correct deformity, leads to considerable stiffening of the subtalar and midfoot joints. Naviculectomy has been described in the treatment of congenital vertical talus and has the advantage of providing a smooth articulation at this joint with the potential for more midfoot motion after remodeling.[4] The cupped articulation of the medial two cuneiforms is fairly congruous with the head of the talus. An attractive approach in the younger patient with severe deformity, but when maintaining range of motion is a priority, is to perform a Lichtblau excision of the anterior process of the calcaneus and a naviculectomy. Remodeling produces a customized midtarsal joint. Multiple metatarsal osteotomy might be considered when there is a significant cavus contribution to equinus. A final resort is to consider adding a distal tibial dorsiflexion osteotomy.

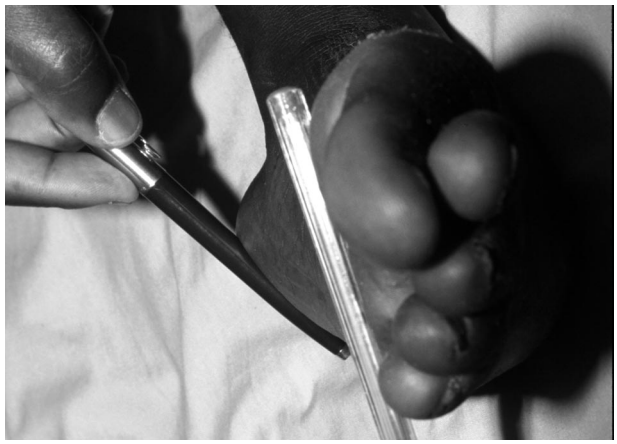

FIG. 11. Forefoot supination with reference to the rearfoot, secondary deformity from walking on a neglected clubfoot.

Correcting Calcaneal Varus

Rarely, after adequate midfoot osteotomy, there is residual varus of the calcaneus. In general, calcaneal varus (calcaneal inversion) corrects as the foot abducts after medial soft tissue release. For persistent calcaneal varus, a lateral slide osteotomy of the calcaneus is performed.[19] The osteotomy is best done through the medial incision, retracting the neurovascular bundle anteriorly to protect it. The calcaneus is cut obliquely and shifted laterally approximately 1 cm. Pin or screw fixation through the calcaneus is required. The alternative is a Dwyer lateral closing wedge osteotomy performed through the lateral incision.[11]

Correcting Forefoot Supination

Persistent forefoot supination usually happens in association with calcaneal varus and is most prevalent in previously operated patients in whom the deformity can be rigid. The more flexible forefoot supination seen in neglected clubfeet that have had no surgery usually corrects adequately with soft tissue release and calcaneal shortening. The neonatal clubfoot invariably exhibits forefoot pronation in reference to the rearfoot. With walking, and if the cavus deformity is not severe, the malleable tarsal bones are compressed and molded into supination as the child bears weight over the lateral border of the foot (Fig. 11). Treatment of more flexible supination is lateral transfer of the tibialis anterior tendon to the lateral (third) cuneiform. This a standard procedure for dynamic supination after successful cast treatment.[28] As experience with neglected clubfoot surgery was gained in Uganda, the threshold for performing a tibialis anterior transfer dropped, both to correct supination and to reduce the risk of relapse after soft tissue release when brace compliance was questionable.

For rigid supination deformity, a complete midfoot osteotomy is performed after the lateral shortening procedure is completed. When the deformity is not severe and where the bones are of sufficient size, a plantar closing wedge osteotomy of the medial cuneiform is done. For more severe degrees of deformity, the osteotomy is carried transversely through all the cuneiforms freeing up the forefoot from the rearfoot. The forefoot can then be pronated on the rearfoot and fixed with pins. This is a difficult correction to achieve. These osteotomies may also be combined with transfer of the tibialis anterior tendon.

Triple Arthrodesis

Triple arthrodesis is a versatile procedure used to correct major deformities in children. In the developed world, triple arthrodesis is used primarily as a salvage procedure for pain after previous surgical correction.[9] In the developing world context, with reference to neglected clubfeet, the procedure has its versatility in correction of large degrees of deformity. In severe deformity, particularly with marked cavus when the foot is facing backward, soft tissue release and osteotomy is unlikely to achieve full correction (Fig. 5). In this case, triple arthrodesis can be very useful. Conventional orthopaedic wisdom recommends triple arthrodesis not be performed before advanced skeletal maturity, at age 10 to 12, to avoid growth retardation by removal of cartilage involved in enchondral ossification. However, I have used triple arthrodesis in children as young as age 6 and have not seen adverse growth characteristics. Moreover, discrepancy in the size of the feet is seldom more than a cosmetic nuisance and in bilateral cases not relevant. Although triple arthrodesis has been recommended as a treatment for the neglected clubfoot in standard texts, insufficient detail is given as to the precise method of performing the arthrodesis. In neglected clubfoot, a specific method of arthrodesis is required with particular reference to correction of equinus. A modification of the classic Lambrinudi triple arthrodeses, originally described for polio equinus deformity, is necessary.[20] In general, resection through the talus should be minimized because of its tenuous blood supply and most of the correction made through the calcaneus. The calcaneus is rich in blood supply with ample bone allowing for large wedge excisions for correction.

The Technique of Triple Arthrodesis

A standard oblique Ollier-type incision is made on the lateral side of the foot and the extensor digitorum brevis shelled out sharply from the sinus tarsi. The calcaneocuboid, subtalar, and talonavicular joints are thus exposed. The peroneal tendons are carefully mobilized around the calcaneocuboid joint. The correction is made principally through the anterior process of the calcaneus (Fig. 12A–B). The first cut is made transverse to the long axis of the calcaneus, removing a large laterally based wedge. The medial aspect of the cut should come out just behind the oblique edge of the calcaneocuboid joint (Fig. 13C). This usually requires 1.5- to 2-cm width of cut on the lateral side. This cut is made more or less transverse to the long axis of the heel. A conservative excision of the cuboid articular surface is done, parallel with the articulation. This is usually transverse to the line of the forefoot (Fig. 13D). Next, a modified Lambrinudi-type cut is made in the neck of the talus (Fig. 13E). This excises the head and a portion of the neck of the talus. The line of resection extends from the dorsal articular margin of the head of the talus obliquely downward to the anterior articulation of the posterior facette of the subtalar joint. This leaves a sharp beak-shaped process on the neck of the talus. Next, an anteriorly based wedge is taken from the anterior process of the calcaneus. Progressive increments of bone can be removed until the equinus is fully corrected. This resection also removes the calcaneal articular surface of the posterior subtalar joint facette. The combination of the Lambrinudi cut in the talus, and anteriorly based wedge resection through the calcaneus, creates a large anterior wedge osteotomy. Finally, the articular surface of the navicular is conservatively excised and the tuberosity removed. A notch is cut in the inferior articular surface of the navicular to accept the neck of the talus. Often, the navicular is very thin and wedge-shaped at this point and little bone is available. The correction is accomplished by depressing the neck of the talus into the notch on the undersurface of the navicular, subluxating the foot dorsally while abducting

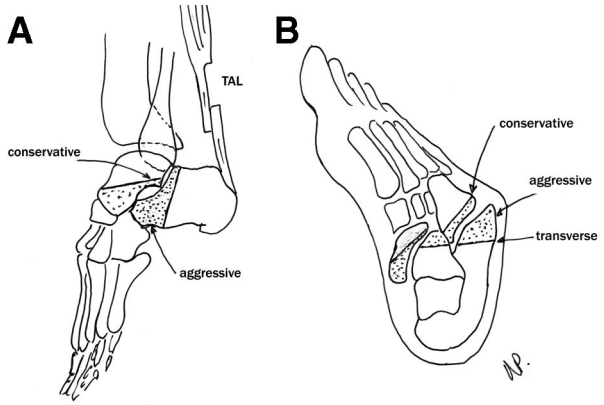

FIG. 12. (**A** and **B**) Schematic representation of the modified Lambrinudi triple arthrodesis. Aggressive wedges taken from the anterior process of the calcaneus.

the forefoot (Fig. 13F–H). With abduction, the heel varus spontaneously corrects. It is not usually necessary to perform a laterally based wedge excision through the subtalar joint to correct heel varus. An additional small amount of equinus correction can be achieved by percutaneous or open lengthening of the Achilles tendon. Plantar fasciotomy can also be added for cavus, performed through a short longitudinal incision in the midfoot.

The decision for triple arthrodesis should be made preoperatively. An extensive medial release combined with triple arthrodesis potentially devascularizes the talus. There is a natural desire to be more conservative in younger children, but for severe deformity, if there is any question, it is preferable to proceed directly to triple arthrodesis. Our experience in Uganda with severe deformities was that patients underdoing triple arthrodesis achieved better corrections than attempts at soft tissue release and osteotomy. Moreover, triple arthrodesis is a straightforward procedure that can be accomplished in a much shorter timeframe than soft tissue dissection and release combined with osteotomy. Operative time constraints are often a serious consideration in outreach surgery, where anesthesia is questionable. The concern for triple arthrodesis is the degree of stiffness it produces and the potential for growth arrest by excising enchondral growth centers. Experience has shown, however, that the degree of stiffness in the foot between triple arthrodesis and soft tissue release with midfoot osteotomy is commensurate, and growth and size characteristics of feet seem similar as well.

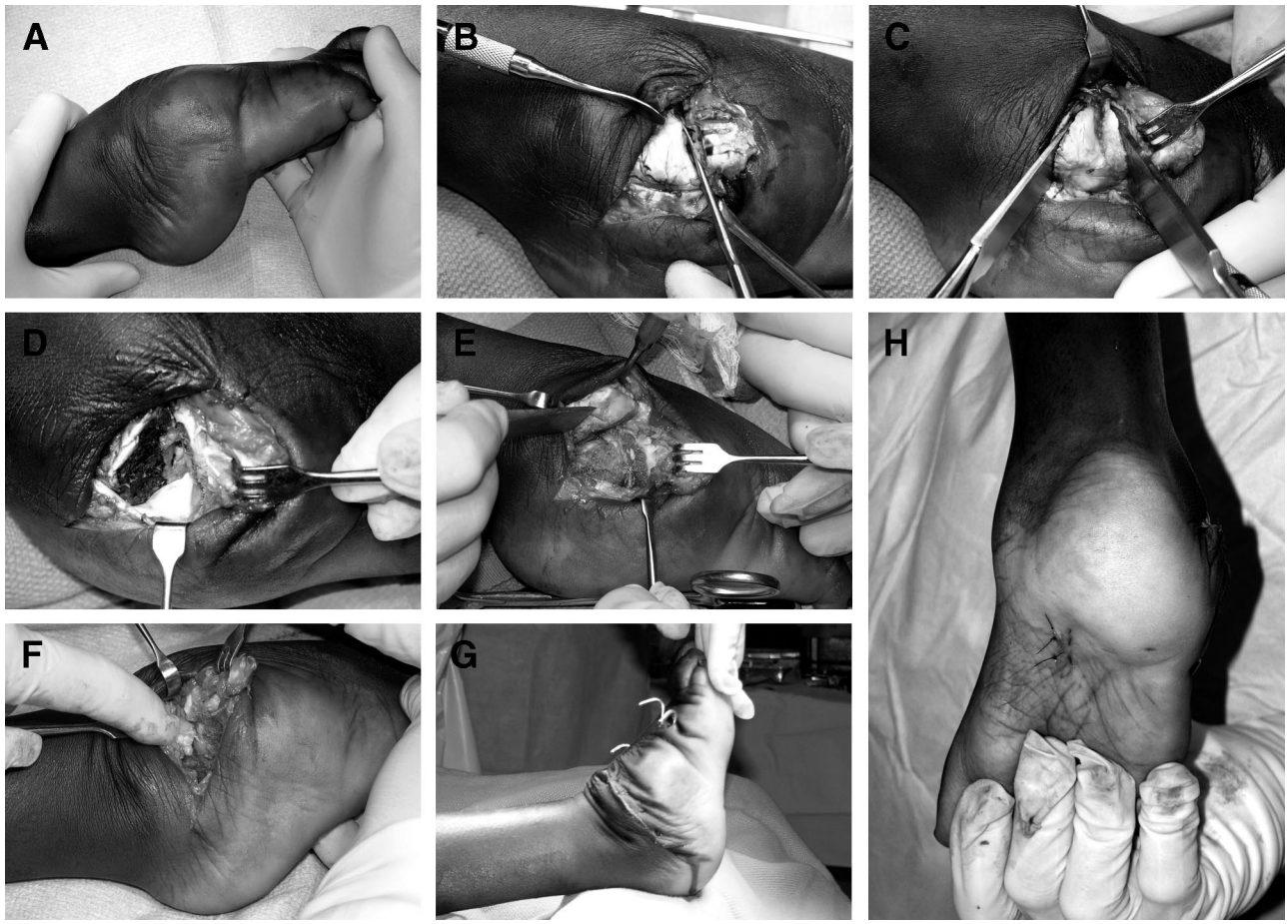

FIG. 13. (**A**) An 8-year-old boy with a moderately stiff forefoot and a rigid rearfoot. Maximal passive correction shows a marked degree of equinus. It is not possible to correct this much deformity with soft tissue release. Triple arthrodesis is chosen. (**B**) Lateral exposure. The extensor digitorum brevis is retracted and the anterior process of calcaneus is exposed. Obliquity of the calcaneocuboid joint outlined with an instrument. (**C**) Calcaneocuboid resection. The distal end of the calcaneus is made transverse, the osteotomy exiting behind the medial edge of the articular surface. Conservative cuboid resection in line with the articular surface. (**D**) After calcaneocuboid excision, the anterior process of the calcaneus is exposed for anterior-based axial wedge. (**E**) The Lambrinudi osteotomy of the head and neck of the talus, from the superior edge of the head of the talus to the posterior subtalar joint. Note the triangular shape of the head of the talus. (**F**) After bone resections, the head of the talus is depressed into the notch in the navicular. (**G**) The foot is dorsally subluxated, dorsiflexed, and abducted. (**H**) Heel varus corrects spontaneously with abduction.

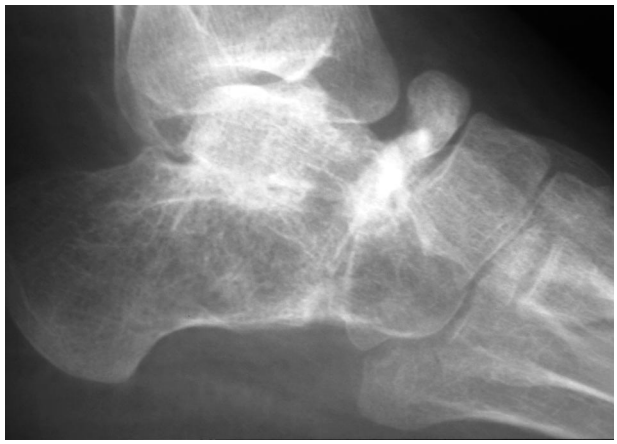

FIG. 14. Radiograph 2 years after modified Lambrinudi triple arthrodesis. The foot is plantigrade and the calcaneocuboid and talocalcaneal joints are fused. The remnant of navicular is high-riding and not fused. The patient had a good clinical result.

Internal fixation of osteotomy surfaces is preferable. In smaller feet, there is not enough space for staples, and K-wire fixation, therefore, becomes the standard. In larger feet, staples may be used. In a follow-up study of triple arthrodesis in children performed in Uganda, there was a pseudoarthrosis rate of 33% at the talonavicular joint.[2] Fixation was not used and likely contributed to this high rate. The small size of the deformed navicular in neglected clubfoot cases and the subluxation dorsally created by the Lambrinudi triple arthrodeses gives very small surface contact for arthrodesis (Fig. 14). This same study showed approximately two thirds of patients has some degree of residual deformity, as well as some degree of chronic pain in 38%. A high proportion (92%) of patients, however, was happy with the procedure because it gave them a plantigrade foot that could use shoes. In a similar follow-up study of triple arthrodesis for neglected clubfoot in 64 patients over 10 years of age, Hersh and Fuchs found 89% of patients happy with the procedure.[17]

Herold and Torok described a two-stage correction for neglected clubfeet in older children and adults.[16] The first stage consisted of extensive posteromedial release, followed by serial casting at two weekly intervals. Several weeks later, a second stage bony procedure was performed, consisting of tarsal wedge osteotomy or triple arthrodeses. Their strategy was to minimize bone resection by preliminary soft tissue correction and serial casting. Their procedure obviously used more surgical resources and required more time commitment than a single-stage procedure. Yadav in India likewise performed triple arthrodeses in association with extensive soft tissue release and reported good results maintained over time.[34] He did not report on the incidence of avascular necrosis of the talus. Avascular necrosis is a known complication of triple arthrodeses surgery.[1] Resection of bone through a lateral incision and cleaning out the sinus tarsi eliminates the lateral side vascular supply to the head of the talus. It would seem prudent, therefore, to avoid any disruption of the important medial blood supply coming in through the deltoid ligament and tarsal canal.

The strategy in Uganda was to accomplish the correction in one stage without medial soft tissue release or dissection. I did not feel that soft tissue release plus triple arthrodesis improved the correction over triple arthrodesis alone yet required significantly longer surgical time and risked the vascularity of the talus.

Talectomy

Talectomy is described for the treatment of equinovarus deformities in myelodysplasia and arthrogryposis, and has also been used for severe clubfeet. Talectomy, however, provides an incongruous joint, and often it is still difficult to obtain fully corrected foot position. Triple arthrodesis is a preferable procedure.

Ilizarov Correction

The Ilizarov apparatus is a powerful means of obtaining correction of severe foot deformities, and it can be applied to neglected clubfoot surgery.[15] Progressive correction can be accomplished with safety regarding blood supply and skin. Rings are fixed to the tibia connected to half rings for the calcaneus and the forefoot. Asymmetric distraction corrects the various deformities. When bony deformity is not severe, an unconstrained frame (lacking fixed hinges) is used to take advantage of the existing articulations, much as with serial casting. For more severe deformities, distraction osteogenesis through osteotomies is accomplished using a more constrained frame with hinges. Joshi has developed a simple frame based on Ilizarov concepts that has been used extensively in India and elsewhere with good results.[33] This frame is less bulky than a similar Ilizarov frame, is less expensive, and more simple to apply. Recent reports from India adapting Ilizarov correction to the Ponseti technique have also been encouraging. An olive wire is inserted into the neck of the talus and an unconstrained construct used to correct forefoot adduction and cavus around the talus.[5] There is a vulnerability to relapse in older children because of the osseous deformity, notably the obliquity of the calcaneocuboid articulation. Combining Ilizarov corrections with osteotomy through the calcaneus is more likely to produce a lasting effect.[23]

Because the clubfoot is a complex three-dimensional

deformity, these are complex and difficult corrections requiring considerable expertise. Use of Ilizarov instrumentation is limited in the developing world by the large number of cases requiring treatment, the lengthy operating time involved, the availability of the instrumentation and intraoperative imaging, and the logistics of adequate postoperative care. Although promising, this technique is not appropriate for the majority of practitioners in the developing world or for volunteer surgeons on short-term assignment. The foot after Ilizarov correction is very stiff, as stiff as after osteotomy procedures. There is a functional advantage in a shorter stiff foot after triple arthrodesis as compared with a longer stiff foot after Ilizarov correction, and so triple arthrodesis remains the procedure of choice in resource-poor environments.

SKIN COMPLICATIONS

In the fully corrected position immediately after surgical procedures to correct the neglected clubfoot, the skin is very tight on the medial side and can easily dehisce or break down from too much tension. A solution is to leave the foot only partly corrected at surgery and plan on remanipulating the foot under anesthesia after 1 or 2 weeks to gain full correction once the skin has had a chance to heal. This requires access to safe anesthesia and supervision by the surgeon or well-trained associate staff. Rotation flap closure was used extensively in Uganda to reduce tension on the medial side (Fig. 15A–C). The medial and lateral incisions are connected with a wide curving incision over the anterior aspect of the dorsum of the foot, and the skin and subcutaneous tissue dissected from the fascial layer. The venous plexus is left in situ on the fascia. By rotating the flap across the dorsum, slack can be taken up on the redundant lateral side and transferred to the medial side. This gives nice closure of the anterior and midportions of the medial incision, but the posterior corner can still be a bit tight. The flap can look edematous and somewhat dusky at the 2-week cast change, but I have never seen a flap necrose. The large proximal base ensures adequate blood supply.

An alternative is a posterior V-Y advancement flap. This reduces tension in the posterior segment of the incision but requires a lengthy proximal dissection. Fasciocutaneous flaps have also been used.[10] These are more technically difficult to perform and potentially risk blood supply in the posterior tibial network. Because it is known that deficiency of the dorsalis pedis arterial supply is not uncommon in clubfeet, the posterior tibial artery becomes the only vascular supply to the foot and great care must be taken when manipulating these vessels.[18]

In the limited resource environment, skin breakdown and infection are more common than in the developed world. Under these circumstances, staff should be instructed not to remove the plaster but to window the plaster for dressing changes. If the cast is soiled, it must be changed and replaced because relapse of the foot is

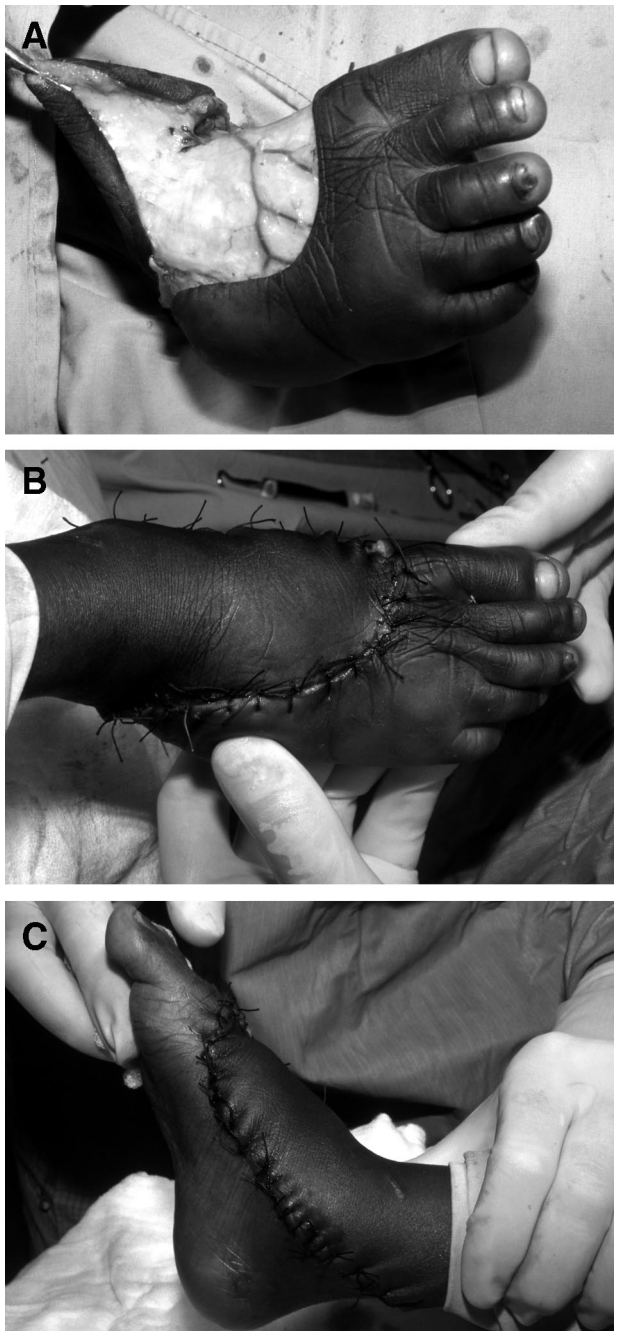

FIG. 15. (**A**) Dorsal rotation flap. The medial and lateral incisions are joined across the dorsum of the foot. Venous plexus is left on the deep layer. (**B** and **C**) After rotation and closure, redundant skin on the lateral side is taken up and tension is relieved on the medial side.

dramatic when it is left unprotected. Satisfactory results can be salvaged in most cases either by skin grafting over the granulating base or allowing epithelialization.

Superficial infection in the lateral wound is a common complication in older children. This is the result of the deep fissures in the skin over the lateral callus and skin redundancy with underlying dead space hematoma. It usually resolves with local dressing changes and antibiotics. The redundant callus on the lateral side of the foot spontaneously disappears once there is no weightbearing over it. It can be ignored. Elliptic excision of redundant skin can be considered, but in my experience resulted in more wound healing problems.

POSTOPERATIVE CARE

The results of treatment are only as good as the postoperative care. There is no purpose in undertaking clubfoot surgery if postoperative plaster care and bracing support is inadequate because relapses will be invariable and will result in more serious disability than initially. Volunteer surgeons visiting the developing world on a short-term assignment must ensure appropriate follow-up services before undertaking clubfoot surgery.

In the immediate postoperative period, vascular supply to the foot is compromised and marked swelling is to be expected. Feet should be kept elevated, particularly during the first 48 hours, and circulation to the toes checked frequently. Casts should be split if there is any concern about undue swelling or sluggish circulation. Elevating the foot of the bed on blocks is particularly helpful.

Plaster changes need to be done expertly, maintaining full correction and in some cases manipulating the foot further. In the case of upcountry outreach surgery, local staff needs to be trained adequately. For most clubfoot surgery, at least 3 months of immobilization is necessary and sometimes longer if postoperative splinting is not available. Discharging children back to the village environment during this time, particularly if plaster of Paris is used, can be problematic with destruction of the plaster and subsequent loss of position. Construction of rehabilitation hostels in outreach areas to house and supervise children has proved beneficial, particularly if attached to a community-based rehabilitation project. Wherever possible, community-based rehabilitation principles should be used.[25]

For younger children who have undergone soft tissue release, casting should be followed up with a foot abduction brace (FAB). Nighttime foot abduction braces for 2 or more years will reduce the risk of relapse. The Steenbeek foot abduction brace has been developed in Africa and is a low-cost appliance made of locally available materials.[31] Plastic ankle–foot orthoses (AFO) technology is not often available in remote areas but is particularly useful in older children to help prevent relapse after soft tissue release and osteotomy.

It is impossible to obtain perfection in the treatment of the neglected clubfoot. The object should be to obtain a foot that is more or less plantigrade, with weightbearing on the plantar skin, and able to fit shoes. Children obtaining this result will be happy the majority of the time.

REFERENCES

1. Angus PD, Cowell HR. Triple arthrodesis. A critical long term review. *J Bone Joint Surg [Br]* 1986;68:260–265.
2. Bitariho D, Penny JN. Triple arthrodesis in children for severe neglected clubfoot deformity. Presented at the Association of Surgeons of East Africa; December 3–5, 2003; Kampala.
3. Bitariho D. Short term outcome in one stage pantalar soft tissue release with transfixation of talonavicular joint in resistant idiopathic congenital clubfoot [MMed (Orth) Thesis Dissertation]. Makarere University; Uganda; April 2001.
4. Clark MW, D'Ambrosia RD, Ferguson AB. Congenital vertical talus: treatment by open reduction and navicular excision. *J Bone Joint Surg [Am]* 1977;59:816–824.
5. Chaudhary M. Using Ponseti principles for external fixation treatment of older children with residual and recurrent clubfoot. Presented at the Baltimore Limb Deformities Pre-course; September 2003; Baltimore.
6. Cooper DM, Dietz FR. Treatment of idiopathic clubfoot: a thirty year follow-up note. *J Bone Joint Surg [Am]* 1995;77:1477–1489.
7. Cummings RJ, Davidson RS, Armstrong P, et al. Congenital clubfoot. AAOS instructional course lecture. *J Bone Joint Surg [Am]* 2002;84:290–308.
8. Dimeglio A, Bensahel H, Souchet P, et al. Classification of clubfoot. *J Pediatr Orthop [lsbq]B]* 1996;4:129–136.
9. Davidson RS. Clubfoot salvage: a review of the past decade's contributions. *J Pediatr Orthop* 2003;23:410–418.
10. D'Souza MS, Aroojis MS, Yagnik MS. Rotation fasciocutaneous flap for neglected clubfoot: a new technique. *J Pediatr Orthop* 1998;18:319–322.
11. Dwyer FC. Osteotomy of the calcaneum for pes cavus. *J Bone Joint Surg [Br]* 1959;41:80–86.
12. Evans D. Relapsed clubfoot. *J Bone Joint Surg [Br]* 1961;43:722–733.
13. Ferlic RJ, Breed AL, Mann DC, et al. Partial wound closure after surgical correction of equinovarus foot deformity. *J Pediatr Orthop* 1997;17:486–489.
14. Herzenberg JE, Radler C, Bor N. Ponseti versus traditional methods of casting for idiopathic clubfoot. *J Pediatr Orthop* 2002;22:517–521.
15. Heurta F. Correction of the neglected clubfoot by the Ilizarov technique. *Clin Orthop* 1994;301:89–93.
16. Herold HV, Torok G. Surgical correction of neglected club foot in the older child and adult. *J Bone Joint Surg [Am]* 1973;55:1385–1395.
17. Hersh A, Fuchs LA. Treatment of the uncorrected clubfoot by triple arthrodeses. *Orthop Clin North Am* 1973;4:103–115.
18. Hootnik DR, Levinsohn EM, Crider RJ, et al. Congenital arterial malformations associated with clubfoot. A report of two cases. *Clin Orthop* 1982;167:160–163.
19. Koutsogiannis E. Treatment of mobile flat foot by displacement osteotomy of the calcaneus. *J Bone Joint Surg [Br]* 1971;53:96–100.

20. Lambrinudi C. New operation on drop-foot. *Br J Surg* 1927;15: 193.
21. Lichtblau S. A medial and lateral release operation for clubfoot. *J Bone Joint Surg [Am]* 1973;55:1377–1384.
22. Lourenco AF, Prata SD, Sodre H, et al. Conservative treatment of clubfoot after walking age. Presented at the Third International Clubfoot Congress; August 27–28, 2002; San Diego
23. Paley D. The correction of complex foot deformities using Ilizarov's distraction osteotomies. *Clin Orthop* 1993;293:97–111.
24. Penny A. School access: children with motor disabilities in rural Uganda [MA Thesis Dissertation]. University of Victoria; 2001.
25. Penny JN, Steenbeek M. Community based rehabilitation (CBR) in the management of clubfoot deformity in Africa. Presented at the Third International Clubfoot Congress; August 27–28, 2002; San Diego.
26. Pirani S. A reliable and valid method of assessing the amount of deformity in the congenital clubfoot. Presented at the Pediatric Orthopaedic Society of North America; May 2004; St. Louis.
27. Pirani S, Zeznik L, Hodges D. Magnetic resonance imaging study of the congenital clubfoot treated with the Ponseti method. *J Pediatr Orthop* 2001;21:719–726.
28. Ponseti IV. *Congenital Clubfoot: Fundamentals for Treatment.* Oxford: Oxford University Press; 1996.
29. Scott WA, Hosking SW, Catterall A. Club foot. Observations on the surgical anatomy of dorsiflexion. *J Bone Joint Surg [Br]* 1984;66:71–76.
30. Sengupta A. The management of congenital talipes equinovarus in developing countries. *Int Orthop* 1987;11:183–187.
31. Staheli L, ed. *Clubfoot: Ponseti Management.* Seattle: Global-HELP Publications, 2003. Available at: http://www.global-help.org/publications/ponseti-cf.html.
32. Steenbeek M. The Steenbeek foot abduction brace (SFAB): preventing recurrence of deformity in developing nations during treatment of congenital clubfoot by the Ponseti method. Presented at the Third International Clubfoot Congress; August 27–28, 2002; San Diego.
33. Suresh S, Ahmed A, Sharma VK. Role of Joshi's external stabilization system fixator in the management of idiopathic clubfoot. *J Orthop Surg (Hong Kong)* 2003;11:194–201.
34. Yadav SS. Observations on operative management of neglected clubfoot. *Int Orthop* 1981;5:189–192.