Correcting Residual Deformity Following Clubfoot Releases

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Abstract There are many possible pitfalls of clubfoot releases and it is important to recognize the problems and provide proper timely treatment. Late residual deformity following clubfoot releases include: dynamic or stiff supination and forefoot adduction deformities, intoeing gait, overcorrection, rotatory dorsal subluxation of the navicular, vascular insult to the talus with collapse, and dorsal bunion. We reviewed 134 clubfeet in 95 children who had primary clubfoot releases between 1988 and 1991. In general, the patients who underwent surgery before 6 months of age had poorer results compared with older children. Twenty-one feet (15.7%) underwent additional procedures. The most common additional procedure was split anterior tibial tendon transfer. Not all patients with residual deformities underwent additional procedures. In treating recurrent and residual deformity following a clubfoot surgery, it is most important to keep function in mind. From this series of patients treated with comprehensive clubfoot release, we have identified the most

common residual deformities encountered after the initial release and effective surgical treatment when necessary.

Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

With the improved results and popularity of nonsurgical treatment of clubfoot by the Ponseti and French methods, the number of surgical cases of clubfoot correction has decreased tremendously in recent years, with estimates of the decrease ranging from 2% to 20% [2, 16]. Outcome evaluations emphasizing patient function and range of motion have guided this transition superseding purely anatomical considerations. In a long-term followup study into adulthood, Ippolito et al. [6] reported better outcomes in a group treated with the Ponseti method in combination and limited posterior releases than a group treated with extensive posterior medial releases after a period of casting. In a 30-year followup study by Dobbs et al. [4], patients treated with combined posterior, medial, and lateral extensive release had generally poor functional results and arthritic changes. They reported a correlation between the extent of the soft tissue releases and degree of functional impairment. However, despite a decreasing number of surgical cases, comprehensive surgical release is still widely performed and is an effective form of treating the clubfoot in special circumstances.

The pediatric orthopaedic surgeon should be aware of the possible pitfalls of clubfoot surgery, as well as recurrence and residual deformities encountered after surgery. In our previous study of 86 feet in 70 patients (from the years 1981 to 1987) who underwent revision surgeries, although

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there was improvement from an equinus position to plantigrade, the final total range of motion of the ankle did not change. Increased dorsiflexion occurred at the expense of decreasing plantarflexion [8].

We will first describe the possible pitfalls of clubfoot release surgery and review the most common residual deformities and their treatment. We then reviewed our consecutive series of cases for the purpose of (1) discussing the early results and complications of comprehensive clubfoot release with the aim of avoiding pitfalls, and (2) identifying common residual deformities encountered after the initial treatment and discussing the most effective treatment based on our experience.

The Procedure

The comprehensive surgical release of clubfoot through a Cincinnati incision [3, 13, 14] identifies all tight musculotendinous and ligamentous structures through a wide surgical exposure. Surgical sectioning of these tight structures allows full correction of all the deformities encountered in the clubfoot. The extent and degree of surgical release depends upon the severity of the contractures as well as the lengthening of structures to provide anatomic positioning of the bones of the foot which are then transfixed with pins. Complications from this extensive and complex surgery can occur intraoperatively, immediately postoperatively, or in the longer term.

In our experience, intraoperatively there can be cartilage damage if a scalpel is introduced too deeply into the joint (most commonly the talar head because of its convex configuration), damage to the neurovascular structures, or inadequate positioning of the bones of the foot secondary to incomplete releases or overzealous lengthening. Immediately postoperatively the major complication is vascular or skin problems related to poor circulation from the extensive release or poor positioning of the foot. Later on, there can be substantial scarring resulting in limited range of motion or even loss of part of the foot from vascular or skin loss.

After a period of 6 to 10 weeks of immobilization in a cast, it is necessary to brace the operative foot to prevent the recurrence of the deformity. The brace consists of a hinged ankle-foot orthosis with lateral strap to prevent varus deformity. In addition, postoperatively there can be extensive scarring, stiffness, and loss of motion of the foot which may persist permanently.

A pseudoaneurysm [12] (Fig. 1) is a rare complication in which a pulsatile mass is encountered either at the level of the incision or on the plantar or dorsal aspect of the foot in association with a rent in one of the major arteries of the foot causing a pulsatile collection of blood. The

Fig. 1 One month after clubfoot release, this patient developed pseudoaneurysm of the calcaneal artery.

pseudoaneurysm can work its way to the surface of the skin and cause substantial bleeding from a relatively minor-appearing skin sore. Alternatively, major blood loss can occur in the subcutaneous tissues, which can lead to presentation of children with very low hematocrit. The proper care of the pseudoaneurysm requires recognition of this rare complication and operative treatment.

The late deformities of the foot encountered 1 or more years after clubfoot surgery include residual heel varus, equinovarus, or cavus. In addition, clinically important midfoot adduction and varus deformities can occur, as well as forefoot adductus. A more complicated deformity can occur in an overcorrected foot where the heel drifts into substantial valgus.

Residual forefoot adduction with supination dynamic deformity is one the most common problems in clubfoot treatment [10, 17], as much as 95% in one series [17]. It can be caused by an overpowering of the anterior tibial tendon [10]. The unbalanced overpull of the anterior tibial tendon can cause recurrence of the equinovarus deformity. It not only occurs in surgically released clubfoot, but also can also occur following the Ponseti method [11]. It causes functional problems such as inability to maintain plantigrade during walking and difficulty in shoe wear. The procedure of choice is anterior tibial tendon transfer. It is important that the foot is passive and correctable to the neutral position before considering this procedure. It can be combined with a revision procedure once the deformity is corrected by soft tissue release.

There are two types of anterior tibial tendon transfers available [10]: full transfer and split anterior tibial tendon transfer. In a full transfer, the tendon is transferred to the middle or lateral cuneiform, while in a lateral transfer to the cuboid. In a study of 55 patients with anterior tibial tendon transfer, we found improved dorsiflexion range of motion, improved dorsiflexion muscle strength due to

better muscle tracking, improved eversion function, and prevention of deformity recurrence by eliminating the deforming factor [10]. Both full transfer and split transfer procedures can correct dynamic supination and adduction deformity. Full transfer may give a little better correction; however, there is a chance of overcorrecting the deformity. Split transfer definitely preserves a better inversion function of the foot [10].

In cases with fixed forefoot adduction deformity, the bony structure is fixed and can no longer be treated with tendon transfer alone and a bony procedure becomes necessary to correct this symptomatic forefoot deformity. Our preferred procedure is shortening of the lateral column with lengthening of the medial column. The removed wedge from shortening of the cuboid bone can be inserted into the osteotomized and distracted osteotomy gap of the medial cuneiform bone for lengthening purposes. However, in some cases, the cuboid bone is soft or the wedge is too small for adequate support of lengthening the medial cuneiform. In these cases we use allograft to obtain lengthening of the medial column (Fig. 2A–B). Internal fixation and casting are necessary to hold the position until the bones are healed.

The other procedure we have used to correct the rigid forefoot adduction is midtarsal lateral wedge osteotomy. In our experience the problem resulting from this is additional

stiffening of the midfoot. We believe the procedure should be used only if no other option is available.

Many patients have persistent intoeing gait following a soft tissue release. Provided the foot is reasonably corrected with plantigrade gait, and without a dynamic deformity, there is no reason to perform a foot procedure because it would further stiffen the foot motion. In this case, distal tibia and fibula external rotation osteotomies with internal fixation are the procedure of choice. The procedure is relatively uncomplicated and predictably corrects the intoeing gait in our experience.

Overcorrection (Fig. 3A–C) is one of the most difficult conditions to rescue following clubfoot releases. In children with generalized joint laxity, clubfoot surgery can be associated with long-term overcorrection [5]. In the absence of generalized laxity, overcorrection may reflect a simple pronated foot, or lateral translation of the calcaneus under the talus, most likely from a complete subtalar release. The subtalar joint usually is very stiff and deformity is fixed. Calcaneal lengthening is not a good choice due to subtalar stiffness. In case of symptomatic overcorrection such as pain and difficulty in shoe wearing, a medial translation calcaneal tuberosity osteotomy is a good salvage procedure. Plantar displacement of the calcaneal fragment can be performed to create an arch of the foot. It does not, however, change the intrinsic deformity of the

Fig. 2A–B (A) Rigid forefoot adduction deformity was present in this right foot. (B) The cuboid was shortened and medial cuneiform lengthened.

Fig. 3A–C (A) An overcorrected left foot with symptomatic heel valgus is shown before correction. (B) The appearance of the foot after calcaneal osteotomy with screw fixations is shown. (C) Postcorrection of left foot heel valgus shows improvement.

subtalar joint, but it does change the look and loading of the foot and may improve the gait pattern [15] and symptoms due to impingement of the calcaneus on the distal fibula. Screw fixation is sufficient. Triple arthrodesis can correct the deformity, however it completely stiffens the hindfoot. It should be reserved as the last resource.

Rarely, lateral positioning of the calcaneus is associated with ankle valgus which can be corrected in skeletally

Fig. 4 In this 14-year-old boy with dorsal subluxation of the navicular after soft tissue releases in his first year of life, the navicular is triangular-shaped.

immature patients with hemiepiphysiodesis of the medial ankle.

Dorsal subluxation of the navicular bone [9] following clubfoot releases can occur progressively even several years following the procedure (Fig. 4). The medial larger end of the navicular rotates cephalically and creates an image of reversed triangular-shaped navicular in the lateral view. The net effects of dorsal subluxation of navicular on talus are (1) shortening of medial column, (2) plantar flexion of midtarsal joint, (3) forefoot adduction deformity, (4) forefoot supination deformity, and (5) cavovarus foot. The foot is shortened in general. It may cause the symptoms and shoe wear problems because of navicular pressure at the dorsum of the foot and increased thickness of the midfoot.

We believe correction of the foot deformity becomes necessary when the children develop disabling pain on the dorsum of the foot. The procedures to realign both the talonavicular and calcaneocuboid axis are necessary to correct this complex deformity caused by dorsal subluxation of the navicular, including medial release to realign the talonavicular joint and lateral release to realign the calcaneocuboid joint with pin fixation. Shortening of lateral column is appropriate in patients with an elongated lateral column. When the navicular becomes irreducible in older patients, excision of navicular or talonavicular fusion may become necessary to reduce the deformity.

With extensive releases, the talar blood supply may be deprived from medial, lateral, and subtalar routes. The talus may collapse over time and be associated with a shortened medial column (Fig. 5). The treatment is difficult in this stiff and short foot. Triple arthrodesis probably is one of the choices for the symptomatic foot. A talectomy in association with a lateral column shortening is another option, particularly when it is necessary to achieve a substantial amount of dorsiflexion.

Dorsal bunion deformity occurs in older children following soft tissue releases for clubfoot and it is usually

Fig. 5 The talus completely collapsed due to vascular insult following soft tissue release before age 1 year.

Fig. 6A–C (A) This photograph shows a dorsal bunion after clubfoot release in the patient's first year of life. (B) A radiograph of standing lateral view of the foot showed dorsal bunion with horizontal position of the first metatarsal and flexed great toe. (C) Following the reverse Jones procedure and first metatarsal osteotomy, the deformity was well-corrected.

associated with weak plantarflexion (Fig. 6A–C). The major factors causing dorsal bunion deformity following clubfoot releases are weak Achilles tendon, overpowering of flexor hallucis longus, strong anterior tibial tendon, and weak peroneus longus tendon [7]. Symptoms include ill-fitting standard shoes and pain.

The treatment of the symptomatic feet mainly requires eliminating the deforming factors. We have utilized the transfer of the distal end of the flexor hallucis longus to the neck of the first metatarsal head through a drilled hole; we call this the “reverse Jones transfer” [20]. In those cases with a stiff tarsometatarsal joint, a proximal first metatarsal plantarflexion osteotomy is indicated. A number of patients have strong unopposed anterior tibial tendons with the forefoot in supination, and a split anterior tibial tendon transfer would be indicated at the same time.

Materials and Methods

We retrospectively reviewed 95 children (134 clubfeet) who underwent primary hindfoot releases between 1988 and 1991. The 95 patients (72 boys and 23 girls) with 134 feet had 56 unilateral (30 right and 26 left) and 39 bilateral cases. There were 22 feet operated before age 6 months, 81 feet operated between 6 months to 1 year, and 31 feet operated after age 1 year. The average age at time of surgery was 1 year. The minimum followup was 2 years (average, 4.5 years; range, 2 to 7.4 years).

All procedures were performed through Cincinnati incision with progressive posterior medial lateral releases. All operations were performed under the supervision of one surgeon (KNK).

A long leg cast was applied for 6 weeks with interval cast change at 2 weeks. Following the cast removal, the percutaneous pins were removed and an ankle-foot orthosis with ankle hinge with limited plantar flexion and lateral strap was applied full time for 6 months. We (PAS and KNK) graded the clinical results as excellent, good, fair, and failure according to Turco's criteria [18, 19]. Those with failure results underwent additional procedures. All patients had standing AP and lateral radiography of the foot performed at final followup. We (PAS and KNK) measured the AP talocalcaneal angle, talo-first metatarsal angle, and lateral talocalcaneal angle.

Using Fisher's exact test for our statistical analysis we compared pin fixation techniques between one pin only for talonavicular joint, one pin each for both talonavicular and talocalcaneal joints and no pin fixation, also we compare the age at time of surgery in relation to the final results.

Results

We rated 67 feet (50%) as excellent, 34 feet (25.4%) good, 12 feet (9%) fair, and 21 feet (15.7%) failed. When the age at surgery was taken into account, patients with surgery after 6 months of age had better ($p < 0.001$) outcomes than those younger than 6 months (Table 1). No ambulatory

Table 1. Patient age at time of surgery and results

Result	Patient age		
	0 to 6 months (22 feet)	7 to 12 months (81 feet)	> 1 year (31 feet)
Excellent	6 (27.3%)	44 (54.3%)	17 (54.8%)
Good	3 (13.6%)	21 (25.9%)	10 (32.3%)
Fair	5 (22.7%)	3 (3.7%)	4 (12.9%)
Failure	8 (36.4%)	13 (16.1%)	0

Table 2. Pin fixation and results

Pin	Result			
	Excellent	Good	Fair	Failure
TN (90)	47 (52.2%)	19 (21.1%)	7 (7.8%)	17 (18.9%)
TN + TC (26)	12 (46.2%)	6 (23.1%)	5 (19.2%)	3 (11.5%)
No pin (18)	8 (44.4%)	9 (50%)	0	1 (5.6%)

Table 3. Residual deformities that required additional surgeries

Deformity	Number of feet
Forefoot adduction and supination	20 (95.2%)
Cavus deformity	7 (33.3%)
Hindfoot varus	8 (38.1%)
Hindfoot equinus	5 (23.8%)

A foot may have more than one deformity.

patient (generally after age 1 year) had a reoperation. We observed no difference ($p = 0.09$) in percentages of outcomes among all three techniques (Table 2).

The three radiographic measurements were qualitatively similar among feet rated excellent, good, and fair but appeared to us qualitatively distinct from those patients rated as failed.

Early complications of wound dehiscence were observed in two of the 134 feet (1.5%); both healed with secondary intention. Avascular necrosis of talus occurred in four feet (3%), overcorrection with pronation deformity in six feet (4.4%), dorsal bunion in six feet (4.4%), and dorsal subluxation of the navicular in 17 feet (12.7%). Despite the presence of late deformity, the patients did not always undergo a corrective surgery but 21 feet (15.7% of the total of 134 feet) underwent additional surgeries for these residual deformities. Forefoot adduction and supination was the most common reason for additional procedures (Table 3).

The most common additional revision procedure was split anterior tibial tendon transfer followed by medial joint releases (Table 4). There was no comprehensive clubfoot release performed as a revision surgery necessary in our

Table 4. The procedures in revision surgeries

Type of procedure	Number of feet (%)
SPLATT	19 (90.5%)
Medial joint release	17 (76.2%)
Plantar release	6 (28.6%)
Lateral release	5 (23.8%)
Posterior release	4 (19.1%)
Lateral column shortening	3 (14.3%)
TAL	3 (14.3%)
Calcaneocuboid fusion	2 (9.5%)
Medial column lengthening	1 (4.8%)
FDL lengthening	1 (4.8%)

A foot may have more than one procedure.

series. The clinical results after the additional revision procedures in these 21 feet were excellent in 5 feet (23.82%), good in 8 feet (38.09%), and fair in 8 feet (38.09%).

Discussion

Late residual deformity following clubfoot releases include: dynamic or stiff supination and forefoot adduction deformities, intoeing gait, overcorrection, rotatory dorsal subluxation of the navicular, vascular insult to the talus with collapse, and dorsal bunion. It is important to recognize these problems and provide proper timely treatment. Our purpose was therefore to identify factors associated with successful clubfoot releases and potential pitfalls. We identified the most common residual deformities

encountered after the initial release and describe some effective surgical approaches when necessary.

The study is a retrospective review of a single author's experience so the findings may not be generalizable, specifically in regard to the type of residual deformities encountered. The limitation of this study is a relatively short followup for clubfoot, however it does show the trend of residual deformity formation and subsequent treatment. One other limitation is that we do not have a documented severity of the clubfoot deformity before correction available for this cohort; therefore we are unable to compare the preoperative severity and postoperative residual deformity.

In general, patients operated before 6 months of age had higher failure rate. This is because the smaller feet may be more deformed, and the anatomy is difficult to judge at the time of surgery. With the advancement and popularity of the Ponseti technique with good functional results, there is even less reason to perform early surgical correction. Some foot deformities may improve as the child grows, especially when the child starts to weight bear. It is easier to judge the amount of correction necessary when the child is able to stand on his or her feet. The other problem with early surgery is that it may result in overlengthening the Achilles tendon and in a weakness of plantarflexion. Achilles tendon strength is the most important determining factor of the foot dynamic function in clubfoot treatment followup long-term. For better function after revision surgery, we believe it better to accept a mild degree of equinus position of the foot than a well-corrected equinus with overweakening of Achilles tendon.

Tarraf and Carroll [17] reported forefoot and supination as the most common residual deformity following clubfoot releases. We concur with their observation. This is evidenced by our most popular residual clubfoot correction following clubfoot releases being anterior tibial tendon transfer to correct the supination and adduction deformity. Atar et al. [1] reported a series of 29 reoperated clubfeet, the most common procedure being repeat complete soft tissue releases alone or combined with other procedures. This is contrary to our findings that most revision procedures were tailored to specific residual deformity through an a la carte approach.

A failure of the initial surgery does not necessarily mean a permanent failure. A satisfactory result can be obtained with subsequent treatment. However, it is crucial to identify the residual dynamic and fixed deformities before considering further intervention. Based on the above information, it is reasonable for the surgeon to inform parents of children undergoing clubfoot comprehensive release that approximately 16% of the time future surgery may be necessary to treat residual deformity, and that a satisfactory result with a plantigrade painless foot can be achieved in more than 80% of cases.

In treating recurrent and residual deformity following a clubfoot surgery, one should keep the ultimate function in mind when designing a treatment. The goals of revision surgery are to obtain a plantigrade painless functional foot, maintain dynamic muscle balance, and maintain maximal available range of motion.

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