Copyright 1985 by The Journal of Bone and Joint Surgery, Incorporated

Complete Subtalar Release in Club Feet

PART I — A PRELIMINARY REPORT*†

BY GEORGE W. SIMONS, M.D., M.S.‡, MILWAUKEE, WISCONSIN

From the Department of Orthopedic Surgery, Milwaukee Children's Hospital and the Medical College of Wisconsin, Milwaukee

ABSTRACT: **The complete subtalar release is an extensive soft-tissue procedure for the treatment of club foot that non-surgical methods have not corrected. It is a more extensive surgical procedure than others currently in use. Two advantages of this procedure are that it produces a greater degree of correction than other procedures and that it provides superior alignment between the foot and leg. The main disadvantage is a tendency to overcorrection. In this report I present the steps in performing the procedure and the anatomical concept on which it is based.**

The complete subtalar release is an extensive surgical procedure for correcting the club foot that has resisted non-surgical treatment. This procedure allows the surgeon to achieve a greater amount of correction and superior alignment of the foot in relation to the leg. In this report I present the background and indications for the procedure, the importance of preoperative diagnosis and treatment, the surgical technique, the indications for secondary procedures, and the postoperative management.

The Procedure

The complete subtalar release consists of a standard posteromedial release[21] with additional releases of the lateral part of the talonavicular joint, the lateral part of the subtalar joint, the calcaneofibular ligament, and the interosseous talocalcaneal ligament. Since the report in 1971 by Turco[21], the posteromedial release has become the operative procedure of choice for most surgeons. Further studies by Turco[22], Thompson et al., and others[1,3,7,15] have demonstrated the value of the posteromedial release. However, deformities may persist or recur after a posteromedial release, as the calcaneus has not been fully freed to allow it to rotate beneath the talus. McKay[10] described his concept of calcaneal rotation in 1977 and in subsequent reports[11-14]. Since then two reports[18,19] on the dissection of club feet of stillborn infants, as well as the recent report by Ghali et al. on the results of pantalar release, have confirmed the correctness of McKay's concept. The posteromedial release, however, does not permit full correction (Fig. 1). Only the complete subtalar release accomplishes full derotation of the calcaneus in a single procedure. It is important to achieve complete correction in a single surgical intervention, as postoperative scar tissue makes subsequent soft-tissue procedures extremely difficult.

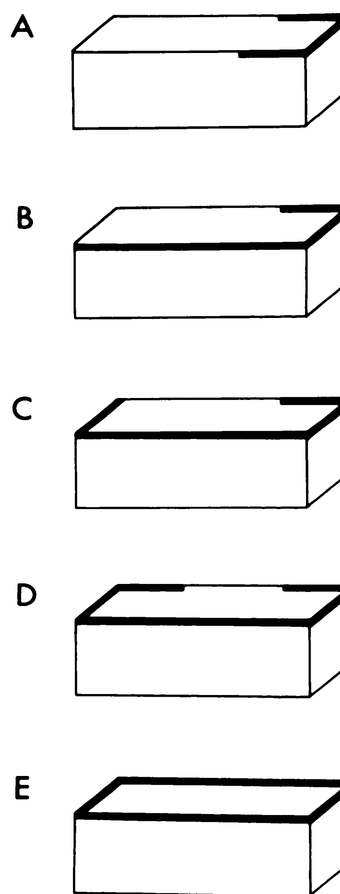

FIG. 1

The box represents the calcaneus. The medial side of the subtalar joint is nearest to the viewer. The anterior aspect of the calcaneus is on the left. The dark wide lines represent the portion of the subtalar capsule, composed of its various ligaments, that is incised and released by various types of surgical releases: *A*, the conventional posterior release; *B*, the extended posterior release, as described in this report (the anterior aspect of the subtalar joint is not incised); *C*, the posteromedial release; *D*, the posteromedial and anterolateral release, as described in this report; and *E*, the complete subtalar release. If rotation between the talus and calcaneus has not been achieved by conservative treatment, then the posteromedial release and lesser procedures will not be adequate to achieve a normal relationship of the positions of these two bones, as the lateral aspect of the subtalar joint is not released with these procedures.

* This article was accepted for publication prior to July 1, 1985. No conflict-of-interest statement was requested from the author.

† Read in part at the Annual Meeting of the Clinical Orthopaedic Society, Milwaukee, Wisconsin, October 8, 1982.

‡ Department of Orthopedic Surgery, Milwaukee Children's Hospital, 1700 West Wisconsin, P.O. Box 1997, Milwaukee, Wisconsin 53201.

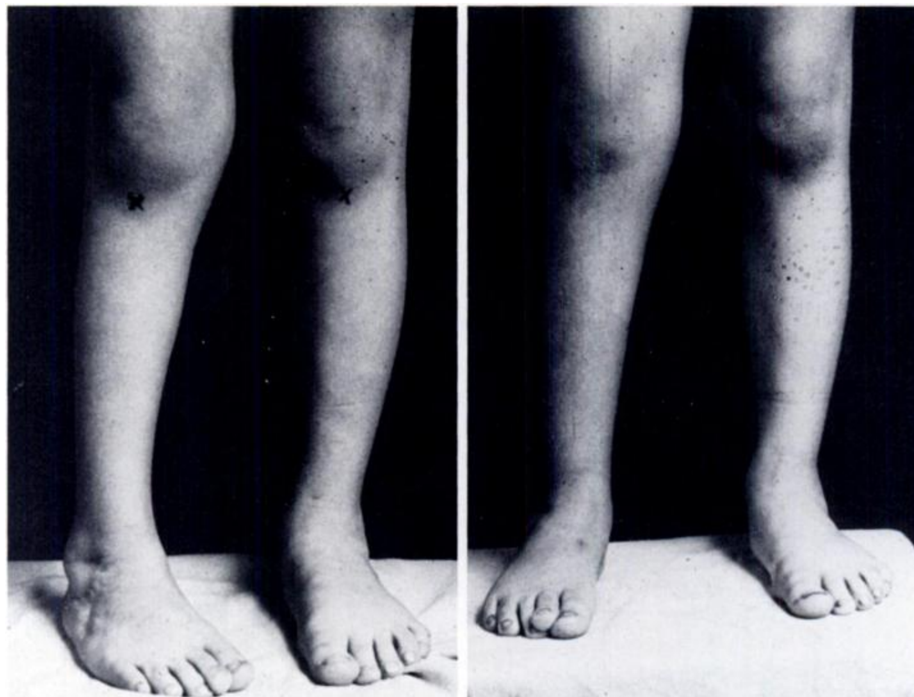

FIG. 2-A FIG. 2-B

Fig. 2-A: Significant medial deviation (toeing-in) due to inadequate correction of subtalar calcaneal rotation after conservative treatment. This often occurs after a posteromedial release.
Fig. 2-B: After complete subtalar release, the knee-foot alignment has been restored to normal.

Indications and Contraindications

There are three indications for complete subtalar release. First, the foot should be at least eight centimeters long; size is more important than age, as small size is technically the limiting factor. Second, the child should be less than four years old for the best results, although this surgery may be performed on a patient who is more than four years old, especially to correct medial rotation of the foot with respect to the knee and leg (Figs. 2-A and 2-B). Third, the procedure should be performed for the correction of resistant deformities of either talonavicular subluxation or varus angulation, or both.

There are two definite and two relative contraindications for the complete subtalar release. The first definite contraindication is the presence of a flat-top talus and the second is severely restricted plantar flexion due to a contracture of the anterior part of the capsule of the ankle, which may follow prolonged conservative treatment in plaster or prolonged retention in a cast after previous surgery. These will limit the success of the procedure. In the young child the two conditions may be differentiated by a lateral ankle-joint arthrogram, as the ossific center of the talus is too small to allow identification of a flat-top talus by standard radiographs. Relative contraindications are the presence of a rocker-bottom deformity and marked pes planus. These may predispose to postoperative formation of a dorsal bunion, although they, as well as the anterior ankle contracture, may be amenable to correction or improvement by conservative measures before surgery, particularly if the patient is less than six months old.

Preoperative Examination and Treatment

Before the complete subtalar release is performed, the foot should be assessed for complications that may have occurred after non-operative or previous surgical treatment. If the clinical examination shows a significant restriction of motion of the ankle, the total range of motion should be determined by lateral radiographs of the ankle in dorsiflexion and plantar flexion, with measurements of the lateral tibiotalar angle. If the total range of motion of the ankle is less than 25 degrees, if plantar flexion is the main component of motion that is restricted, and if the child is less than one year old, the parents should perform stretching exercises on the child for at least two weeks before surgery. They should stretch out the dorsiflexion contracture by gently forcing the child's foot into plantar flexion for fifty repetitions each time they change the diaper. If the child is more than six months old, stretching exercises may not be effective. If exercises are unsuccessful, an arthrogram of the ankle should be made to determine if a flat-top talus is present, for which, unfortunately, there is no known successful treatment. If a flat-top talus is present, an arthrogram will show the dome of the talus to be flat on the lateral radiograph, a finding that cannot be seen on a standard radiograph of a child at this age. If the limited plantar flexion is due to a capsular contracture of the anterior part of the ankle, the arthrogram will show a normal dome of the talus. In this instance, the surgeon should consider capsulotomy of the anterior part of the ankle before a complete subtalar release in order to ensure maximum mobility of the talus. Repositioning the calcaneus beneath the talus when the talus is

fixed in dorsiflexion results in a calcaneal position of the heel and a weak push-off during gait.

Much more frequently, however, the talus is limited in dorsiflexion (that is, there is a plantar flexion contracture). This is easily corrected by the posterior capsulotomy that is performed as part of the complete subtalar release.

In the child who is less than six months old, a flat foot or rocker-bottom deformity often can be treated successfully with successive plaster casts by reversing the corrective forces and applying the casts with the foot in the reverse position. For the flat foot, pressure is applied beneath the head of the talus on the medial plantar aspect of the foot while the hind part of the foot is inverted and the fore part is pronated and plantar flexed. In this way, the head of the talus is forced upward onto the sustentaculum tali. If a rocker-bottom deformity has occurred at the tarsometatarsal level, the fore part of the foot is plantar flexed, with pressure being applied to the plantar surface of the tarsometatarsal joint. Several cast applications may be necessary to achieve correction.

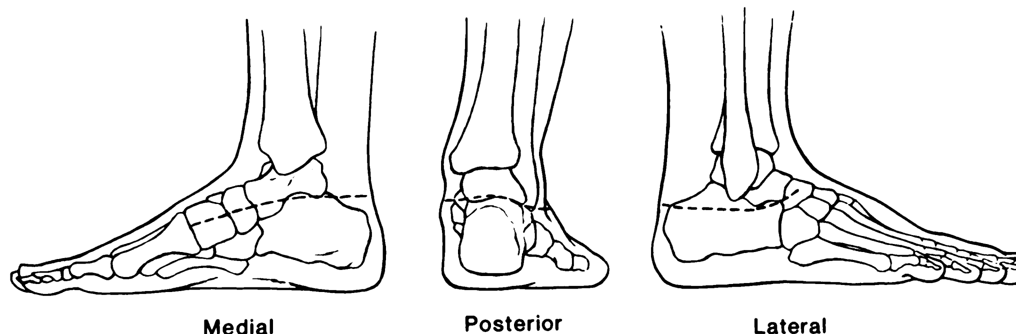

FIG. 3

The Cincinnati incision.

Surgical Technique

Complete subtalar release should be performed only by surgeons who have an excellent understanding of the anatomy and pathology that is involved. The use of magnifying glasses is essential for surgery on a foot that is less than ten or twelve centimeters long.

With the patient in a prone position, the knee is draped free and the patella and tibial tubercle are marked with indelible ink to facilitate realignment of the foot in relation to the knee. The operative approach is the u-shaped (Cincinnati) incision described by Crawford et al. (Fig. 3). A two-incision approach, using conventional posteromedial and oblique posterolateral incisions, is useful in patients who are more than three years old, in whom skin necrosis is more likely to develop[17].

The complete subtalar release is performed in four basic stages. The superficial dissection of the medial side of the foot, the dissection of the posterior part, the dissection of the lateral side of the foot, and the deep dissection of the medial side of the foot. To these may be added the calcaneocuboid capsulotomy or anterior calcaneal osteotomy, and the plantar release when necessary. The order in which the first four stages are performed may vary according to the surgeon's preference, but at the conclusion of the procedure, all described structures must have been dealt with. I prefer to perform the procedure in the order described.

The incision starts at the first metatarsal-cuneiform joint and is carried around the heel at the level of the posterior skin crease. It extends forward along the lateral surface of the foot to the lateral aspect of the talonavicular joint, curving upward at its lateral anterior aspect. The sural nerve is identified and freed of soft tissue for approximately 2.5 centimeters (one inch) proximally and distally. While the nerve can probably be cut without permanent loss of sensation, preserving it is preferable.

Stage I (Superficial Dissection of the Medial Side of the Foot)

The medial side of the foot is dissected next. The superficial origin of the abductor hallucis muscle is reflected from its origin on the laciniate ligament, toward the plantar surface. Its deep origin on the calcaneus is left intact. The medial neurovascular bundle is dissected free and mobilized distally to the level of the calcaneal branch.

Stage II (Dissection of the Posterior Part of the Foot and Ankle)

Dissection is continued in the posterior portion of the wound, where the Achilles tendon is dissected from the soft tissues on its posterior, medial, and lateral aspects so that as much length of each arm of the z as possible is achieved by a z-plasty in the sagittal plane. The sheath of the flexor digitorum communis is incised proximal to the ankle and is opened distal to the so-called Henry's knot, a thickening in the distal portion of the sheaths of the flexor hallucis longus and flexor hallucis brevis[6]. This knot is also released. The posterior tibial tendon is then lengthened proximal to the ankle by the z-lengthening technique so that it may be repaired in a lengthened manner at the end of the procedure. Part of its sheath that is distal to the ankle is opened later. The flexor hallucis longus tendon is also exposed from proximal to the ankle to its canal beneath the talus, as it will be necessary to retract it later.

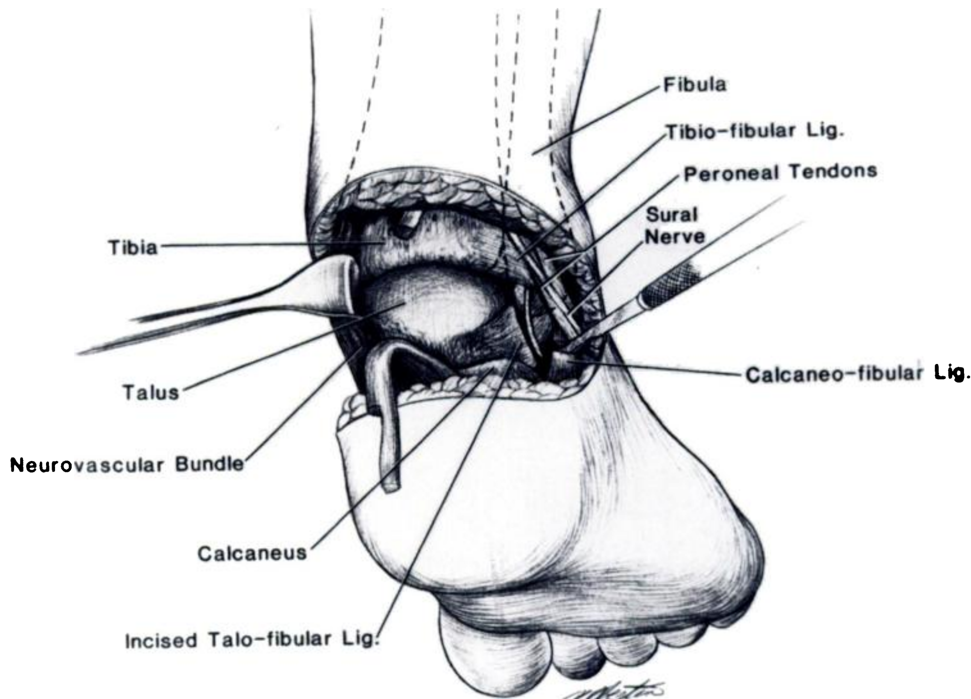

FIG. 4

Capsulotomies of the posterior part of the ankle and subtalar joint have been performed. Also, the posterior talofibular ligament has been released. The release of this ligament is essential for full dorsiflexion of the talus in the mortise. The calcaneofibular ligament has been partially incised by the scalpel.

A capsulotomy of the posterior aspect of the ankle joint is then done (Fig. 4). Starting laterally from the peroneal tendon sheath, the capsular incision is carried medially beneath the flexor hallucis longus, the neurovascular bundle, and the flexor digitorum communis to the edge of the posterior tibial-tendon sheath.

The flexor hallucis longus tendon lies on the medial side of the subtalar joint and serves as a guide to locating the subtalar joint. The posterior subtalar capsulotomy extends from the flexor hallucis longus tendon medially to the peroneal sheaths laterally. These sheaths are not opened at this level.

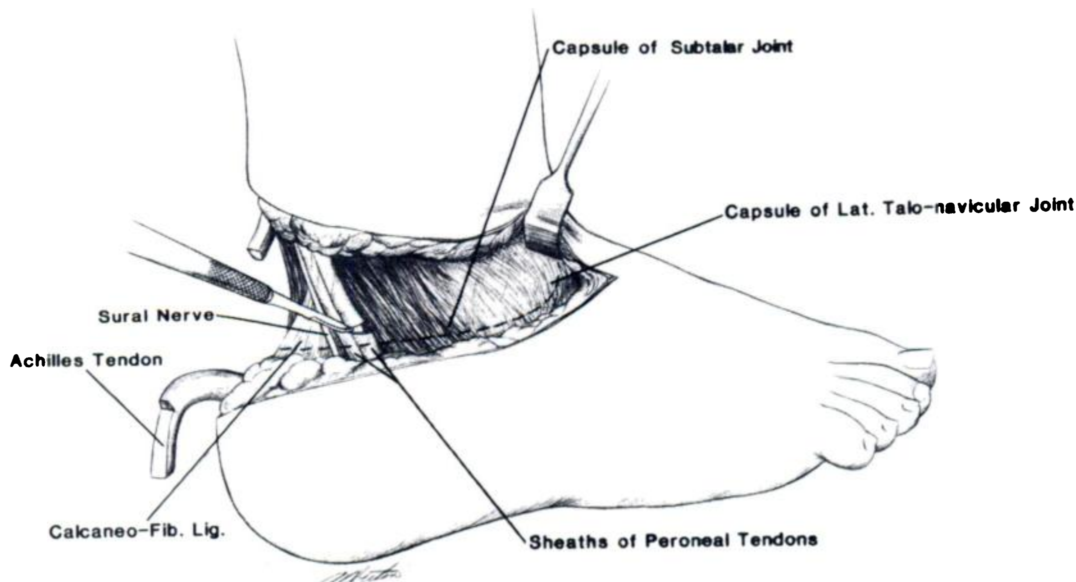

FIG. 5

The sheaths of the peroneal tendon are incised at the level of the skin incision on the lateral side of the foot. The tendons are then retracted, and the deep layers of the sheaths are incised.

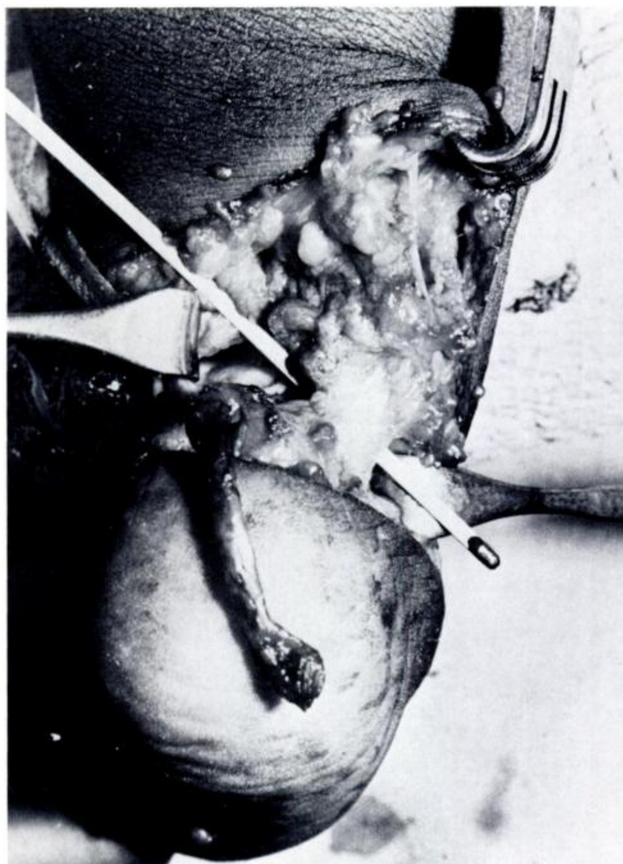

FIG. 6

The sheaths of the peroneal tendon have been incised in line with the skin incision, and the peroneal tendons have been retracted laterally (lower right retractor) with the sural nerve. The neurovascular bundle is retracted to the left. The probe lies beneath the large calcaneofibular ligament. This ligament must be completely released.

Stage III (Dissection of the Lateral Side of the Foot)

Dissection is then performed on the lateral side of the foot (Fig. 5). The peroneal tendon sheaths are incised at the level of the lateral subtalar joint, rather than proximally, to prevent the tendons from subluxating anteriorly over the malleolus. The tendon sheaths must be circumferentially incised around both tendons, leaving the tendons intact. Once the lateral portion of both sheaths is incised, both peroneal tendons are retracted, first posteriorly and then anteriorly, to facilitate the completion of the incision of the deep portions of these two sheaths. The tendons are mobilized (with the sural nerve) and are retracted anteriorly, allowing access for release of the large calcaneofibular ligament at the subtalar joint line (Fig. 6). It is very difficult to completely release this large ligament through a posteromedial incision. It is important to realize that in order to achieve rotation of the calcaneus, complete release of the calcaneofibular ligament is crucial. A hemostat or Frazier elevator is inserted beneath the calcaneofibular ligament from posterior to anterior. The ligament is incised as close to the calcaneal attachment as possible by cutting down onto the hemostat through the ligament. Thus, the peroneal sheaths will remain intact. The peroneal tendons are retracted laterally and the posterior talofibular ligament is incised vertically.

The lateral aspect of the subtalar capsule is opened next by cutting outward from within the joint to the level of the lateral part of the talonavicular joint (Fig. 5). Blunt dissection is then done, directed from laterally to medially, staying on the capsule and beneath the extensor tendons and the dorsal neurovascular bundle. The dorsal aspect of the neck of the talus is avoided so that the leash of vessels, which pass from the dorsalis pedis to the talar neck, are not injured. The blunt end of a Senn retractor is inserted across the dorsum of the foot, beneath the extensor tendons and neurovascular bundle. Capsulotomy of the lateral part of the talonavicular joint is then performed from its inferior lateral aspect to across the dorsum of the foot. The lateral part of the subtalar joint is then opened wide, and as much as possible of the interosseous talocalcaneal ligament is released (Fig. 7).

Stage IV (Deep Dissection of the Medial Side of the Foot)

Dissection is continued on the medial side of the foot (Fig. 8). The posterior tibial tendon was previously lengthened proximal to the level of the ankle by the z technique. A blunt probe is inserted into the canal of the posterior tibial tendon from proximal to the ankle and a small incision (one to two centimeters) is made in the sheath, perpendicular to the tibionavicular articulation. This incision is made over the tip of the probe, just proximal to the insertion of the posterior tibial tendon. The distal portion of the posterior tibial tendon is then passed down through the canal with a hemostat and out through the incision at the distal portion of the canal. One advantage of this technique is that the tendon can be reinserted back through its canal at the end of the procedure. Thus, it is more likely to function normally than if it is replaced in its open sheath, where fibrous adherence may take place. The tendon also acts as a pulley in helping to maintain the longitudinal arch.

The superficial deltoid ligament is next exposed for later release. To do this, the medial neurovascular bundle is retracted forward, so that it lies anterior to the flexor hallucis longus. The medial branch of the plantar nerve is retracted to help protect it during the release. Using a grooved Frazier dural elevator and scalpel, the flexor hallucis longus is released from its sheath to the level of Henry's knot[4]. It is necessary to remove the flexor hallucis longus tendon from its sheath, because the tendon passes directly over the subtalar joint in its course into the foot. Once this tendon has been retracted, the superficial deltoid ligament (medial aspect of the capsule of the subtalar joint) is opened from posterior to anterior using a Beaver blade scalpel (Rudolph Beaver; Waltham, Massachusetts) or a small, blunt-tipped scissors, cutting outward from within the subtalar joint. At the anterior end of the medial aspect of the subtalar joint, the talonavicular joint line is often difficult to identify, and the anterior medial end of the calcaneus can be am-

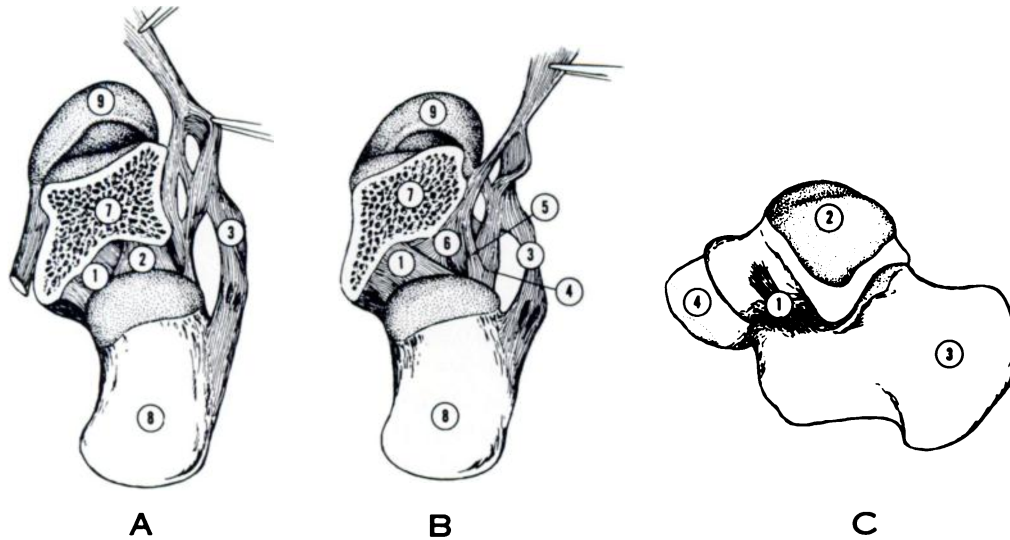

FIG. 7

The interosseous talocalcaneal ligament. *A* and *B* are drawings of an anatomical preparation of the tarsal canal. The posterior half of the talus has been removed by an oblique osteotomy. *A:* The anterior capsular ligament of the posterior talocalcaneal joint partially obscures the interosseous talocalcaneal ligament. *B:* It has been removed and the full width of the interosseous talocalcaneal ligament is visible. The medial root of the inferior extensor retinaculum crosses the interosseous talocalcaneal ligament anteriorly and joins with it as it inserts into the talus. 1 = interosseous talocalcaneal ligament, 2 = anterior capsular ligament of the posterior part of the talocalcaneal joint, 3 = insertion of the lateral root of the inferior extensor retinaculum on the inferior peroneal retinaculum, 4 = intermediate root of the inferior extensor retinaculum, 5 and 6 = medial roots of the inferior extensor retinaculum, 7 = talus, 8 = calcaneus, and 9 = navicular. (Adapted by permission from Sarrafian, S. K.: Anatomy of the Foot and Ankle. Descriptive, Topographic, Functional, p. 179. New York, J. B. Lippincott, 1983.)

C is a drawing of an anatomical preparation of the talus, calcaneus, and navicular as seen laterally. The cervical ligament (anterolateral talocalcaneal ligament) is the strongest ligament connecting the talus and calcaneus. It is frequently considered to be part of the interosseous talocalcaneal ligament, but only rarely are the two ligaments continuous. 1 = cervical ligament, 2 = talus, 3 = calcaneus, and 4 = navicular. (Adapted by permission from Sarrafian, S. K.: Anatomy of the Foot and Ankle. Descriptive, Topographic, Functional, p. 178. New York, J. B. Lippincott, 1983.)

putated in error. If visualizing the talonavicular joint line is difficult, the surgeon should return to this area after the talonavicular joint has been dissected.

Once the distal part of the posterior tibial tendon has been removed from its sheath, it serves as a guide to the location of the talonavicular joint (Fig. 8). The talonavicular joint is opened as follows. The distal portion of the posterior tibial tendon is retracted and the tibionavicular articulation

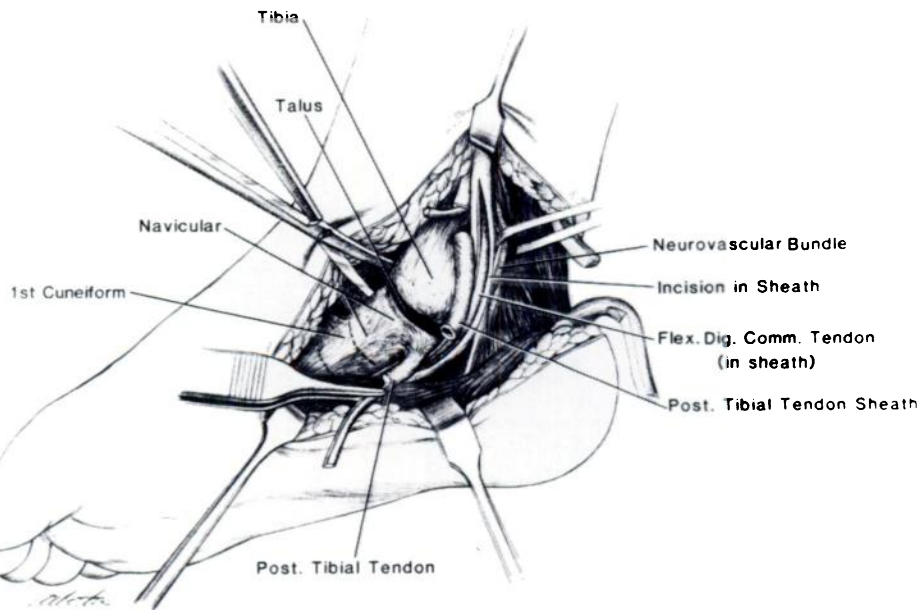

FIG. 8

The medial exposure of the talonavicular joint is often difficult. Exposure is facilitated by retracting the posterior tibial tendon, exposing the dorsal and volar aspects of the capsule, and incising the ligament tissue within the tibionavicular articulation. The head of the talus lies deep in this tissue and is often convex, but it can be flattened on its medial surface. One must use great care not to cut into the head of the talus.

is opened as much as possible. Using a blunt-tipped scissors, dissection across the dorsal part of the capsule is done, staying beneath the extensor tendons and neurovascular bundle and distally on the dorsum of the talar head to avoid the dorsal blood supply to the talus. Blunt dissection around the volar part of the capsule is performed. A Beaver blade is used for the rest of the dissection. The dorsal and volar parts of the capsule (spring ligament complex) are released as far laterally as possible. The head of the talus usually lies deep within this joint and can be damaged easily if dissection proceeds straight into the depth of the wound. With an instrument, palpation in the depth of the wound is used to locate the head of the talus, which may be either flat or convex on its medial side. The navicular lies on its medial surface. Therefore, retraction of the posterior tibial tendon distally will lift the navicular away from the talar head. The opening into the talonavicular joint may then be seen. It often lies at 90 degrees to the tibionavicular joint; that is, parallel to the long axis of the foot. This joint is opened by incising the dorsal and volar aspects of the capsule. An attempt should be made to join the incision in the dorsal part with the one in the lateral part of the talonavicular capsule. If the incision in the lateral part cannot be reached, after returning to the lateral wound as much of the interosseous talocalcaneal ligament as possible and the remainder of the lateral part of the talonavicular joint are freed. From the medial side of the foot the anteromedial aspect of the subtalar joint is released, if this has not already been done. The anteromedial aspect of the calcaneus projects upward and may easily be amputated. This area occasionally forms a coalition with the talus, which must be released. A prominent anteromedial calcaneal beak may be differentiated from a small fibrocartilaginous coalition by distracting the calcaneus plantarward and viewing the subtalar joint from its posterior aspect. It is then often possible to see the medial side of the joint and to follow its level during dissection. When there is no coalition, an incision is made from posterior to anterior and outward from within the joint. The release is then carried across the small anterior portion of the subtalar joint. Any remaining part of the interosseous talocalcaneal ligament is then incised, as are any remaining portions of the dorsal and volar aspects of the capsule of the talonavicular joint. Often a remnant of the dorsal part of the capsule remains, preventing free movement of the navicular around the head of the talus. Once the navicular is free, nothing less than complete freedom of movement of the middle part of the foot around the talus should be accepted. To check for complete release, a hemostat is inserted between the talus and calcaneus, and they are spread apart for approximately a centimeter. The hemostat is passed around the head of the talus to be sure that there are no remaining capsular strands.

Calcaneocuboid Osteotomy or Calcaneal Osteotomy

The next step, release of the calcaneocuboid joint or wedge resection of the anterolateral part of the calcaneus, is indicated if the fore part of the foot still cannot be overcorrected with gentle abduction or if there is a strong tendency for the fore part of the foot to spring back into adduction when released. The calcaneocuboid release is used in patients who are less than three years old, while vertical wedge resection of the anterior part of the calcaneus is used for older patients. Calcaneal osteotomy is preferable to the Evans and Lichtblau wedge resections because the calcaneocuboid joint is retained.

Releasing the calcaneocuboid joint may be technically difficult. The foot is displaced laterally beneath the talus so

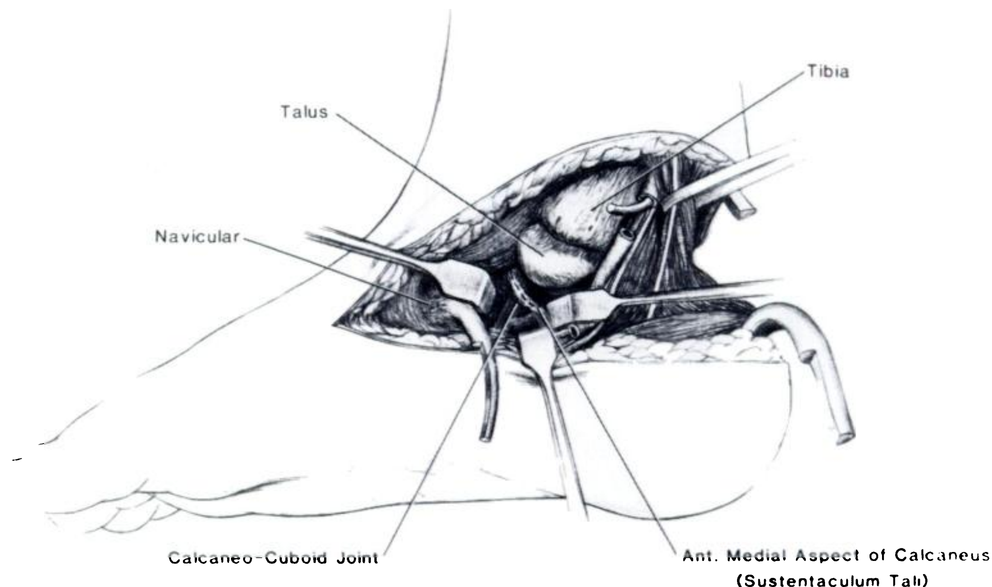

FIG. 9

The medial aspect of the calcaneocuboid joint lies deep within the medial wound. The peroneus longus lies on the inferior surface of the joint, and care must be taken not to injure this while cutting the plantar aspect of the capsule.

that the dorsum of the calcaneocuboid joint is easily accessible through the lateral wound. The anterolateral aspect of the calcaneus projects forward. The joint can frequently be identified by probing the soft tissues that overly this region. If it cannot be identified, a Keith needle should be inserted into the area and a lateral radiograph should be made to determine the position of the joint. The dorsal aspect of the joint capsule should then be released except for the lateral one-third. This helps to prevent dorsal subluxation of the joint. A dural elevator should be inserted in the joint through the medial part of the capsule to subsequently help to locate this joint from the medial wound.

vertically, approximately one centimeter posterior to the calcaneocuboid joint. After the wedge has been removed, the osteotomy is closed and fixed with a threaded Kirschner wire. If this does not correct the adduction of the fore part of the foot, a plantar release may be done at this time. One reason why calcaneocuboid capsulotomy or calcaneal osteotomy is preferred to the plantar release as a first step in the correction of adduction of the fore part of the foot is that either one provides a greater degree of correction than the plantar release. With the former the whole fore part of the foot shifts as a unit, while with a plantar release only the first ray tends to move laterally while the other rays

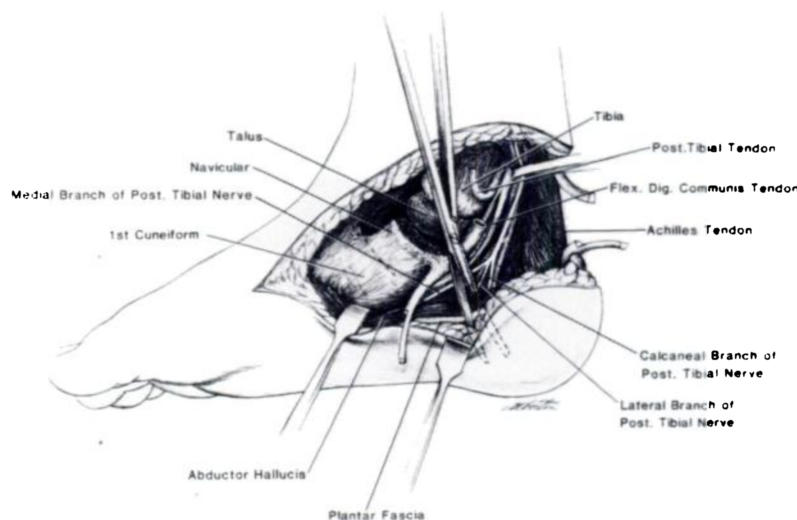

FIG. 10

The plantar release is performed through the medial wound by incising the abductor hallucis muscle near its origin, the medial half of the plantar fascia and the quadratus plantae. To accomplish this, the space between the lateral plantar nerve and the calcaneal nerve must be opened to permit insertion of the scissors.

Next, the calcaneocuboid joint is exposed from the medial wound. For access to this joint, the medial part of the calcaneonavicular ligament should now be released if it has not been released previously. Three Senn retractors are inserted in the space that lies between the anterior end of the medial part of the calcaneus, the proximal edge of the navicular, and the plantar structures (Fig. 9). The joint lies deep in the wound, and the fat that occupies the depths of this space must be removed in order to visualize the joint. Once the dural elevator has been located in the depths of the wound, the remainder of the medial aspect of the joint can be incised easily. The peroneus longus tendon can be visualized lying beneath the joint and is retracted inferiorly. The plantar portion of the capsule of the joint is then incised. The lateral part of the capsule and lateral one-third of the dorsal part of the capsule of this joint should not be opened because they act as a hinge that stabilizes the middle part of the foot on the hind part.

If vertical wedge resection of the anterior part of the calcaneus is required, it is performed by removing a laterally based one-half to one-centimeter wedge. The peroneus longus is dissected free from the lateral surface of the calcaneus and is protected with a retractor. The osteotomy is made

show much less correction. Also, with the calcaneocuboid capsulotomy and calcaneal osteotomy the plantar arch is retained, while it is frequently lost with the plantar release. Therefore, a plantar release is performed if any cavus deformity, talonavicular subluxation, or residual adduction of the fore part of the foot is still present after complete subtalar release and calcaneocuboid capsulotomy or calcaneal osteotomy. I now believe that a plantar release is necessary in fewer than 15 per cent of club feet.

Plantar Release

To perform the plantar release, the axilla between the calcaneal nerve and the lateral plantar nerve and artery is developed by blunt dissection. The edge of the plantar fascia is identified in the plantar soft tissues and its plantar surface is freed of adipose tissue. The blades of a Metzenbaum or Mayo scissors are then placed over and under the plantar fascia, the latter lying within the axilla of the two nerves. The quadratus plantae and the origin (deep head) of the abductor hallucis are incised simultaneously. If the inner blade of the scissors is kept against the anterior part of the calcaneus, the lateral plantar nerve and vessel will not be injured (Fig. 10).

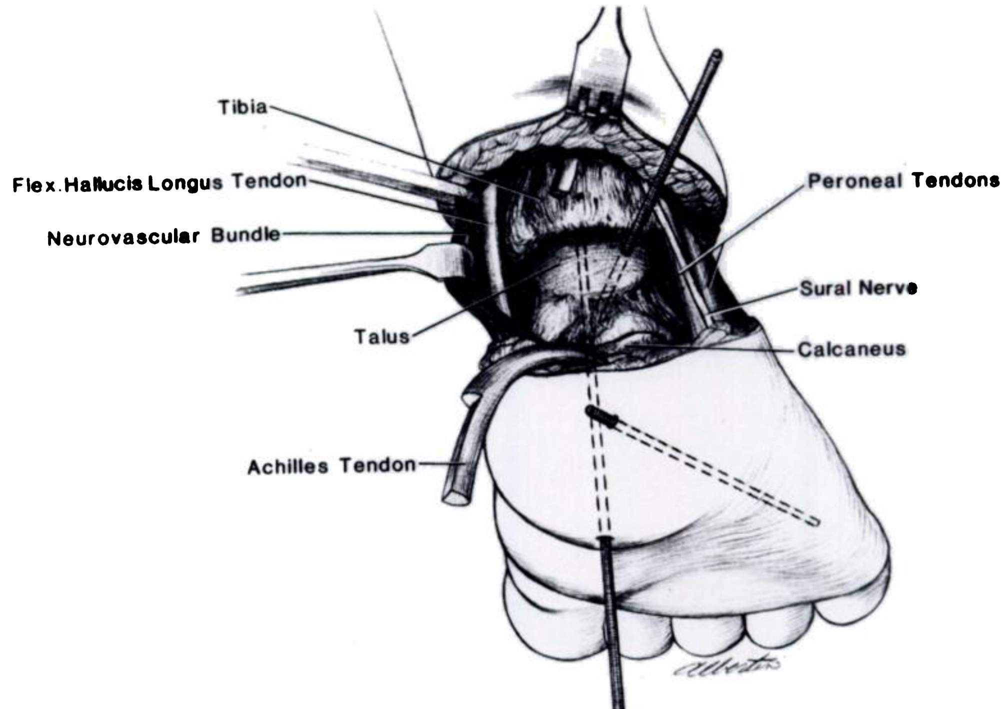

FIG. 11
The three Kirschner wires are shown in place.

Repositioning of the Bones and Placement of the Pins

This is the most important part of the procedure. After release of the interosseous talocalcaneal ligament and the talonavicular joint, the foot can move freely about the talus. For this reason, the use of Kirschner-wire fixation of the foot to the talus is imperative until ligament healing occurs. The use of threaded Kirschner wires is essential. If a non-threaded wire is used and the talonavicular pin migrates anteriorly, a troublesome pin-tract infection may result. If the pin migrates several millimeters posteriorly, its retrieval becomes extremely difficult and opening the posterior wound may be necessary. Furthermore, with subsequent postoperative manipulations of the ankle, pin migration may occur if threaded wires are not used. The pins that are most frequently used in children who are less than one year old are 0.062 and 0.045 centimeter in diameter.

Talonavicular Pin and Talocalcaneal Pin (Fig. 11)

The navicular is displaced lateral to the talar head. If it cannot be easily displaced, the usual cause is incomplete release of the dorsal part of the capsule, which must be completely incised before the Kirschner wire is inserted. A Kirschner wire is inserted through the lateral aspect of the posterior ridge of the talus so that it emerges at the center of the distal tip of the talar head.

Before the pin is inserted farther, the relationship of the navicular to the talar head must be carefully scrutinized. The medial side of the navicular normally should protrude slightly medially beyond the edge of the talar head and should not be flush with the side of the talar head and neck. The talus should not be plantar flexed with respect to the navicular, nor should the navicular be displaced superiorly in relationship to the talar head. This relationship can be palpated manually or with an instrument. The lateral side of the talonavicular joint also should be palpated carefully to be certain that there is no lateral step-off at the level of the joint.

The talonavicular pin is then inserted into the navicular. Before it is passed through the dorsum of the foot, the position of the foot must be checked carefully (Fig. 12). The long axis of the foot should be in approximately 10 degrees of external rotation with respect to the previously marked tibial tubercle. The foot must not be supinated, and it must not be translated or tilted laterally into a valgus position. If the position is not satisfactory, the talonavicular pin is withdrawn from the navicular, the navicular is re-positioned, and the talonavicular pin is reinserted. The proper position can usually be achieved at the first or second attempt.

Placement of the talocalcaneal pin through the center of the interosseous ligament restores the axis of rotation between the talus and calcaneus to its normal position and helps to prevent malplacement, particularly medial and lateral translation. Proper placement of the pin is essential. To accomplish this, the posterior part of the calcaneus is pulled plantarward so that the articular surfaces of the subtalar joint are visible and the approximate center of the remnants of the interosseous calcaneal ligament on both the calcaneus and the talus are identified. The second threaded Kirschner wire is inserted through the plantar surface of the calcaneus to emerge at the center of the remnant of the interosseous

talocalcaneal ligament on the calcaneus. The talocalcaneal pin is then inserted in the talus at the center of the attachment of the interosseous talocalcaneal ligament. It should not protrude into the ankle joint. The subtalar joint should be closed or should be almost completely closed when the pin is inserted.

The correct position of the talonavicular joint and the position of the foot with respect to the knee are critical to normal realignment of the foot. They must be positioned precisely. This cannot be overemphasized.

Calcaneocuboid Pin (Fig. 11)

A third pin is used if an anterolateral calcaneal osteotomy has been done. An assistant applies three-point manual correction: over the medial part of the heel, over the lateral aspect of the calcaneal osteotomy site, and medially over the first metatarsal head. The pin is inserted through the posterior part of the calcaneus, several millimeters below the edge of the skin incision, and is directed toward the center of the cuboid.

If one pin does not securely fix the joint, a second pin may be inserted through the cuboid into the calcaneus. After calcaneocuboid capsulotomy, pin fixation is not required, provided the lateral part of the capsule remains intact. The joint will hinge open medially and remain open with three-point molding of the cast. If the incision in the capsule is excessive and dorsal or lateral subluxation occurs, the joint can easily be reduced and stabilized by inserting a Kirschner wire across the joint.

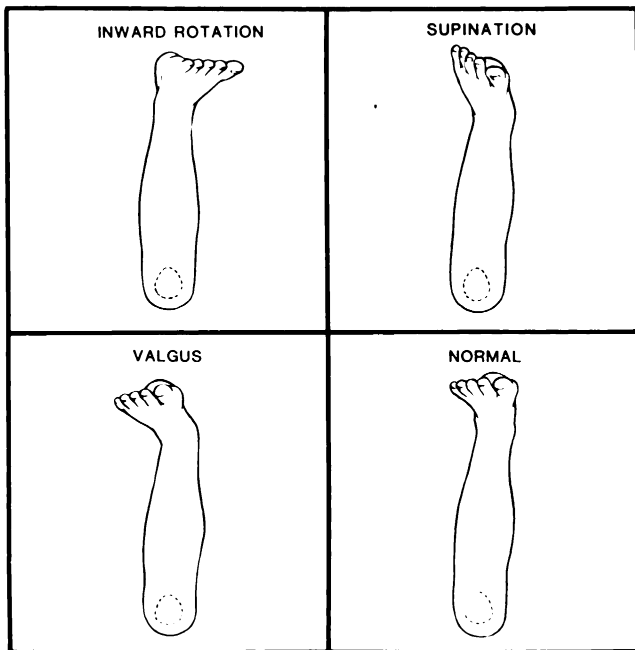

FIG. 12

The position of the foot with respect to the knee during surgery is shown. The patient is in the prone position and the knee is flexed 90 degrees. The knee has been marked with an indelible pen. The foot must be rotated around the talus until it is aligned with the knee, and then it is properly aligned in other planes. The figure shows the three characteristically abnormal positions (inadequate external rotation, supination, and valgus) and the normal position of the foot.

Lengthening of the Tendon, Intraoperative Radiographs, and Repair of the Tendon

Next, the flexor hallucis longus and flexor digitorum communis are evaluated to determine whether lengthening is required. These tendons stretch to some degree with subsequent changes of the cast, but if they are tight and cannot be stretched passively past the neutral position, they should be lengthened by means of a z-plasty.

At this point, the tourniquet is released and bleeding vessels are coagulated with electrocautery. Posteroanterior and lateral radiographs should be made routinely. Although all of the patients reported on in Part II of this paper had intraoperative anteroposterior radiographs, I have recently started making posteroanterior radiographs. These are easier to make and the angular measurements are identical to those on the anteroposterior radiograph. The technique involves placing a cassette on the table, placing the dorsum of the foot on the cassette, and angling the x-ray tube so that the beam is directed 30 degrees from the vertical. The posteroanterior and lateral talocalcaneal angles should be measured (normal posteroanterior talocalcaneal angle, 20 to 40 degrees; normal lateral talocalcaneal angle, 35 to 50 degrees). A line through the talar axis should bisect the base of the first metatarsal as shown on the posteroanterior radiograph. If the lateral border of the foot clinically appears to have a sharp angular deformity, or if the cuboid appears to be displaced medially on the posteroanterior radiograph, this indicates subluxation of the calcaneocuboid joint, which requires reduction and Kirschner-wire fixation. On the lateral radiograph, a line through the talar axis should pass through the base of the first metatarsal. These two talar axes give an approximate indication that the navicular is in acceptable alignment with the talus and is not displaced too far laterally or dorsally. On the lateral radiograph, if the first metatarsal cannot be identified, the most dorsal metatarsal should be used. To achieve these relationships precisely may be difficult, but if excellent results are to be obtained the surgeon must strive for radiographic correction. If the radiographs show satisfactory position of the talus and calcaneus and a satisfactory talar-metatarsal relationship, the talonavicular pin is withdrawn from the dorsum of the foot until the posterior tip of the pin no longer protrudes from the posterior part of the talus. All pins are then cut off subcutaneously.

The posterior tibial tendon is passed up through its canal and reattached under physiological tension. This is done by placing the foot in maximum dorsiflexion and applying tension to both ends of the tendon simultaneously with two pairs of forceps while they are sutured. The proper length of the Achilles tendon is determined in the same manner, except that the foot should not be placed in more than 10 degrees of dorsiflexion.

Postoperative Care: Casts, Pin Removal, Braces, and Exercises

The position of the foot at which capillary refill of the

proximal skin edge is complete is observed, and the foot is placed in 10 degrees less dorsiflexion while a long cast is applied with the knee at 90 degrees of flexion. While the plaster is setting, the foot is positioned so that it is in approximately 10 degrees of external rotation with respect to the knee. Three-point pressure is again applied to the foot. This opens the calcaneocuboid joint on the medial side and helps to achieve correction of the adduction of the fore part of the foot. The cast is placed in an overhead sling until the first time the cast is changed. There is often significant swelling, and it is imperative that the child not be allowed to go home before most of the swelling has subsided. It is rarely necessary to bivalve the cast if the leg is elevated immediately. The cast is changed at ten days and again at three weeks, at which time the pins are removed. These cast changes are performed on an outpatient basis under light general anesthesia, which allows the surgeon to examine the wound, gently manipulate the ankle joint (especially into plantar flexion), and achieve further dorsiflexion as the wound heals. The last cast is removed at six weeks without an anesthetic. After removal of the cast, McCollum's orthosis is used at night and straight-last shoes are worn during the day. The parents perform stretching exercises on the child for a minimum of two years postoperatively. The foot is gently but firmly plantar flexed and dorsiflexed and the heel is inverted and everted twice a day, for twenty-five to fifty repetitions of each movement.

Discussion

Although the principles on which the complete subtalar release have been developed are identical to those of McKay[12], the complete subtalar release just described differs from McKay's technique[13] in a significant number of ways. Probably the greatest differences in the two procedures are not the specific structures that are released but the technique by which the bones are repositioned, the use of intraoperative radiographs to verify correction, and the postoperative care.

McKay used different clinical criteria for repositioning the foot and did not use intraoperative radiographs to demonstrate that the bones have been repositioned in the proper alignment[13]. His technique of hinged casts for early motion, especially to improve plantar flexion, is appealing. However, I have found the application of these casts to be time-consuming, and the child's foot has a tendency to come out of the slipper portion.

The surgical technique has many less important differences. I invariably release the interosseous talocalcaneal ligament and the posterior talofibular ligament, while McKay occasionally left these ligaments intact. I have found that the release of these structures invariably gives greater correction than when they are not released, and the release of other ligaments becomes much easier. McKay's treatment of tendons differs from mine in that he released the sheaths of the flexor hallucis longus and flexor digitorum longus from the underlying tissues and rolled the sheaths up the tendons, while I incise the sheaths. If the flexor digitorum and flexor hallucis longus have to be lengthened, I believe that the chances for embedment in scar are just as great with the tendons in their sheaths as they would be if the sheaths are opened longitudinally. McKay opened the sheath of the posterior tibial tendon, while I retain it. I prefer to retain this sheath, which passes beneath the malleolus, so that the tendon can be reinserted through its canal, which then acts as a pulley, giving support to the medial longitudinal arch of the foot. McKay used a coronal incision for lengthening the Achilles tendon while I prefer a sagittal incision, leaving the distal portion attached laterally and thereby creating a more effective valgus force on the heel. I prefer to incise the peroneal sheath at the level of the skin incision on the lateral side of the foot rather than proximally behind the malleolus, as McKay did, and thereby prevent the tendons from subluxating over the malleolus. McKay achieved this by suturing soft tissue to the tendon sheath proximal to the ankle.

McKay routinely performed a plantar release, while I reserve this for the more severely affected foot and now use this in only a few selected instances. I think that the medial part of the longitudinal arch is maintained and the appearance of the foot is substantially improved when this release can be avoided. I use a calcaneal osteotomy in the correction of the fore part of the foot in the older child, whereas McKay apparently employed a calcaneocuboid capsulotomy in patients of all age groups.

Finally, McKay occasionally excised the prominent medial portion of the navicular and part of the articular surface of the calcaneus. I find it undesirable to remove articular cartilage and have not found it necessary to do so when the navicular is positioned properly on the head of the talus, as the articular surface of the subtalar joint usually closes satisfactorily.

Interosseous Talocalcaneal Ligament (Fig. 7)

Surgical release of the interosseous talocalcaneal ligament is a controversial issue. The argument for leaving the interosseous talocalcaneal ligament intact is based on the belief that there is less chance of subsequent overcorrection of the talonavicular and subtalar joints. Overcorrection that is seen postoperatively is due to malpositioning at surgery and is very rarely due to a subsequent gradual drift that results from the release of the interosseous talocalcaneal ligament. It is believed that the other structures can be released while leaving this ligament intact and still obtaining full correction. I have been able to retain the interosseous talocalcaneal ligament in dissections of fetal specimens of club feet and achieve full correction, but after two or three months of conservative treatment the interosseous talocalcaneal ligament is usually too contracted to permit the easy release of the other ligaments. However, when the surgeon is able to release the other ligaments without great difficulty and to prove radiographically that correction is complete, then I believe that the interosseous talocalcaneal ligament should be retained. Whenever this ligament is not released, I believe that the surgeon has an obligation to the patient

to prove objectively, by intraoperative radiographs, that correction is complete. However, when this ligament is released, one must be absolutely certain that the calcaneus and navicular are repositioned precisely on the talus and their correct positions are verified radiographically.

Conclusions

The complete subtalar release consists of a standard posteromedial release with additional releases of the lateral part of the talonavicular joint, the lateral part of the subtalar joint, the calcaneofibular ligament, and the interosseous talocalcaneal ligament. It is indicated when the foot is at least eight centimeters long, the patient is less than four years old, and there is talonavicular subluxation or varus deformity, or both, that has resisted non-operative treatment. Definite contraindications include flat-top talus and severely restricted plantar flexion due to contracture of the ankle. Relative contraindications include rocker-bottom deformity and marked pes planus.

Preoperative care involves a thorough evaluation and, if possible, correction of the complications of conservative treatment and previous surgery.

The operative approach through the u-shaped (Cincinnati) incision is recommended. A two-incision approach is indicated in patients who are more than three years old, who are more likely to experience skin necrosis. Secondary procedures include release of the calcaneocuboid joint or wedge resection of the anterolateral part of the calcaneus as indicated for persistent adductus deformity of the fore part of the foot. Plantar release may also be indicated for persistent adductus deformity of the fore part of the foot, talonavicular subluxation, or pes cavus.

Proper positioning of the foot for Kirschner-wire fixation is critical. Two or three threaded Kirschner wires are inserted with precision to hold the foot in the corrected position. Intraoperative radiographs are mandatory to determine that the bones are in their normal positions and relationships.

Postoperative care includes manipulations of the ankle under anesthesia, early removal of the pins and cast, daily exercises to improve motion of the ankle, and prolonged bracing at night.

References

1. BETHEM, DANIEL, and WEINER, DENNIS: Radical One-Stage Posteromedial Release for the Resistant Clubfoot. Clin. Orthop., **131:** 214-223, 1978.
2. CRAWFORD, A. H.; MARXEN, J. L.; and OSTERFELD, D. L.: The Cincinnati Incision: A Comprehensive Approach for Surgical Procedures of the Foot and Ankle in Childhood. J. Bone and Joint Surg., **64-A:** 1355-1358, Dec. 1982.
3. EILERT, R. E., and ELIAS, S. G.: A Comparison of Lloyd-Roberts and Turco Release for the Treatment of Idiopathic Talipes Equinovarus. Orthop. Trans., **8:** 379, 1984.
4. EVANS, DILLWYN: Relapsed Club Foot. J. Bone and Joint Surg., **43-B(4):** 722-733, 1961.
5. GHALI, N. N.; SMITH, R. B.; CLAYDEN, A. D.; and SILK, F. F.: The Results of Pantalar Reduction in the Management of Congenital Talipes Equinovarus. J. Bone and Joint Surg., **65-B(1):** 1-7, 1983.
6. HENRY, A. K.: Extensile Exposure. Ed. 2. Edinburgh, E. and S. Livingstone, 1957.
7. JOHANSON, J. E.; HORAK, R. D.; and WINTER, R. B.: Gillette Children's Hospital Experience with the Turco Procedure for Clubfeet (Talipes Equinovarus). Minnesota Med., **64:** 745-749, 1981.
8. LICHTBLAU, SHELDON: A Medial and Lateral Release Operation for Club Foot. A Preliminary Report. J. Bone and Joint Surg., **55-A:** 1377-1384, Oct. 1973.
9. McCOLLUM, R. G.: A Functional Brace for Congenital Clubfoot. A Preliminary Report. Clin. Orthop., **89:** 197-200, 1972.
10. McKAY, D.: The Ankle and Talonavicular Joints. Read at Pediatric Orthopaedic International Seminar, San Francisco, California, May 8, 1977.
11. McKAY, D.: The Surgical Treatment of Talipes Equinovarus with Emphasis on Subtalar Realignment. Read at the Annual Meeting of the Pediatric Orthopaedic Society, San Diego, California, Oct. 4, 1980.
12. McKAY, D. W.: New Concept of and Approach to Clubfoot Treatment: Section I — Principles and Morbid Anatomy. J. Pediat. Orthop., **2:** 347-356, 1982.
13. McKAY, D. W.: New Concept of and Approach to Clubfoot Treatment: Section II — Correction of the Clubfoot. J. Pediat. Orthop., **3:** 10-21, 1983.
14. McKAY, D. W.: New Concept of and Approach to Clubfoot Treatment: Section III — Evaluation and Results. J. Pediat. Orthop., **3:** 141-148, 1983.
15. PORAT, S.; MILGROM, C.; and BENTLEY, G.: The History of Treatment of Congenital Clubfoot at the Royal Liverpool Children's Hospital: Improvement of Results by Early Extensive Posteromedial Release. J. Pediat. Orthop., **4:** 331-338, 1984.
16. SARRAFIAN, S. K.: Anatomy of the Foot and Ankle. Descriptive, Topographic, Functional. Philadelphia, J. B. Lippincott, 1983.
17. SIMONS: Cincinnati Approach for Complete Subtalar Release of Clubfeet [abstract]. J. Pediat. Orthop., **2:** 439, 1982.
18. SIMONS, G. W., and SARRAFIAN, SHAHAN: The Microsurgical Dissection of a Stillborn Fetal Clubfoot. Clin. Orthop., **173:** 275-283, 1983.
19. SMITH, R. B.: Dysplasia and Effects of Soft Tissue Release in Congenital Talipes Equinovarus. Clin. Orthop., **174:** 303-309, 1983.
20. THOMPSON, G. H.; RICHARDSON, A. B.; and WESTIN, G. W.: Surgical Management of Resistant Congenital Talipes Equinovarus Deformities. J. Bone and Joint Surg., **64-A:** 652-665, June 1982.
21. TURCO, V. J.: Surgical Correction of the Resistant Club Foot. One-Stage Posteromedial Release with Internal Fixation: A Preliminary Report. J. Bone and Joint Surg., **53-A:** 477-497, April 1971.
22. TURCO, V. J.: Resistant Congenital Club Foot — One-Stage Posteromedial Release with Internal Fixation. A Follow-up Report of a Fifteen-Year Experience. J. Bone and Joint Surg., **61-A:** 805-814, Sept. 1979.