Triple Arthrodesis in Adults

Keith L. Wapner, MD

Abstract

Surgical fusion of the subtalar, talonavicular, and calcaneocuboid joints historically evolved for the treatment of paralytic deformities of the foot where there was often notable bone deformity. Today most of these procedures are performed in adults for posttraumatic arthritis, rheumatoid arthritis, or end-stage posterior tibial tendon rupture with fixed bone deformity. Triple arthrodesis is a technically demanding procedure that generally involves a prolonged recovery time. When proper alignment is obtained, predictable and significant improvement in symptoms occurs, but the resultant loss of hindfoot motion is not without consequence. Residual discomfort and secondary arthrosis of the ankle and tarsometatarsal joints should be expected. Because of the complications of residual deformity, pseudarthrosis, avascular necrosis of the talus, and ankle and midtarsal arthritis, it has been recommended that it be used only as a salvage operation in older patients who have a painful, fixed deformity or disabling instability refractory to other treatment options. Despite these caveats, most patients who undergo triple arthrodesis for appropriate indications report significant improvement in their symptoms and level of function.

J Am Acad Orthop Surg 1998;6:188-196

In 1913, Davis[1] first established the concepts of simultaneous fusion of the talocalcaneal and talonavicular joints as a means of correcting varus-valgus and abduction-adduction deformities of the foot. Ryerson[2] felt that failure to fuse the calcaneocuboid and tarsometatarsal joints was a main cause for recurrent deformity and advanced the concept of including these joints in the fusion mass.

Over time, the concept of including the calcaneocuboid joint with the talonavicular and talocalcaneal joints gained acceptance, and incorporating the tarsometatarsal joints was abandoned. In paralytic deformities, it was often necessary to perform osteotomies and bone resection to correct the foot into a plantigrade position. At present, most of these procedures in the adult are performed for posttraumatic arthritis, rheumatoid arthritis, or end-stage posterior tibial tendon rupture with fixed bone deformity in which the involved tarsal bones have lost their normal anatomic configuration.[3]

There is extensive documentation of the results and complications of triple arthrodesis in children with paralytic disorders.[4-13] Only recently have there been reports on the long-term results in adults[14-20] (Table 1). Similar complications resulting from residual deformity, pseudarthrosis, avascular necrosis, and ankle and midtarsal arthritis have been reported in children and adults.

Most clinical investigators have concluded that triple arthrodesis is a technically demanding procedure that can improve the position and function of the foot. However, because of the associated complications, it should be reserved as a salvage procedure for the end-stage painful unstable foot or the foot with a fixed, disabling deformity.[17]

Indications for Triple Arthrodesis

The goal of hindfoot procedures of this type is to achieve a stable, painless plantigrade foot. Whenever possible, a procedure that preserves normal hindfoot motion and mechanics should be considered. In instances in which this would be inappropriate, triple arthrodesis can be used as a valuable salvage procedure. The most common indications include posttraumatic degenerative arthritis and rheumatoid arthritis. If the arthritis is limited to the subtalar joint and the transverse tarsal joints have not

Dr. Wapner is Professor of Orthopedic Surgery and Director of the Division of Foot and Ankle Surgery, Allegheny University, Philadelphia.

Reprint requests: Dr. Wapner, Division of Foot and Ankle Surgery, Allegheny University, 219 North Broad Street, Fifth Floor, Philadelphia, PA 19107.

Table 1
Results of Triple Arthrodesis in Adults

Study	Average Follow-up, months (range)	No. of Patients	Results*
Graves et al[17]	42 (27-156)	17	14 (82) satisfied
Sangeorzan et al[19]	60 (30-132)	44	34 (77) good, 6 (14) fair
Scranton[20]	67 (12-120)	47	27 (57) good, 15 (32) fair
Bennett et al[14]	43 (36-60)	22	8 (36) good, 13 (59) fair
Cracchiolo et al[15]	44 (24-80)	26	24 (92) good, 1 (4) fair
Figgie et al[16]	60 (36-156)	49	46 (94) good

* Expressed as number of patients (%).

developed any compensatory deformity, they need not be fused. This reduces the load on the ankle and midfoot. Similarly, if the arthritis is limited to the calcaneocuboid joint, an isolated fusion should be considered, as it will preserve approximately 70% of residual hindfoot motion.[21] If more than one joint is involved or if there is a fixed deformity of the foot, triple arthrodesis is recommended.

In the case of end-stage posterior tibial tendon dysfunction, the best choice of fusion continues to be debated. With severe fixed abduction of the forefoot, isolated subtalar fusion may lead to undercorrection at the talonavicular joint. Double arthrodesis of the talonavicular and calcaneocuboid joints may be sufficient in those instances in which the transverse tarsal joint is supple, the subtalar joint is flexible, and the forefoot can be brought back into a plantigrade position. The double arthrodesis entails less patient morbidity but produces the same degree of loss of motion as a triple arthrodesis. In patients with fixed deformities, triple arthrodesis allows correction to a plantigrade foot.

Patients with a variety of neuromuscular deformities may present with pes cavus or pes planus deformities. A thorough preoperative understanding of the type and degree of deformity is essential for appropriate correction (Fig. 1).

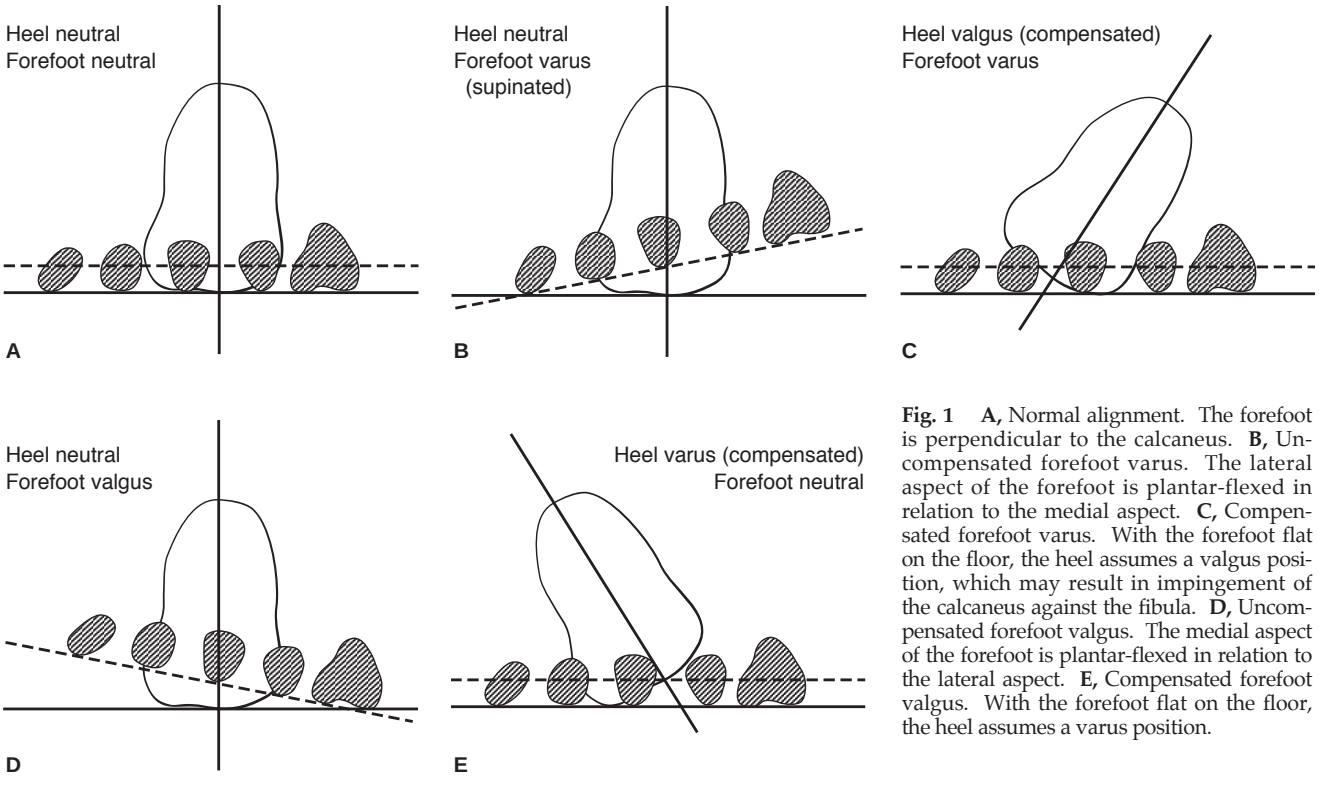

Fig. 1 **A,** Normal alignment. The forefoot is perpendicular to the calcaneus. **B,** Uncompensated forefoot varus. The lateral aspect of the forefoot is plantar-flexed in relation to the medial aspect. **C,** Compensated forefoot varus. With the forefoot flat on the floor, the heel assumes a valgus position, which may result in impingement of the calcaneus against the fibula. **D,** Uncompensated forefoot valgus. The medial aspect of the forefoot is plantar-flexed in relation to the lateral aspect. **E,** Compensated forefoot valgus. With the forefoot flat on the floor, the heel assumes a varus position.

Triple arthrodesis will allow correction of these severe deformities and restoration of a plantigrade foot. In younger adult patients, corrective osteotomy and soft-tissue releases should be used if possible.

Preoperative Evaluation

All patients who undergo triple arthrodesis should have adequate circulation. If pedal pulses are not palpable, preoperative arterial Doppler evaluation for ankle brachial indices, dorsalis pedis indices, and normal waveforms should be performed. Sensation should be documented preoperatively so that intraoperative nerve damage can be avoided. The presence of peripheral neuropathy must be identified to avoid the potential complication of postoperative Charcot arthropathy.

A complete understanding of the relationship between the forefoot and the hindfoot in supination and pronation deformities of the foot is essential for proper positioning of a triple arthrodesis. Pes planus deformity involves a pronated foot. The heel is in valgus, and the forefoot is abducted at the talonavicular joint and is in varus (Fig. 2, A). To obtain proper positioning of the foot at surgery, the heel must be brought out of excessive valgus to approximately 5 degrees of residual valgus. Forefoot abduction must be corrected by bringing the navicular medially to cover the head of the talus. This correction can be assessed by palpation of the medial side of the foot at the talonavicular joint to identify any residual subluxation. In general, adequate reduction will align the midline of the ankle joint with the second web space. Temporary pin fixation can be performed intraoperatively. The alignment should be confirmed radiographically before final fixation. Forefoot varus should be corrected to neutral by derotation of the metatarsals in the coronal plane.

In pes cavus, the foot is supinated with excessive heel varus and forefoot adduction and valgus (Fig. 2, B). At surgery, the heel must be reduced, and the forefoot must be corrected to neutral. Correction of deformity must occur in the sagittal and coronal planes to derotate the forefoot (Fig. 3) and restore the talocalcaneal angle (Fig. 4). Contraction of the plantar fascia may produce a plantar-flexed first ray, which contributes to the degree of fixed forefoot varus deformity. The Coleman block test can demonstrate this deformity; with this test, one observes the patient's foot from behind while placing the lateral aspect of the heel on wooden blocks of graduated heights until the forefoot is plantigrade.[22] Release of the plantar fascia may be required to gain full correction.

Patients with long-standing pes planus deformities will often have secondary contracture of the gastrocnemius-soleus complex. This can be best assessed by reducing the talonavicular joint to neutral and then dorsiflexing the ankle. If there is a contracture, Achilles tendon lengthening may be indicated.

Full-weight-bearing plain radiographs of the foot in the anteroposterior, lateral, and oblique projections and posterior, lateral, and mortise views of the ankle are usually sufficient for preoperative evaluation. The presence of any degenerative changes of the ankle or midfoot joints should be documented. Valgus angulation of the talus in the ankle mortise is suggestive of deltoid ligament insufficiency. This may promote degenerative arthritic changes in the ankle joint after triple arthrodesis due to

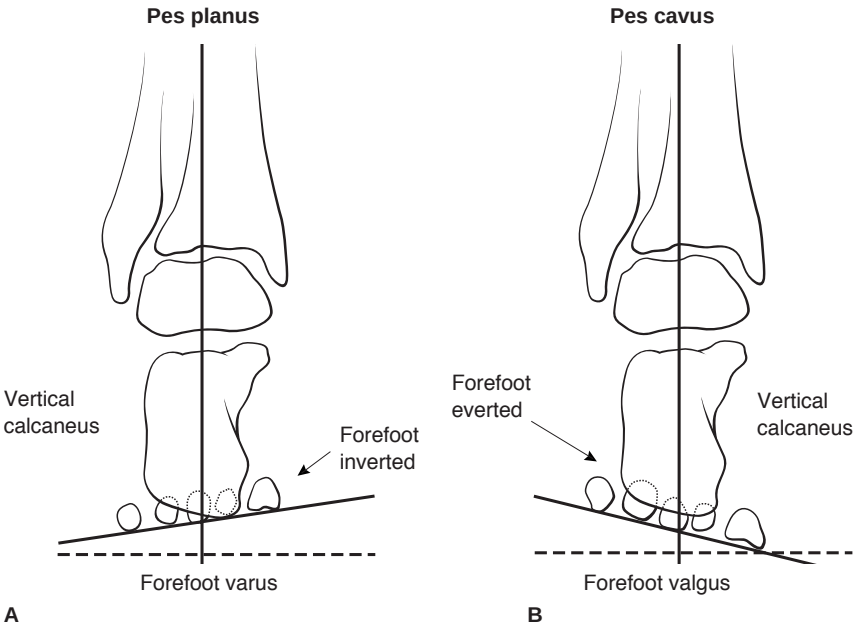

Fig. 2 **A,** Forefoot varus exists when the calcaneus is held vertical and the medial border of the foot is raised relative to the lateral border. **B,** Forefoot valgus exists when the calcaneus is held vertical and the lateral border of the foot is raised. (Adapted with permission from Graves SC: Triple arthrodesis in adults: Indications, technique, and results. *Operative Techniques Orthop* 1992;2:151-156.)

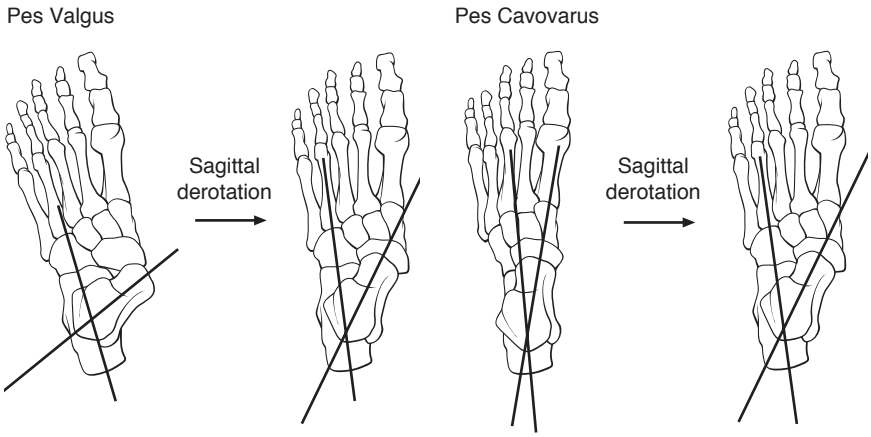

Fig. 3 Sagittal correction in the anteroposterior plane for pes valgus and cavovarus deformities. Talocalcaneal divergence is corrected by decreasing it in a valgus foot **(left)** and increasing it in a cavus foot **(right)**. (Adapted with permission from Scranton PE: Results of arthrodesis of the tarsus: Talocalcaneal, midtarsal and subtalar joints. *Foot Ankle* 1991;12:156-164.)

increased load on the lateral portion of the joint. In cases of severe deformity, preoperative computed tomography with sagittal reconstructions is helpful.

Surgical Technique

A number of techniques have been described for triple arthrodesis. Certain basic principles should be followed regardless of the surgeon's preferred technique. To lessen patient morbidity, the surgical incisions should be placed so as to avoid injury to the sensory nerves of the dorsum of the foot. Anatomic realignment of the hindfoot to 3 to 5 degrees of residual heel valgus and neutral alignment of the forefoot should be obtained. When preparing the joint surfaces, it is essential to remove all the residual cartilage and subchondral bone to the level of the exposed cancellous surfaces. Rigid fixation with compression of the joint surfaces is preferred to ensure maintenance of the corrected position and to promote fusion. Bone grafting may be needed if a large bone defect must be bridged.

The approach described by Mann[3] utilizes two incisions, one medial and one lateral (Fig. 5). The subtalar and calcaneocuboid joints are first approached from the lateral side. The first incision is made from the tip of the fibula and is carried down toward the base of the fourth metatarsal. This incision lies between the course of the sural nerve and the intermediate branch of the superficial peroneal nerve. Care must be taken at the distal aspect of the incision to avoid a branch of the sural nerve, which may be found crossing in a dorsomedial direction to unite with the intermediate dorsal cutaneous nerve in 40% of patients.[23]

The incision is deepened through the subcutaneous tissues. The inferior border of the extensor digitorum brevis muscle and the fat of the sinus tarsi are identified. The fat and the short extensor muscles are reflected dorsomedially by means of subperiosteal dissection. It is essential to reflect the extensor digitorum brevis muscle in a medial direction toward the deep peroneal nerve,

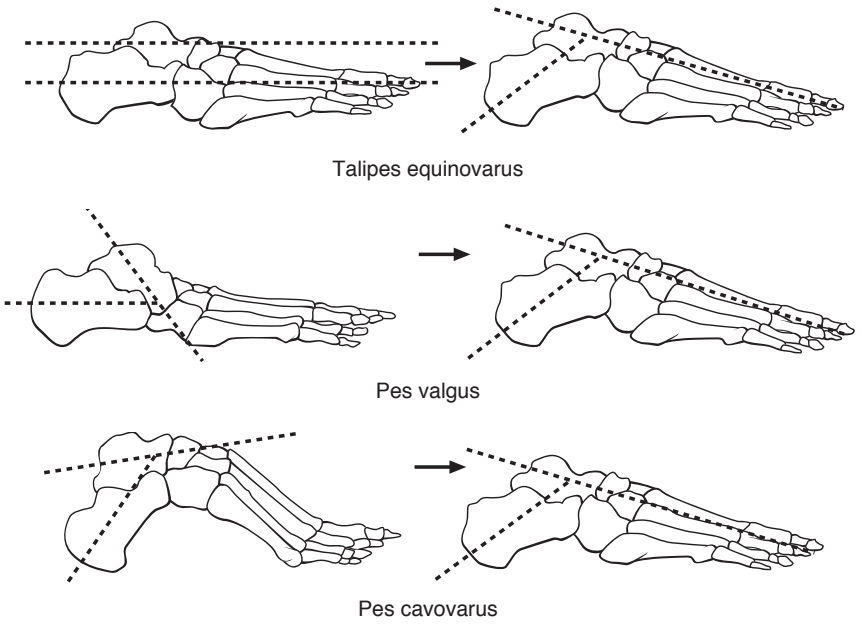

Fig. 4 Effect of sagittal and coronal correction on lateral talocalcaneal convergence. (Adapted with permission from Scranton PE: Results of arthrodesis of the tarsus: Talocalcaneal, midtarsal and subtalar joints. *Foot Ankle* 1991;12:156-164.)

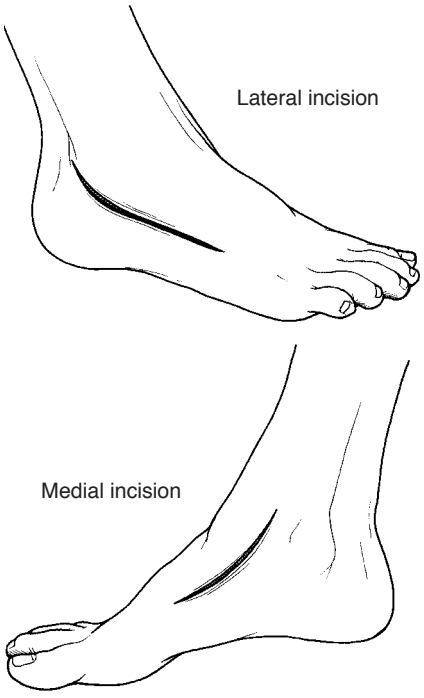

Fig. 5 The lateral incision is placed from the tip of the fibula to the base of the fourth metatarsal. The medial incision is placed over the talonavicular joint between the posterior and anterior tibial tendons.

which provides its innervation. The interosseous ligament is removed, and a small laminar spreader is then placed below the neck of the talus and is opened to provide improved visualization of the subtalar joints.

The remaining cartilage and the subchondral bone of the posterior facet are removed down to the level of cancellous bone with the use of curettes, working from posterior to anterior. The laminar spreader can then be moved to the posterior facet, and the middle and anterior facets can be curetted to the level of cancellous bone. The joint surfaces are feathered with a 0.25-inch osteotome. Care must be taken to avoid injury to the flexor hallucis longus as it courses behind and under the sustentaculum tali at the posterior border of the middle facet.

Attention is then turned to the calcaneocuboid joint. The capsule is opened, and a laminar spreader can be placed within the joint to assist in visualization. A curette is used to remove the remaining cartilage and subchondral bone. Care is taken to preserve the normal saddlelike shape of the joint surfaces. Once the cancellous bone has been exposed, the joint surfaces are feathered with an osteotome.

Attention is then directed medially. A dorsomedial incision is made from the tip of the medial malleolus to the level of the navicular-cuneiform joint. An incision is made in the interval between the anterior tibial tendon and the posterior tibial tendon. As the incision is deepened, care must be taken to avoid the saphenous nerve and vein. The talonavicular joint is identified by moving the foot in abduction and adduction. This allows palpation of the joint as the navicular moves and the head of the talus remains stationary. The joint capsules are then opened.

Exposure of the joint is assisted by subperiosteal dissection of the dorsum of the navicular. Care should be taken to minimize the dissection around the talar neck so as to preserve the arterial branches of the dorsalis pedis. A medium-size Cobb elevator can be placed within the talonavicular joint to facilitate opening of the joint. With the elevator providing traction, a laminar spreader can be placed within the joint as well. Visualization can also be improved by using a towel clip to hold the navicular in an abducted position. Again, with use of a curette or an osteotome, all of the remaining cartilage and subchondral bone should be removed from the surface of the head of the talus and the proximal surface of the navicular, attempting to preserve the normal contour of the joint. The cancellous bone should again be feathered with a 0.25-inch osteotome.

Proper reduction of the joints is essential for a successful arthrodesis. The subtalar joint should be placed in 3 to 5 degrees of valgus. The transverse tarsal joints must be placed in neutral position in regard to varus-valgus and abduction-adduction. In most instances, it is easiest to stabilize the subtalar joint first and then correct the forefoot to a neutral posture. The preferred method of fixation for the subtalar joint is with a cannulated screw, 7.0 to 7.3 mm in diameter, which can be driven from the neck of the talus through the posterior facet into the posterior body of the calcaneus.

The guide pin can be introduced either from the talar neck, directed inferiorly, or from the calcaneus, directed superiorly. An anterior cruciate guide system can be utilized to assist in pin placement, as described by Mann[3] (Fig. 6). Fixation of the talonavicular and calcaneocuboid joints can also be accomplished with the use of a 4.5-mm-diameter or larger cannulated screw or multiple staples placed with a power stapler (Fig. 7).[3,19,24]

If there has been significant bone loss, it may be necessary to add bone graft to ensure that the heel is properly corrected. The heel should not remain in excessive valgus rotation; the lateral talocalcaneal angle must be restored to prevent postoperative anterior tibiotalar impingement.[25]

Postoperatively, non-weight-bearing status is maintained with use of a compressive dressing and plaster splints for 10 to 14 days, after which the sutures are removed. The patient remains in a non-weight-bearing cast for an additional 4 weeks. If radiographs at 6 weeks demonstrate adequate bone healing with evidence of consolidation of the fusion sites, the patient can then be immobilized in

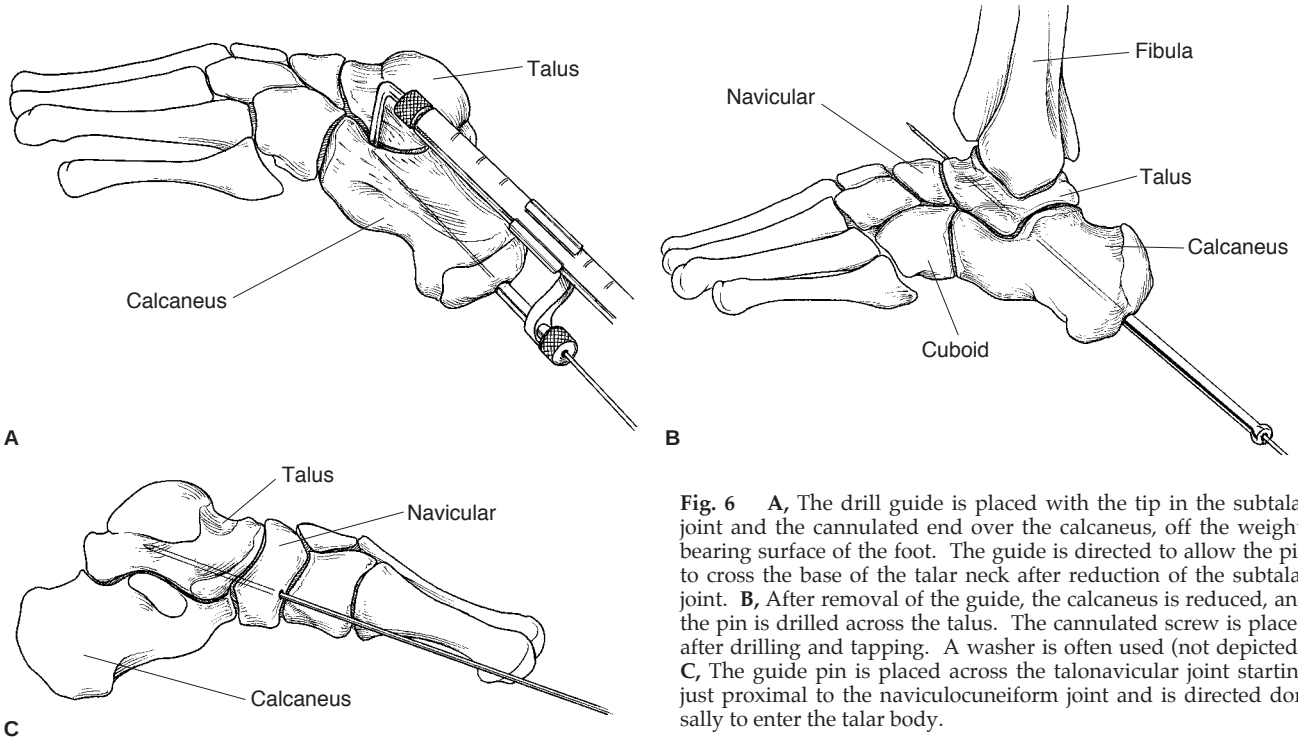

Fig. 6 **A,** The drill guide is placed with the tip in the subtalar joint and the cannulated end over the calcaneus, off the weight-bearing surface of the foot. The guide is directed to allow the pin to cross the base of the talar neck after reduction of the subtalar joint. **B,** After removal of the guide, the calcaneus is reduced, and the pin is drilled across the talus. The cannulated screw is placed after drilling and tapping. A washer is often used (not depicted). **C,** The guide pin is placed across the talonavicular joint starting just proximal to the naviculocuneiform joint and is directed dorsally to enter the talar body.

a walking cast for an additional 8 to 10 weeks. Immobilization is continued until there is radiographic evidence of solid union with consolidation of the fusion sites evidenced by formation of trabeculae across the fused joints. This will generally occur within 16 weeks, but casting should be continued until fusion is obtained. Once solid union has been achieved, a strengthening program for the muscles of the leg will facilitate rehabilitation.

Fig. 7 Lateral radiograph of a healed triple arthrodesis performed with use of the described technique. (Reproduced with permission from Graves SC: Triple arthrodesis in adults: Indications, technique, and results. *Operative Techniques Orthop* 1992;2:151-156.)

Complications

Multiple complications have been reported after triple arthrodesis. Malalignment of the fusion will not only lead to patient dissatisfaction but can also considerably increase the forces on the ankle joint. Excessive hindfoot valgus has been shown to increase the stress on the deltoid ligament by as much as 76% and to secondarily increase the force across the ankle joint.[26] Residual hindfoot valgus may also lead to lateral subfibular impingement and lateral pain. Residual hindfoot varus will often cause overloading of the lateral column of the foot, with resultant pain at the cuboid or the base of the fifth metatarsal. In addition, it may lead to lateral ankle instability and secondary ankle arthritis. Significant residual varus or valgus of the forefoot will result in an abnormal gait pattern and cause excessive forces across the ankle joints as the foot goes from heel-strike to toe-off. Malalignment may require revision of the triple arthrodesis. If extensive calcaneal varus or valgus of the calcaneus remains, it can be corrected with a Dwyer-type calcaneal osteotomy to move the heel into an acceptable position.[3]

Nerve injury or entrapment of the sural nerve at the lateral incision may necessitate neurolysis or nerve resection if the symptoms become severe. Incisions based on intraneural areas of the foot can prevent this from occurring.[24] Utilization of medial and lateral

incisions allows excellent visualization of the joints while minimizing the chances of nerve injury.

Failure to address an Achilles tendon contracture at the time of surgery can lead to excessive midfoot stresses. This is best addressed by doing an Achilles tendon lengthening at the time of primary surgery; however, it can be done at a later sitting. The Achilles tendon should be lengthened to achieve no more than 10 degrees of dorsiflexion. A percutaneous triple-hemisection technique of lengthening is generally successful (Fig. 8).[27] The patient should be informed that some atrophy of the calf muscle may occur after Achilles tendon lengthening.

Secondary degenerative arthritis in the ankle and midfoot has also been reported.[14-20] This is more common in patients with residual malalignment. Ankle symptoms can often be treated with the use of a molded polypropylene ankle-foot orthosis. Midfoot pain can be treated with a UCBL-type insert to allow free ankle motion. If bracing is unsuccessful, fusion of the affected joints should be considered.

Avascular necrosis of the talus has also been reported.[28] If this is present and symptomatic, initial treatment should involve bracing. If this is unsuccessful, ankle fusion should be considered.

Nonunion of one of the fusion sites may occur, most commonly involving the talonavicular joint. It has been theorized that nonunion results from inadequate exposure and preparation of the joint surfaces. If nonunion is asymptomatic, no treatment is required. If nonunion of one of the joints continues to produce symptoms, revision of the nonunion with internal fixation and bone grafting is generally effective.

For most deformities, the technique outlined by Mann[3] is successful in correcting a plantigrade foot. One exception is a severe cavus deformity in a neuromuscular foot; correction is best obtained by using a beak triple arthrodesis, as defined by Siffert.[11]

Avoidance of Pitfalls

Triple arthrodesis is a technically demanding procedure. It has been said that to ensure proper alignment of the foot, the operation must be approached with "the accuracy and care of a cabinet maker."[29]

Early in the evolution of the operation, undercorrection, overcorrection, recurrent deformity, avascular necrosis of the talus, and arthrosis of the ankle and midfoot joints were recognized as complications. With the exception of secondary arthrosis, it was considered that better fixation could reduce these complications. Ryerson[2] and Patterson et al[30] attempted to stabilize the bones with chromic suture to prevent loss of position in the early stages of healing.

Friedenberg[31] demonstrated the importance of maintaining accurate positioning of the joints in the early postoperative period by meticulous attention to cast application. If joint contact was lost, the incidence of nonunion increased, especially at the talonavicular joint. The development of pseudarthrosis predisposed to recurrent deformity due to the remaining neuromuscular imbalance. This was in agreement with the work of Crego and McCarroll.[6] They attributed recurrence to four factors: residual muscle imbalance, associated deformities of the remainder of the limb, subsequent abnormal bone remodeling with skeletal maturity, and inability to maintain the position of fusion in a cast.

In adults, remodeling of bone is sufficiently slow to not be a factor in recurrence.[19] The remaining factors can be overcome with rigid internal fixation. With the advent of better fixation devices, loss of correction can be prevented, but the need for accurate bone alignment at the time of surgery is critical.

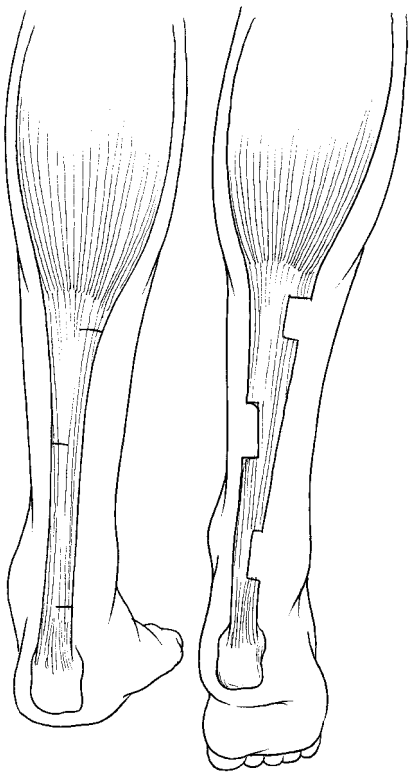

Fig. 8 Achilles tendon lengthening through three short transverse skin and tendon incisions. (Adapted with permission from Hoffer MM: Neurologic conditions: Cerebral palsy, in Mann RA, Coughlin MJ [eds]: *Surgery of the Foot and Ankle*, 6th ed. St Louis: Mosby-Year Book, 1993, vol 1, p 596.)

The Case for Minimization of Bone Resection

In the adult, the concept of bone realignment without resection of large wedges of bone has gained acceptance.[14-20,23-26] Release of the joint capsules generally allows realignment to the anatomically correct position. Preservation of

the concave-convex relationship of the talonavicular joint rather than bone resection allows less dissection around the neck of the talus. This increases the ability to preserve the dorsalis pedis branches to the neck of the talus and decrease the incidence of avascular necrosis of the talus.[3,17,19,24] The calcaneus can generally be reduced under the talus to restore a residual 3 to 5 degrees of valgus. If there has been a large amount of bone loss from trauma or erosive arthritis, defects can be filled with graft rather than being corrected with further bone resections.[3,17,19,24] Proper positioning of the calcaneus is essential to reduce the forces at the ankle joint. Excessive residual valgus has been demonstrated to significantly increase forces at the ankle.[25]

The Case for Internal Fixation

The use of compression arthrodesis has led to improved fusion rates and eliminates the reliance on postoperative casting for maintenance of the position of fusion.[3,17,19,24] The use of cannulated screws has made proper alignment easier to achieve. Guide pins can be placed into the joints, and the position of fusion can be assessed radiographically in the operating room. Adjustment of the position of the bones can be accomplished before final screw placement. Once rigid screw fixation of the subtalar joint has been accomplished, the talonavicular and calcaneocuboid joints can be properly positioned to correct abduction-adduction or varus-valgus malalignment. Fixation of the transverse tarsal joints can be performed with cannulated screws or power-stapler techniques.

Loss of Motion and Secondary Arthritis

Loss of motion in the hindfoot after triple arthrodesis remains a problem. The normal motion of these hindfoot joints works as an efficient means of dissipating forces in ambulation. The loss of this motion has been demonstrated to produce secondary arthrosis of the ankle and tarsometatarsal joints. These changes are often not apparent clinically, but radiographic changes have been reported in over 50% of patients.[14,15] This problem remains unsolved, and the long-term implications are unclear.

This loss of motion may also account for why many patients remain symptomatic despite radiographic evidence of complete fusion in proper position. Despite this, most patients generally feel greatly improved from their preoperative condition.[14-17] The time to optimum resolution of symptoms in these patients is prolonged and ranges from 2 to 36 months.[17] Patients should be informed of this preoperatively, so that they enter the procedure with appropriate expectations.

Summary

Triple arthrodesis is a technically demanding procedure that generally involves a prolonged recovery time. When proper alignment is obtained, it can give predictable improvement in patient symptoms, but the resultant loss of hindfoot motion is not without consequences. Residual discomfort and secondary arthrosis of the ankle and tarsometatarsal joints should be expected. It has been recommended that it be used only as a salvage operation in older patients who have a painful fixed deformity or disabling instability refractory to other treatment options.[17] Despite these caveats, most patients who have undergone triple arthrodesis for these indications report significant improvement in their symptoms and level of function.[14-20]

References

1. Davis GG: The treatment of hollow foot (pes cavus). *Am J Orthop Surg* 1913;11:231-242.
2. Ryerson EW: Arthrodesing operations on the feet. *J Bone Joint Surg* 1923;5: 453-471.
3. Thompson FM, Mann RA: Arthritides, in Mann RA, Coughlin MJ (eds): *Surgery of the Foot and Ankle*, 6th ed. St Louis: Mosby-Year Book, 1993, vol 1, pp 615-671.
4. Adelaar RS, Dannelly EA, Meunier PA, Stelling FH, Goldner JL, Colvard DF: A long term study of triple arthrodesis in children. *Orthop Clin North Am* 1976;7:895-908.
5. Angus PD, Cowell HR: Triple arthrodesis: A critical long-term review. *J Bone Joint Surg Br* 1986;68:260-265.
6. Crego CH Jr, McCarroll HR: Recurrent deformities in stabilized paralytic feet: Report of 1100 consecutive stabilizations in poliomyelitis. *J Bone Joint Surg Am* 1938;20:609-620.
7. Duncan JW, Lovell WW: Hoke triple arthrodesis. *J Bone Joint Surg Am* 1978; 60:795-798.
8. El-Batouty MM, Aly ESM, El-Lakkany MR, Abdellatif FY: Triple arthrodesis for paralytic valgus: A modified technique—Brief report. *J Bone Joint Surg Br* 1988;70:493.
9. Olney BW, Menelaus MB: Triple arthrodesis of the foot in spina bifida patients. *J Bone Joint Surg Br* 1988;70: 234-235.

10. Samilson RL, Dillin W: Cavus, cavovarus, and calcaneocavus: An update. *Clin Orthop* 1983;177:125-132.
11. Siffert RS, del Torto U: "Beak" triple arthrodesis for severe cavus deformity. *Clin Orthop* 1983;181:64-67.
12. Tang SC, Leong JCY, Hsu LCS: Lambrinudi triple arthrodesis for correction of severe rigid drop-foot. *J Bone Joint Surg Br* 1984;66:66-70.
13. Wetmore RS, Drennan JC: Long-term results of triple arthrodesis in Charcot-Marie-Tooth disease. *J Bone Joint Surg Am* 1989;71:417-422.
14. Bennett GL, Graham CE, Mauldin DM: Triple arthrodesis in adults. *Foot Ankle* 1991;12:138-143.
15. Cracchiolo A III, Pearson S, Kitaoka H, Grace D: Hindfoot arthrodesis in adults utilizing a dowel graft technique. *Clin Orthop* 1990;257:193-203.
16. Figgie MP, O'Malley MJ, Ranawat C, Inglis AE, Sculco TP: Triple arthrodesis in rheumatoid arthritis. *Clin Orthop* 1993;292:250-254.
17. Graves SC, Mann RA, Graves KO: Triple arthrodesis in older adults: Results after long-term follow-up. *J Bone Joint Surg Am* 1993;75:355-362.
18. Johnson KA: Hindfoot arthrodeses. *Instr Course Lect* 1990;39:65-69.
19. Sangeorzan BJ, Smith D, Veith R, Hansen ST Jr: Triple arthrodesis using internal fixation in treatment of adult foot disorders. *Clin Orthop* 1993;294: 299-307.
20. Scranton PE Jr: Results of arthrodesis of the tarsus: Talocalcaneal, midtarsal, and subtalar joints. *Foot Ankle* 1991;12: 156-164.
21. Deland JT, Otis JC, Lee KT, Kenneally SM: Lateral column lengthening with calcaneocuboid fusion: Range of motion in the triple joint complex. *Foot Ankle* 1995;16:729-733.
22. Coleman SS, Chestnut WJ: A simple test for hindfoot flexibility in the cavovarus foot. *Clin Orthop* 1977;123:60-62.
23. Sarrafian SK: *Anatomy of the Foot and Ankle: Descriptive, Topographic, Functional*, 2nd ed. Philadelphia: JB Lippincott, 1993, pp 356-362.
24. Graves SC: Triple arthrodesis in adults: Indications, technique, and results. *Operative Techniques Orthop* 1992;2:151-156.
25. Carr JB, Hansen ST, Benirschke SK: Subtalar distraction bone block fusion for late complications of os calcis fractures. *Foot Ankle* 1988;9:81-86.
26. Resnick RB, Jahss MH, Choueka J, Kummer F, Hersch JC, Okereke E: Deltoid ligament forces after tibialis posterior tendon rupture: Effects of triple arthrodesis and calcaneal displacement osteotomies. *Foot Ankle Int* 1995;16:14-20.
27. Hoffer MM: Neurologic conditions: Cerebral palsy, in Mann RA, Coughlin MJ (eds): *Surgery of the Foot and Ankle*, 6th ed. St Louis: Mosby-Year Book, 1993, vol 1, pp 594-601.
28. Marek FM, Schein AJ: Aseptic necrosis of the astragalus following arthrodesing procedures of the tarsus. *J Bone Joint Surg Am* 1945;27:587-590.
29. Ingram AJ: Paralytic disorders, in Crenshaw AH (ed): *Campbell's Operative Orthopaedics*, 7th ed. St Louis: CV Mosby, 1987, vol 4, pp 2932-2933.
30. Patterson RL Jr, Parrish FF, Hathaway EN: Stabilizing operations on the foot: A study of the indications, techniques used, and end results. *J Bone Joint Surg Am* 1950;32:1-26.
31. Friedenberg ZB: Arthrodesis of the tarsal bones: A study of failure of fusions. *Arch Surg* 1948;57:162-170.