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CLINICAL PRACTICE GUIDELINE

Diagnosis and Treatment of Pediatric Flatfoot

Clinical Practice Guideline Pediatric Flatfoot Panel: Edwin J. Harris, DPM,[1] John V. Vanore, DPM,[2] James L. Thomas, DPM,[3] Steven R. Kravitz, DPM,[4] Stephen A. Mendelson, MD,[5] Robert W. Mendicino, DPM,[6] Stephen H. Silvani, DPM,[7] and Susan Couture Gassen[8]

This clinical practice guideline (CPG) is based on the consensus of current clinical practice and review of the clinical literature. The guideline was developed by the Clinical Practice Guideline Pediatric Flatfoot Panel of the American College of Foot and Ankle Surgeons. The guideline and references annotate each node of the corresponding pathways.

Introduction to Pediatric Flatfoot (Pathway 1)

Foot and ankle specialists acknowledge that flatfoot deformity is a frequently encountered pathology in the pediatric population. Flattening of the medial arch is a universal finding in flatfoot and it is common in both pediatric and adult populations. Pediatric flatfoot comprises a group of conditions occurring in infants, children, and adolescents (1) that are distinguished by anatomy and etiologic factors (2, 3–8).

Flatfoot may exist as an isolated pathology or as part of a larger clinical entity (4). These entities include generalized ligamentous laxity, neurologic and muscular abnormalities, genetic conditions and syndromes, and collagen disorders.

Pediatric flatfoot can be divided into flexible and rigid categories. Flexible flatfoot is characterized by a normal arch during nonweightbearing and a flattening of the arch on stance (Fig 1). Flexible flatfoot may be asymptomatic or symptomatic. Rigid flatfoot is characterized by a stiff, flattened arch on and off weightbearing. Most rigid flatfeet are associated with underlying pathology that requires special consideration.

Skewfoot is an uncommon disorder characterized by severe pronation of the rearfoot and an adductovarus forefoot. Skewfoot has characteristics of flatfoot and adductovarus deformity (8).

Significant History (Pathway 1, Node 1)

Pediatricians and parents often are the first to recognize foot and ankle pathology in infants and children, but problems may go unrecognized for a long period of time. The age of onset is important for diagnostic and therapeutic decision making. Additional considerations include family history, associated medical conditions, presence or absence of symptoms, trauma history, activity level, previous treatment, and a thorough review of systems.

Documented failure to improve, or a clinical worsening, is contrary to the normal course and suggests that the problem is more likely to persist with the possibility of pathologic sequel. A family history of flatfoot suggests that there may be similar issues in the child. Obesity, neuromuscular disorders, and structural abnormalities above the level of the ankle (eg, ankle valgus, tibia varum, genu valgum, tibial torsion, femoral anteversion, limb-length discrepancy) can influence both the natural history and the severity of pediatric flatfoot.

Flatfoot can be associated with a number of subjective symptoms that may include pain in the foot, leg, and knee, and postural symptoms. A history of trauma—acute or repetitive—may cause or unmask the foot deformity. Flatfoot deformity may result in decreased endurance and voluntary withdrawal

[1]Chair, Pediatric Flatfoot Panel, Westchester, IL; [2]Chair, Clinical Practice Guideline Core Committee, Gadsden, AL; [3]Board Liaison, Birmingham, AL; [4]Philadelphia, PA; [5]Pittsburgh, PA; [6]Pittsburgh, PA; [7]Walnut Creek, CA; [8]Chicago, IL. Address correspondence to: John V. Vanore, DPM, Gadsden Foot Clinic, 306 South 4th St, Gadsden, AL 35901. E-mail: jvanore@bellsouth.net

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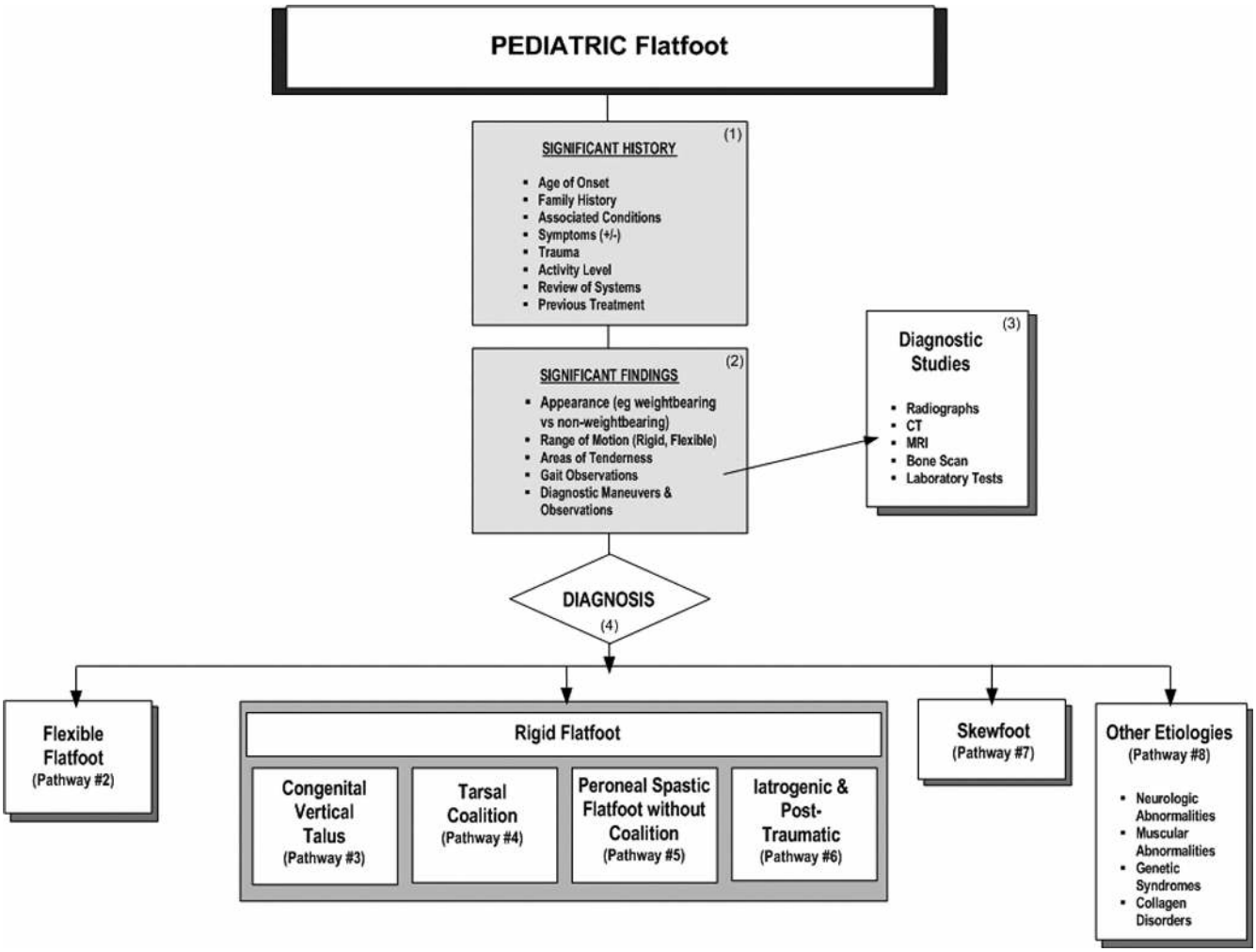


PATHWAY 1

from physical activities. Previous treatment may have modified the clinical presentation (4). A comprehensive history and review of systems may show previously unsuspected medical conditions (4). For example, a history may disclose clumsiness and frequent falling. Difficulty climbing and difficulty arising from the floor in association with flatfoot may indicate Becker or Duchenne muscular dystrophy.

Significant Findings (Pathway 1, Node 2)

The appearance of the foot during weightbearing and nonweightbearing suggests the presence and type of flatfoot deformity (Fig 1). Physical findings may include low arch structure, rearfoot eversion, medial talar head prominence, altered walking, and the presence of calluses.

Evaluation of flatfoot requires assessment of ankle dorsiflexion and plantarflexion (with knee extended and flexed) and rearfoot, midfoot, and forefoot ranges of motion. The forefoot-to-rearfoot relationship is also assessed. Tenderness may be present in pediatric flatfoot, occurring along the medial column and at the metatarsal heads, plantar fascia, sinus tarsi, and ankle.

Gait observation should be conducted when the child is barefoot and is wearing shoes. Gait should be assessed for prominence of the medial border of the midfoot, the foot progression angle, calcaneal eversion (pronation and resupination during stance phase), the heel-to-toe contact, position of the knee, and presence of limp.

Diagnostic observations and maneuvers include inversion of the heel on toe rise, recreation of the medial arch with dorsiflexion of the hallux, and the "too many toes sign." Other physical findings include obesity, tibia varum, genu valgum, tibial torsion, femoral torsion, disorders of muscle tone, and ligamentous laxity that can modify both the natural history and the severity of flatfoot (9).

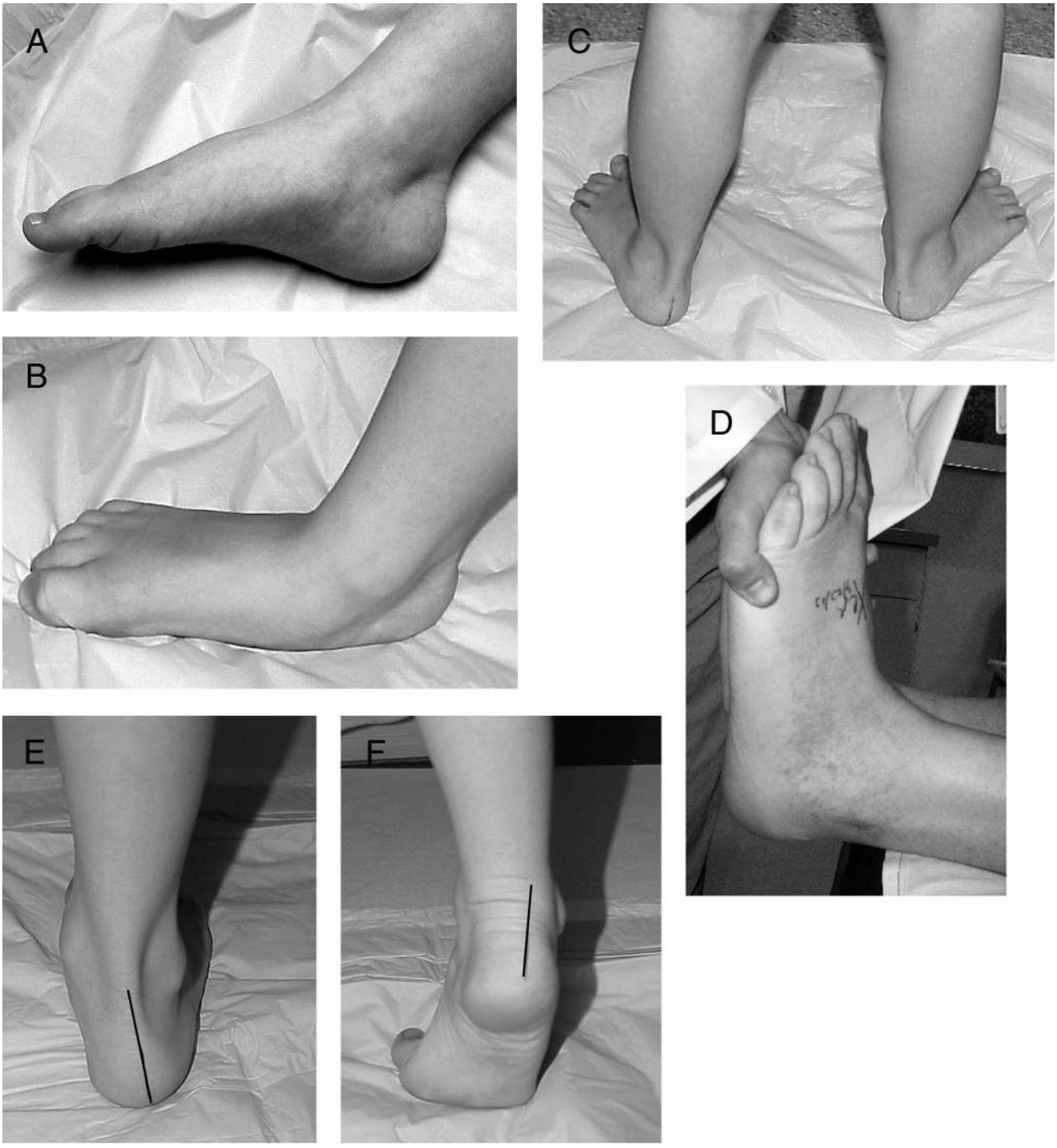


FIGURE 1 Clinical examination of the foot begins with nonweightbearing inspection. (*A*) The pediatric flexible flatfoot shows preservation of the medial arch off weightbearing, whereas (*B*) the arch depresses or flattens with weightbearing. (*C*) The relaxed calcaneal stance position is viewed from the posterior. The heels may evert and the tendo-Achilles bows laterally (positive Helbing sign). (*D*) Ankle dorsiflexion is assessed during the examination, because equinus is a frequent component or etiologic factor of flatfoot pathologies. (*E*) The everted or valgus heel in stance changes to (*F*) a varus position with the clinical maneuver of heel rise to the toes, showing the flexible nature and the reducibility of the deformity.

Diagnostic Studies (Pathway 1, Node 3)

Imaging options may include radiographs (Fig 2) (weightbearing), computed tomography (CT), magnetic resonance imaging (MRI), and bone scans. Serologic studies may be warranted to differentiate mechanical or overuse symptoms from arthralgia, arthritis, and other childhood inflammatory diseases.

Diagnosis (Pathway 1, Node 4)

Information from the initial evaluation and diagnostic tests is correlated into a diagnosis. The differential diagnosis of the pediatric flatfoot includes the following: flexible flatfoot (Pathway 2); rigid flatfoot: congenital vertical talus (CVT) (Pathway 3); tarsal coalition (Pathway 4); peroneal spastic flatfoot without coalition (Pathway 5); iatrogenic and posttraumatic deformity (Pathway 6); skewfoot (Pathway 7); and flatfoot caused by other, less frequent causes (Pathway 8) (2, 4, 8, 10). Note that 4 of these conditions—vertical talus, tarsal coalition, peroneal spastic flatfoot without coalition, and iatrogenic/posttraumatic deformity—are types of rigid flatfoot.

Flexible Flatfoot (Pathway 2)

Asymptomatic Flexible Flatfoot (Pathway 2)

The asymptomatic flexible flatfoot may be physiologic or nonphysiologic (Nodes 5 and 6) (11). Most flexible flatfeet are physiologic, asymptomatic, and require no treatment (7, 12, 13). Physiologic flexible flatfoot follows a natural history of improvement over time (Fig 3). Periodic observation may be indicated to monitor for signs of progression (Node 5). Treatment generally is not indicated (14).

Nonphysiologic flexible flatfoot is characterized by progression over time. The degree of deformity is more severe in nonphysiologic than in physiologic flexible flatfoot. The amount of heel eversion is excessive; the talonavicular joint is unstable. Additional findings include tight heel cords and gait disturbance. Periodic observation is indicated in nonphysiologic flexible flatfoot (Node 7). Patients with tight heel cords may benefit from stretching (Node 8) (13). Orthoses may also be indicated.

Children with asymptomatic flexible flatfoot should be monitored clinically for onset of symptoms and signs of progression (Node 7). Continued progression requires reassessment to identify other underlying disease.

Symptomatic Flexible Flatfoot (Pathway 2, Node 6)

Unlike physiologic and asymptomatic nonphysiologic flexible flatfoot, symptomatic forms of flexible flatfoot produce subjective complaints, alter function, and produce significant objective findings. These include pain along the medial side of the foot; pain in the sinus tarsi, leg, and knee; decreased endurance; gait disturbances; prominent medial talar head; everted heels; and heel cord tightness.

Initial treatment (Node 8) includes activity modifica-

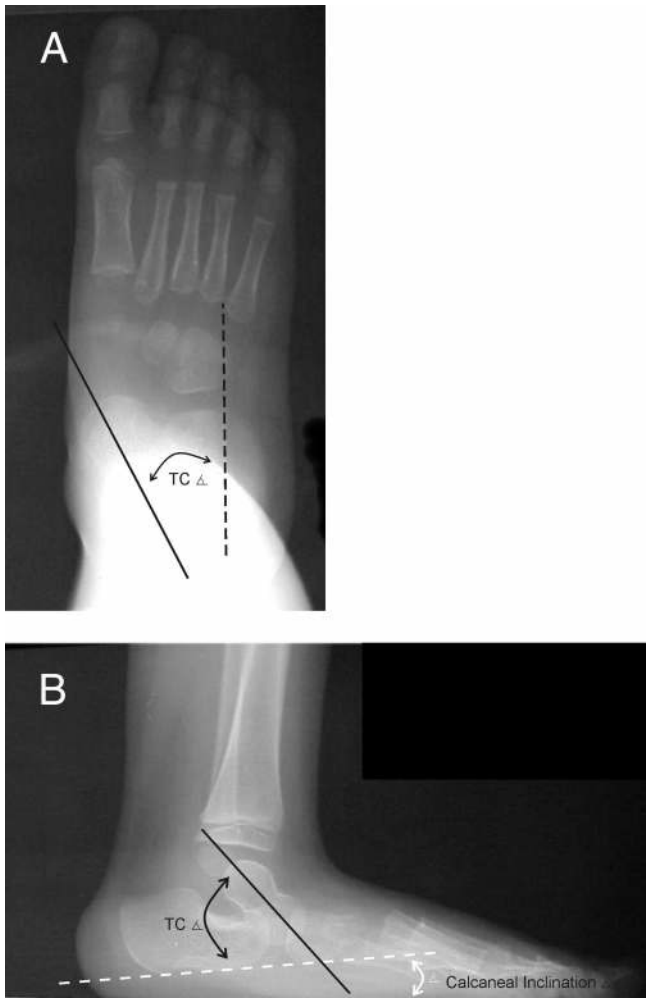
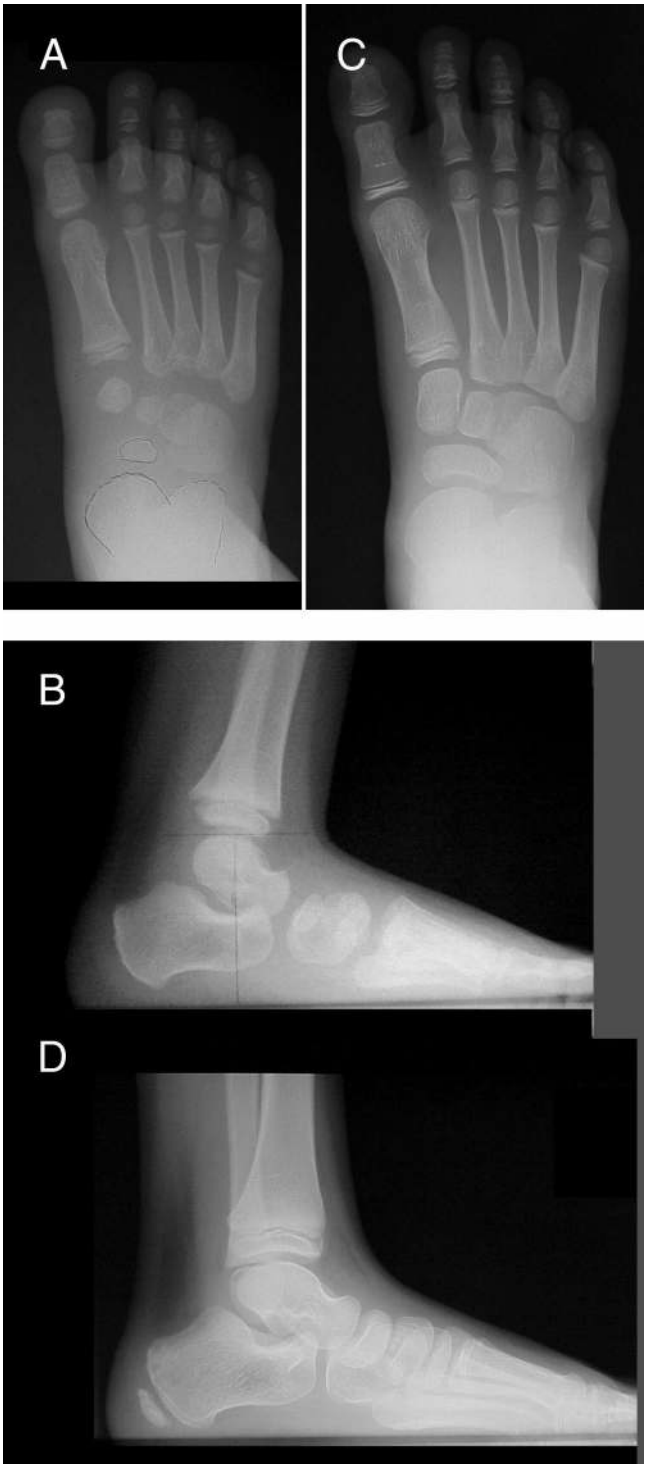


FIGURE 2 Radiographic examination includes weightbearing (*A*) AP and (*B*) lateral radiographs taken in the angle and base of gait for further evaluation and documentation of the degree of deformity. Radiographic flatfoot parameters focus on the relationship of the talus and calcaneus. The midtalar line (solid black line), talocalcaneal angle (TC) and calcaneal inclination angle provide information on the sagittal plane position of these bones on lateral view and transverse plane position on the AP view. In flatfoot, the talocalcaneal angle increases in size both on the AP and lateral radiographs. The talus plantarflexes in flatfoot deformity on the lateral radiograph. The normal midtalar line should pass through the first metatarsal. On the weightbearing AP radiograph, the talar head is no longer covered by its articulation with the navicular. This results in a wide AP talocalcaneal angle (Kite angle). Calcaneal inclination decreases in flatfoot. (Further discussion can be found in the American College of Foot and Ankle Surgeons Clinical Practice Guideline on Adult Flatfoot.)

tions and orthoses. Stretching exercises for equinus deformity can be performed under physician or physical therapist supervision. Nonsteroidal antiinflammatory medications may be indicated in more severe cases. Comorbidities, such as obesity, ligamentous laxity, hypotonia, and proximal limb problems, must be identified and managed, if possible.



If there is a positive clinical response and symptoms are resolved, observation and orthoses (when appropriate) are instituted. If clinical response is not satisfactory, reassessment and additional work-ups are indicated. When all nonsurgical treatment options have been exhausted, surgical intervention can be considered (13, 15–21).

Surgical Intervention (Pathway 2, Node 10)

Surgical management of the flexible flatfoot can be grouped into 3 types: reconstructive procedures, arthrodesis, and arthroereisis.

Soft tissue reconstruction of the flexible flatfoot is rarely successful as an isolated procedure. Bony procedures include rearfoot, midfoot, and forefoot osteotomies. Depending on the plane of dominance of the deformity, lateral column lengthening (Fig 4) and/or medial displacement osteotomy of the posterior calcaneus may be used. A heel cord lengthening and medial plication are often included as a part of these procedures. Although excellent results from surgical treatment of flatfoot have been described, questions remain regarding successful long-term correction (14).

Arthroereisis involves insertion of a spacer into the sinus tarsi for the purpose of restricting subtalar joint pronation (22–25) (Fig 5). Proponents of this procedure argue that it is a minimally invasive technique that does not distort the normal anatomy of the foot (24, 26–28). Others have expressed concern about placing a permanent foreign body into a mobile segment of a child's foot (29, 30). The indication for this procedure remains controversial in the surgical community (25, 26, 28, 31–38).

Arthrodesis of the rearfoot has also been described for treatment of symptomatic flexible flatfoot. Subtalar arthrodesis is typically performed as the primary procedure. Triple arthrodesis is reserved as a salvage procedure for previously failed surgical treatment. Although arthrodesis provides a

FIGURE 3 Radiographic examination of foot deformities is essential for both diagnostic evaluation and documentation. Radiographs of pediatric deformities allow comparison of progression with time and assessment of therapeutic results. This case is a neurologically healthy 4-year-old girl who was treated for flexible flatfoot with nonpronating orthotics. (*A*) The initial AP and lateral radiographs show medial talar head uncovering and a wide talocalcaneal angle. (*B*) The initial lateral radiograph shows decreased calcaneal inclination angle and increased talar declination angle. (*C*) Three years later, there is improvement in the radiographic parameters with increased talar head coverage on the AP view. (*D*) The lateral radiograph shows improvement of arch height, although the calcaneal inclination and talar declination are similar to the pretreatment studies. Although it is tempting to credit orthotic therapy for the observed improvement, it is equally possible that these changes are the result of the natural history of spontaneous improvement.

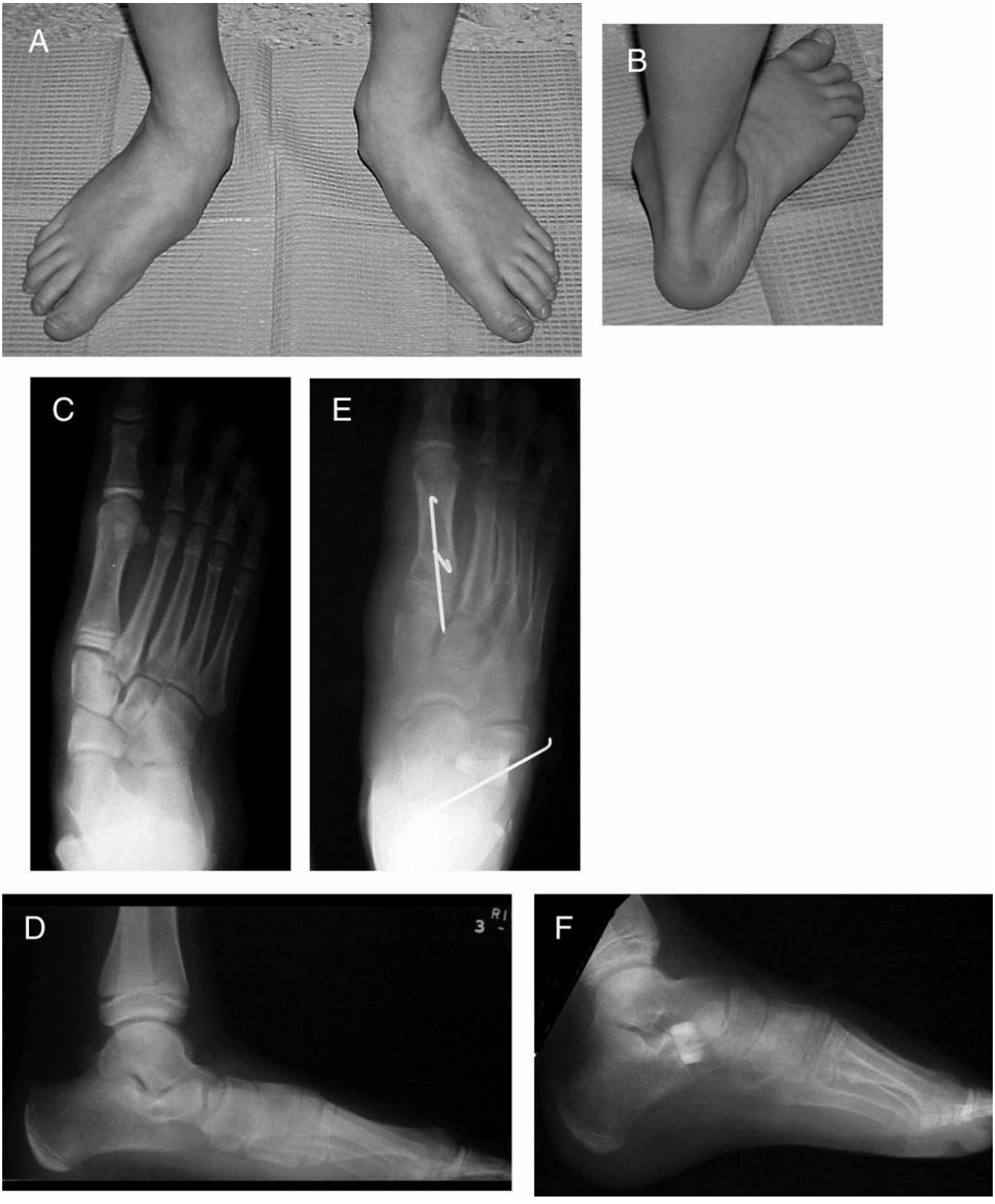


FIGURE 4

stable foot and durable correction, eventual transfer of energy to the nonfused joints adjacent to the fusion is of concern (39, 40).

If surgical intervention is successful in producing a functional painless result, the child should be further treated by periodic observation and appropriate orthoses. If surgery fails, salvage through appropriate intraarticular or extraarticular arthrodesis is appropriate.

Rigid Flatfoot (Pathway 3 to 6)

Rigid flatfoot is characterized by a lowered arch on both weightbearing and nonweightbearing and by a decrease or absence of motion of the rearfoot and midfoot. Rigid flatfoot can be symptomatic or asymptomatic. Most cases are associated with underlying primary pathology that can be diagnosed by clinical and imaging examinations.

The differential diagnosis of rigid pediatric flatfoot includes CVT (Pathway 3), tarsal coalition (Pathway 4), peroneal spastic flatfoot without coalition (Pathway 5), and iatrogenic or traumatic joint pathology (Pathway 6).

Congenital Vertical Talus (Pathway 3)

CVT deformity, also known as congenital convex pes valgus, is characterized by severe equinus of the rearfoot and by a rigid rocker-bottom appearance. There are 2 classes of this deformity: teratologic and idiopathic.

Teratologic CVT indicates the presence of underlying comorbid conditions. These include genetic syndromes, spinal dysraphisms (41–43), prune belly syndrome (44), de Barsy syndrome (45), distal arthrogryposis (46), arthrogryposis multiplex congenita (47), congenital metacarpotalar syndrome (48), Rasmussen syndrome (49–51), and a host of chromosomal abnormalities (52).

Idiopathic CVT lacks specific etiologic factors (52–61). CVT has been associated with a tarsal coalition (62). Genetic issues in idiopathic CVT have not been resolved because of inconclusive data. Results of some studies suggest a hereditary component (58, 63, 64), whereas others fail to show patterns of inheritance (65, 66).

Significant History (Pathway 3, Node 1)

CVT deformity should be diagnosed at birth but it is sometimes confused with calcaneovalgus deformity or physiologic flatfoot. Symptoms begin at walking age, with difficulty bearing weight and wearing shoes. There may be a history of previous unsuccessful treatment.

Significant Findings (Pathway 3, Node 2)

CVT is characterized by a rigid rocker-bottom appearance to the foot (Fig 6). Pathology findings include dorsal dislocation of the talonavicular joint, ankle equinus, contracture of the tendo-Achilles, long-toe flexors, posterior ankle capsule, peroneal tendons, and the anterior compartment tendons (59, 67). The tibionavicular ligament is contracted; the calcaneonavicular (spring) ligament is elongated.

The forefoot is most frequently abducted, but may occasionally be adducted (68). The calcaneocuboid articulation often remodels so that the entire plantar aspect of the foot is convex (68). Tibialis posterior and the peroneals may be displaced, the talar head becomes misshapen, and the deformity is extremely rigid. It is most likely resistant to closed reduction (53, 66, 69–71).

Diagnostic Imaging (Pathway 3, Node 3)

Plain radiographs are most often diagnostic (61). Lateral weightbearing radiographs show parallelism between the tibia and the talus. The calcaneus is in equinus (Fig 6).

If the navicular has not ossified, a plantarflexion stress lateral radiograph will determine the reducibility of the forefoot on the talus. The longitudinal axis of the first metatarsal will not align with the bisection of the talus. If the navicular has already ossified, its malposition in reference to the talus is visualized. It is not reduced on plantarflexion.

On the anteroposterior (AP) projection, the talocalcaneal (Kite) angle will be very wide. The navicular (if visualized)

FIGURE 4 Selection of apropriate surgical treatment is based on the clinical and radiographic evaluation. Planal dominance is an important factor. A flatfoot deformity will usually show significant deformity in one or more of the cardinal body planes. A 12-year-old boy had a 2-year history of progressing pain in both feet after walking long distances and after athletic activities. (*A*) The medial border of the foot is characterized by talar-head bulging and by the loss of medial arch height. (*B*) The lateral border is abducted and the calcaneus is everted. (*C*) The midtarsal joint complex is pronated on the AP radiograph, and the talar head is uncovered. (*D*) The lateral radiograph shows abnormal calcaneal inclination, increased talocalcaneal angle, and sagittal collapse of the medial column. The patient underwent an Evans opening calcaneal osteotomy with insertion of banked bone graft, a plantarflexing first metatarsal osteotomy, and a percutaneous tendo-Achilles lengthening. (*E* and *F*) Marked improvement in the talocalcaneal angle, and improved calcaneal inclination and height of the medial arch, are seen on the AP and lateral postoperative radiographs.

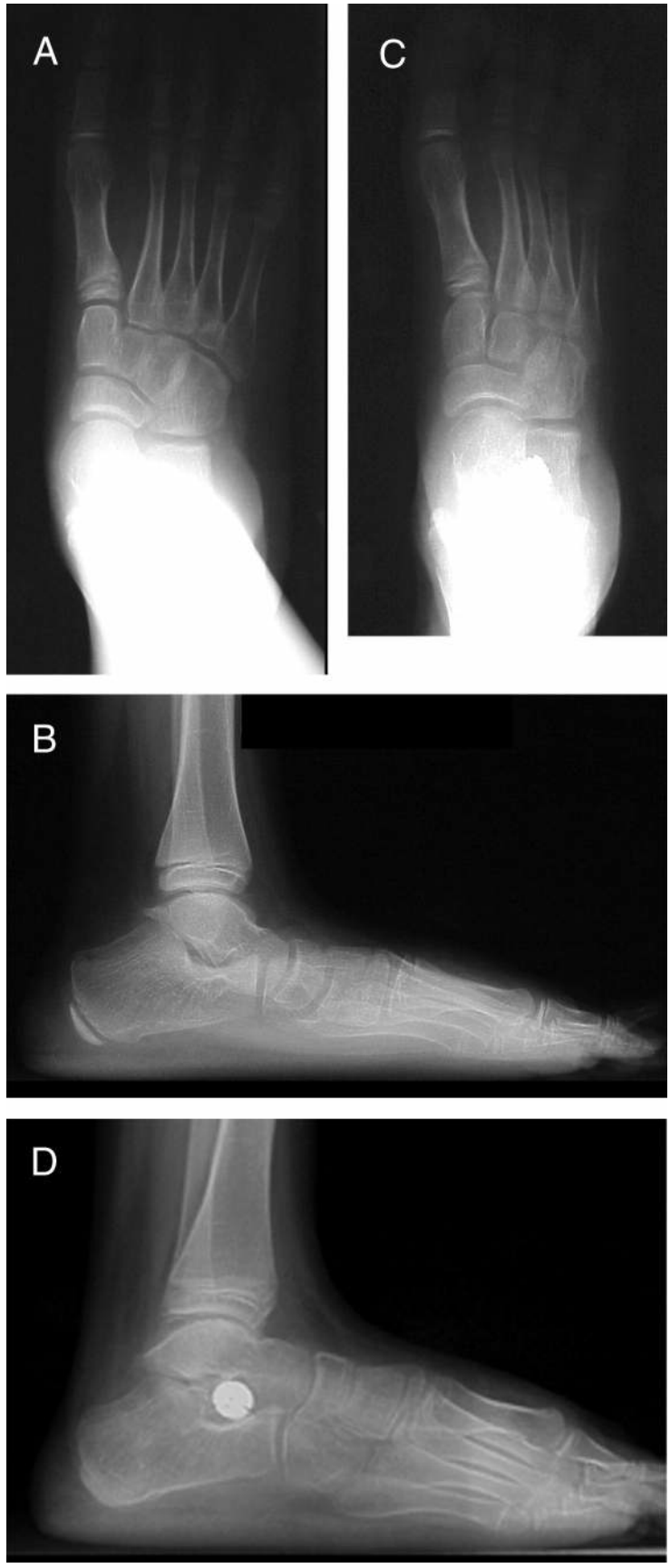
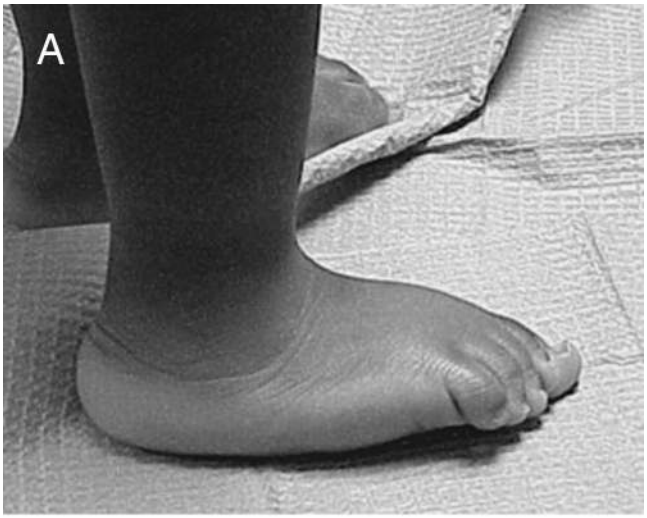
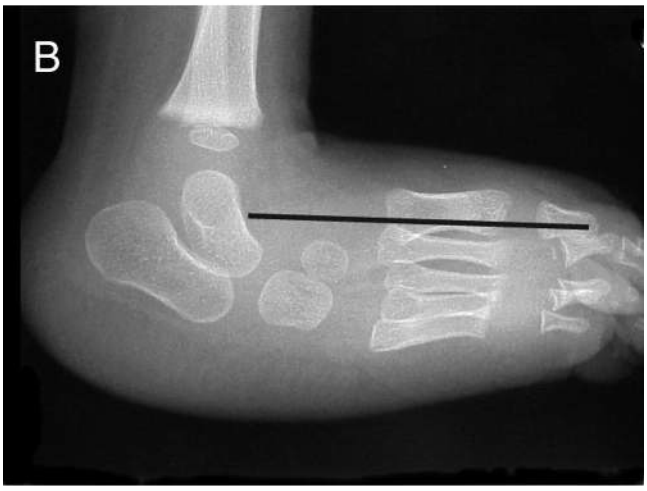


FIGURE 5 Arthroereisis is an evolving procedure for the treatment of flexible flatfoot. Both polymer and metallic implants are commercially available. (*A*) This weightbearing preoperative AP radiograph shows a wide talocalcaneal angle with approximately 50% of the medial talar head uncovered. The midtarsal joint complex is completely pronated. (*B*) The preoperative lateral radiograph shows a large lateral talocalcaneal angle, decreased calcaneal inclination angle, anterior alteration of the Cyma line, and midtarsal fault. (*C*) After metallic subtalar arthroereisis, the postoperative AP shows the talonavicular joint completely reduced. The AP talocalcaneal (Kite) angle is also reduced compared with the preoperative study. (*D*) The postoperative lateral shows significant change in the talotibial and talocalcaneal relationships. The forefoot is supinated. (Case courtesy of John Grady, DPM, Chicago, IL.)





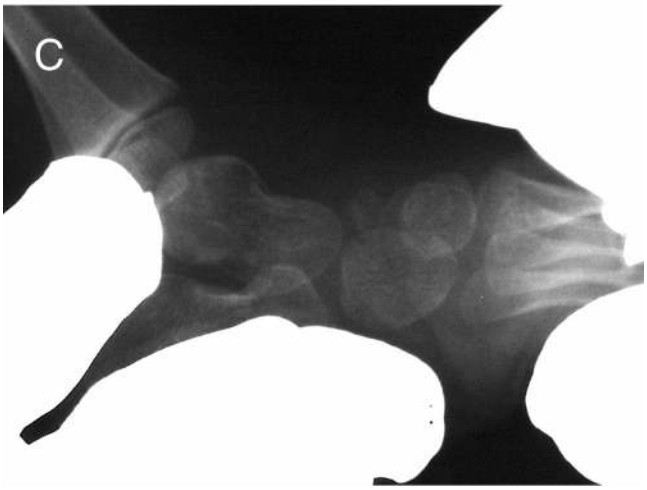


FIGURE 6 Rigid flatfoot deformities are often congenital. Vertical talus is 1 pathology that should be diagnosed early in life. (*A*) A child with CVT (congenital convex pes valgus) is characterized clinically by a pathologic plantigrade foot with weight borne at the midfoot and the heel off the ground. (*B*) The lateral radiograph shows the ankle and calcaneus in equinus position, the talus almost vertical, and the talonavicular joint dislocated. The navicular is not ossified, but a line passing through the first metatarsal shaft intersects the dorsal talar neck instead of the talar head. (*C*) A stress plantarflexion radiograph is diagnostic and shows that only partial reduction of the talonavicular dislocation is possible.

will be displaced laterally and will appear to overlap the distal aspect of the talar head.

MRI, CT, and ultrasound studies may be useful in imaging the deformity for diagnosis and for surgical planning (72–75).

Diagnosis (Pathway 3, Node 4)

Diagnosis of vertical talus is made by the appearance of a rigid and irreducible foot, with support from imaging studies. The differential diagnosis must include calcaneovalgus deformity, which is flexible, does not have a rocker-bottom configuration, and does not have a talonavicular dislocation (76).

Initial Treatment (Pathway 3, Node 5)

Initial management of CVT consists of manipulation and serial casting for approximately 6 weeks (77). During manipulation, an attempt is made to pull the navicular distally, downward, and medially to relocate it on the talar head.

If closed reduction occurs (Node 6), the talonavicular joint can be pinned in percutaneous fashion (Fig 7). At that point, the equinus may be corrected by casting. If complete reduction is achieved, an ankle-foot orthosis can be prescribed (Node 7). The patient must be carefully observed because of an extremely high recurrence rate.

Surgical Intervention (Pathway 3, Node 8)

Long-term results of closed reduction have been reported as poor (70). If closed reduction is not successful, open surgical reduction is necessary (65, 66, 68, 69, 77, 78). Reduction may be performed in 1 (52, 53, 59, 79, 80) or 2 (68, 81) stages. The benefits and value of the 2 techniques have been examined by a number of authors (54, 82).

For infants, the Cincinnati incision gives excellent exposure to the rearfoot components of the deformity (61). However, this incision is not recommended for older children because of concerns about skin perfusion after this approach (83). The goal of surgery is to correct hindfoot equinus, to restore talonavicular congruity, and to restore functional anatomy. Recurrence is a common problem and bracing is recommended (Fig 7).

In older children, the talonavicular joint may be so de-

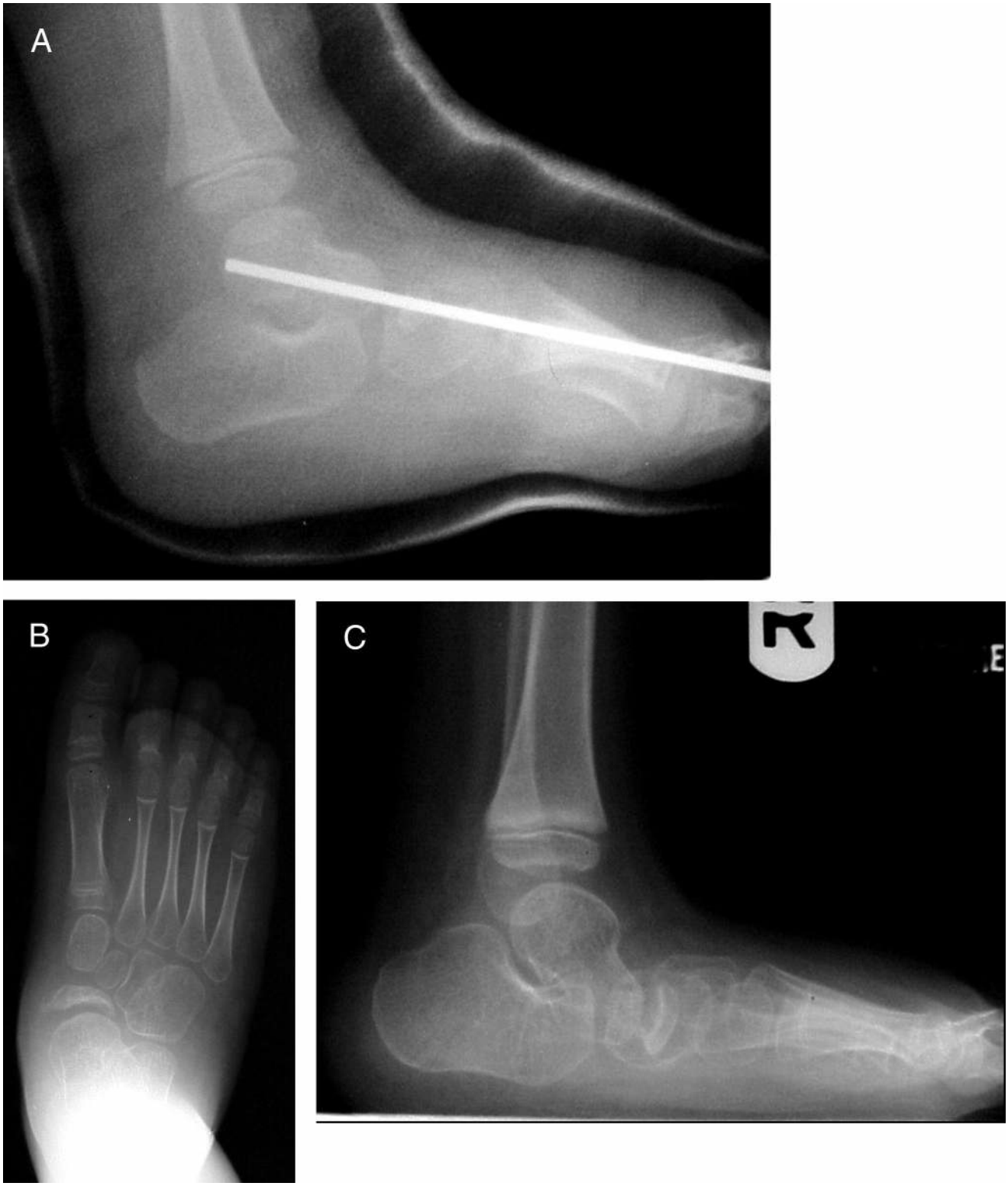


FIGURE 7 Vertical talus is generally irreducible nonsurgically. This 3-year-old neurologically healthy girl was diagnosed at 22 months with CVT deformity. Nonsurgical reduction was not successful. (*A*) The initial surgical approach is peritalar release and pinning of the talonavicular joint. (*B* and *C*) These radiographs show some recurrence of the deformity after peritalar release. Note the deformed navicular and severe talar declination combined with a rocker-bottom deformity.

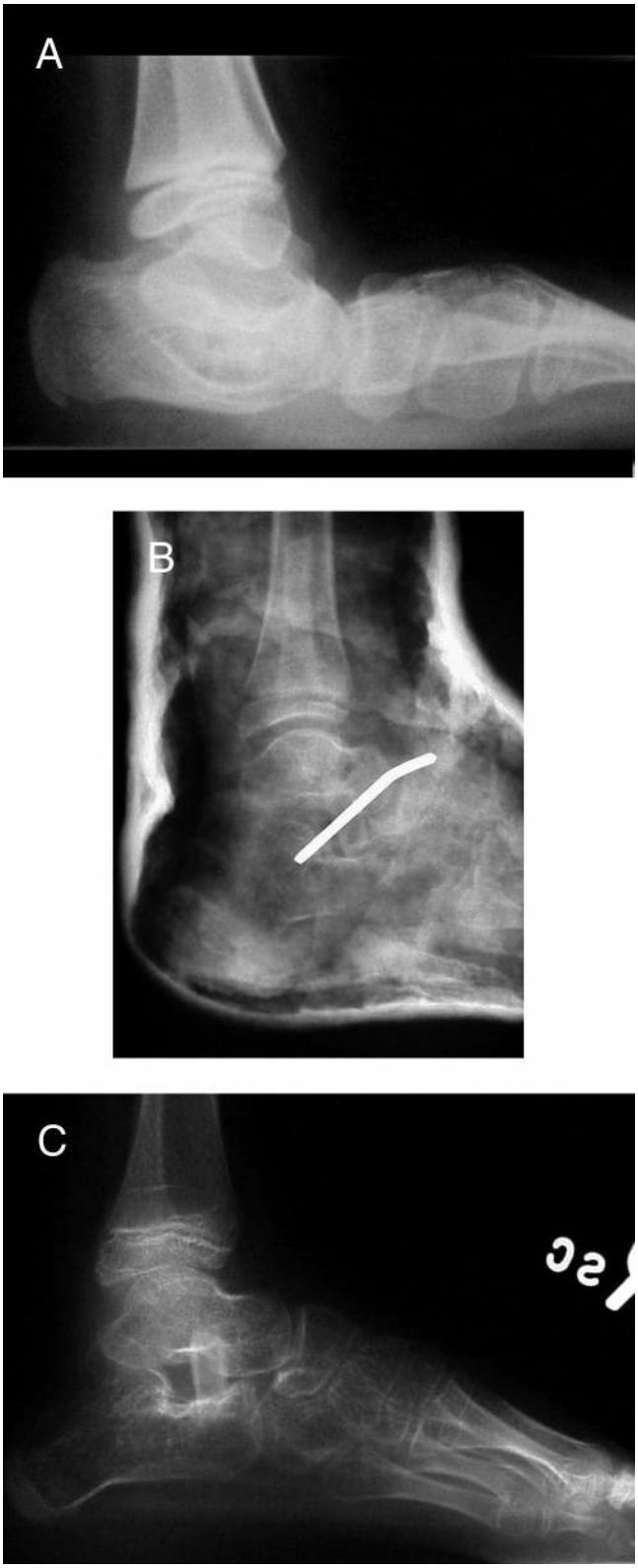


FIGURE 8 Recurrence of vertical talus deformity is not uncommon and may require further treatment with bracing or additional surgery. (*A*) This radiograph shows recurrent deformity in a young girl with myelomeningocele. Equinus of the talocalcaneal complex, rocker-bottom deformity, and talonavicular subluxation are present. (*B*) The patient was treated with a Green-Grice extraarticular subtalar arthrodesis. (*C*) Excellent reduction of deformity is seen immediately postoperative and is maintained on the follow-up radiograph. (Case courtesy of Loyola University Department of Orthopaedics and Rehabilitation Pathology Collection, Maywood, IL.)

formed that reconstruction is not possible. For these patients, naviculectomy may be the procedure of choice (53, 84–86). The Green-Grice procedure for extraarticular stabilization may also be used (53, 58, 87–89) (Fig 8). It may be necessary to consider lateral column lengthening (87), osteotomy of the calcaneus, and subtalar arthrodesis to maintain the corrected position. Talectomy may also be indicated in selected cases (68). Tendon transfer for rebalancing is frequently added in the surgical treatment plan. Continued observation and appropriate orthosis therapy follows.

Tarsal Coalition (Pathway 4)

Tarsal coalition is a congenital union between 2 or more tarsal bones that may be an osseous, cartilaginous, or a fibrous connection (90, 91). The incidence of tarsal coalition is 1% to 2% (90–92). Talocalcaneal and calcaneonavicular bars are the most common. Talocalcaneal coalitions are most commonly found at the middle facet (90, 91, 93, 94). Talonavicular and calcaneocuboid coalitions also have been described but are much less common. Autosomal dominant inheritance has been proposed (90, 95–97).

Significant History (Pathway 4, Node 1)

Tarsal coalitions may be asymptomatic (91). The child and parents may become aware of stiffness in the foot and ankle, altered foot shape, muscle spasm, and protective gait abnormalities. Symptoms of tarsal coalitions most commonly present in preadolescents or adolescents who suddenly gain weight and who take on physical activities, such as sports and forms of manual labor. Onset of symptoms may be insidious, precipitated by minor trauma or change in activity (98, 99).

Significant Findings (Pathway 4, Node 2)

Most symptomatic coalitions present with local tenderness around the lateral ankle, sinus tarsi, subtalar joint, or the coalition site. There is decreased or absent rearfoot range of motion with or without muscle spasm and some degree of rigid flatfoot.

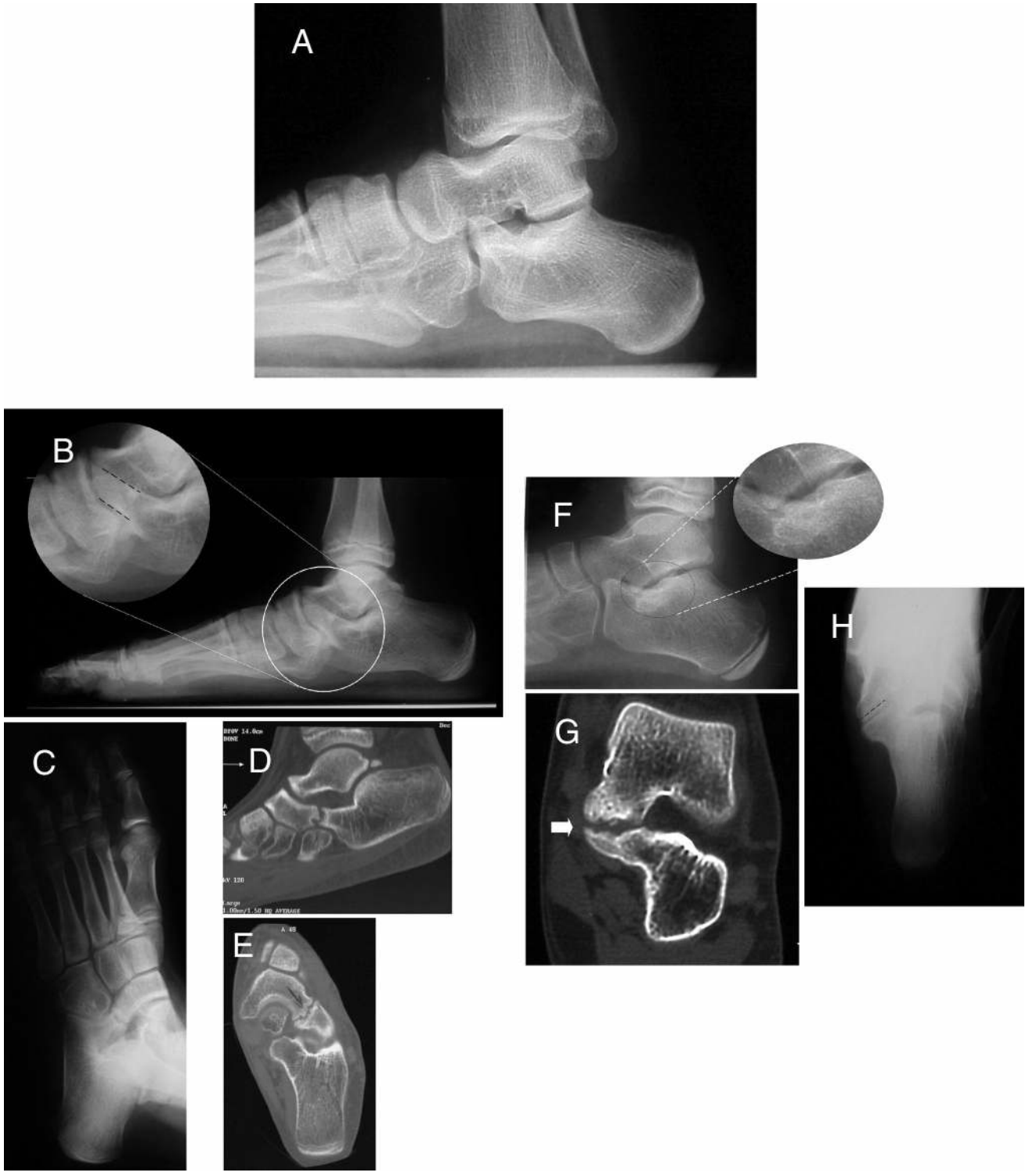


FIGURE 9 Tarsal coalitions account for most rigid flatfoot deformities seen at the community level. (*A*) Talonavicular coalition may be seen as an incidental finding. These feet are usually asymptomatic. Calcaneonavicular bars are common. (*B*) The lateral radiograph shows an exaggerated projection of the distal calcaneus (anteater sign). (*C*) Lateral oblique projection shows the connection between the calcaneus and the navicular. (*D* and *E*) MRI and CT imaging techniques better delineate the pathology. The talocalcaneal coalition may be diagnostically more difficult. (*F*) The lateral radiograph may show irregularity of the middle facet or complete obliteration of the middle facet. (*G*) Special views, such as the Harris-Beath projection, should show parallel relationship between the middle and posterior facets. (*G*) Shown here is an oblique and poorly visualized middle facet. (*H*) This is verified with a CT image.

Diagnostic Imaging (Pathway 4, Node 3)

Calcaneonavicular coalitions can be seen on both lateral and oblique radiographs of the foot as an upward and medial prolongation of the calcaneus toward the inferolateral navicular (Fig 9). Depending on the degree of ossification of the bridge, there may be a lucent line separating the 2 bones. The 45° oblique plain radiographic view is best for detection of the calcaneonavicular coalition.

Middle facet talocalcaneal coalitions are difficult to visualize because of the complexity of the anatomy and because many are cartilaginous. The lateral radiograph may show the "C" or halo sign (the C-shaped line formed by the medial outline of the talar dome and sustentaculam tali, which is a secondary sign of a coalition) (100). Harris-Beath projections may be useful, but they may be difficult to interpret because of problems with underpenetration. If positive, the articular end plates of the middle facet are irregular, the facets angulate down and medial, and there may be partial bridging evident (101). If angulation is more than 20°, coalition is probable (90, 93, 102). Because of the difficulty of interpretation, CT and MRI studies have largely replaced Harris-Beath projections (Fig 9).

CT is the diagnostic test of choice because of its ability to show the osseous structures (103–105). It is particularly useful for visualizing talocalcaneal coalitions and for evaluating multiple coalitions. Coronal images show the location and extent of their involvement (106–111, 112).

MRI is particularly useful in evaluating the immature skeleton and in determining the presence of other causes of peritalar pain (90, 103). It is helpful in evaluating fibrocartilagenous coalitions and nonossified coalitions in the very young (90, 113–116).

Bone scans have been used to show increased stresses at articular surfaces. Bone scans are sensitive but nonspecific (117–119).

Diagnosis (Pathway 4, Node 4)

Diagnosis of tarsal coalition is based on pain and loss of motion and supported by appropriate imaging studies. Coalitions are classified by site, type of interposing tissue, extent of involvement, and secondary degenerative changes (Table 1).

Initial Treatment (Pathway 4, Node 5)

The initial treatment for any coalition should be nonsurgical (90, 120–122). Patients with mild symptoms may respond well to footwear modifications, arch supports, or custom orthoses. Activity modifications, weight reduction, antiinflammatory medication, and local anesthetic blocks may also be indicated (90). Cast immobilization for several weeks may be indicated for patients with more severe symptoms or with peroneal spasm (97).

TABLE 1 Classification of tarsal coalitions

Tissue types	Anatomic
	Extraarticular
Cartilaginous	Calcaneonavicular
Fibrous	Cuboidonavicular
Osseous	Trigonal
	Intraarticular
	Talocalcaneal
	Middle
	Posterior
	Anterior
	Combination
	Talonavicular
	Calcaneocuboid
	Naviculocuneiform
Articular	
Juvenile (osseous immaturity)	Adult (osseous maturity)
Type I: Extraarticular coalition	Type I: Extraarticular coalition
A. No secondary arthritis	A. No secondary arthritis
B. Secondary arthritis	B. Secondary arthritis
Type II: Intraarticular coalition	Type II: Intraarticular coalition
A. No secondary arthritis	A. No secondary arthritis
B. Secondary arthritis	B. Secondary arthritis

Clinical Response (Pathway 4, Node 6)

After a period of nonsurgical treatment, patients should be reevaluated. If symptoms have been relieved, the initial treatment options should be continued (Node 7), with periodic observation of clinical progress (Node 8).

Surgical Intervention (Pathway 4, Node 9)

Surgical consideration should be given to those who fail to respond to nonsurgical treatment (6, 101, 122). Surgical treatment depends on the type of coalition. Resection of the coalition may be indicated for individuals without significant deformity or arthrosis (Fig 10). In some cases, arthrodesis may be the procedure of choice.

In children with foot deformity, osteotomy should be performed in conjunction with resection. If significant arthritic changes are found, arthrodesis should be considered. Isolated talocalcaneal arthrodesis is indicated for subtalar coalitions (96). If peritalar degeneration is evident, triple arthrodesis may also be indicated (Fig 11) (101, 102, 120, 122).

Observation and supportive orthoses should follow surgery (Node 8). If symptoms recur, the patient may need to return to nonsurgical options. These measures are not likely to provide adequate relief of symptoms.

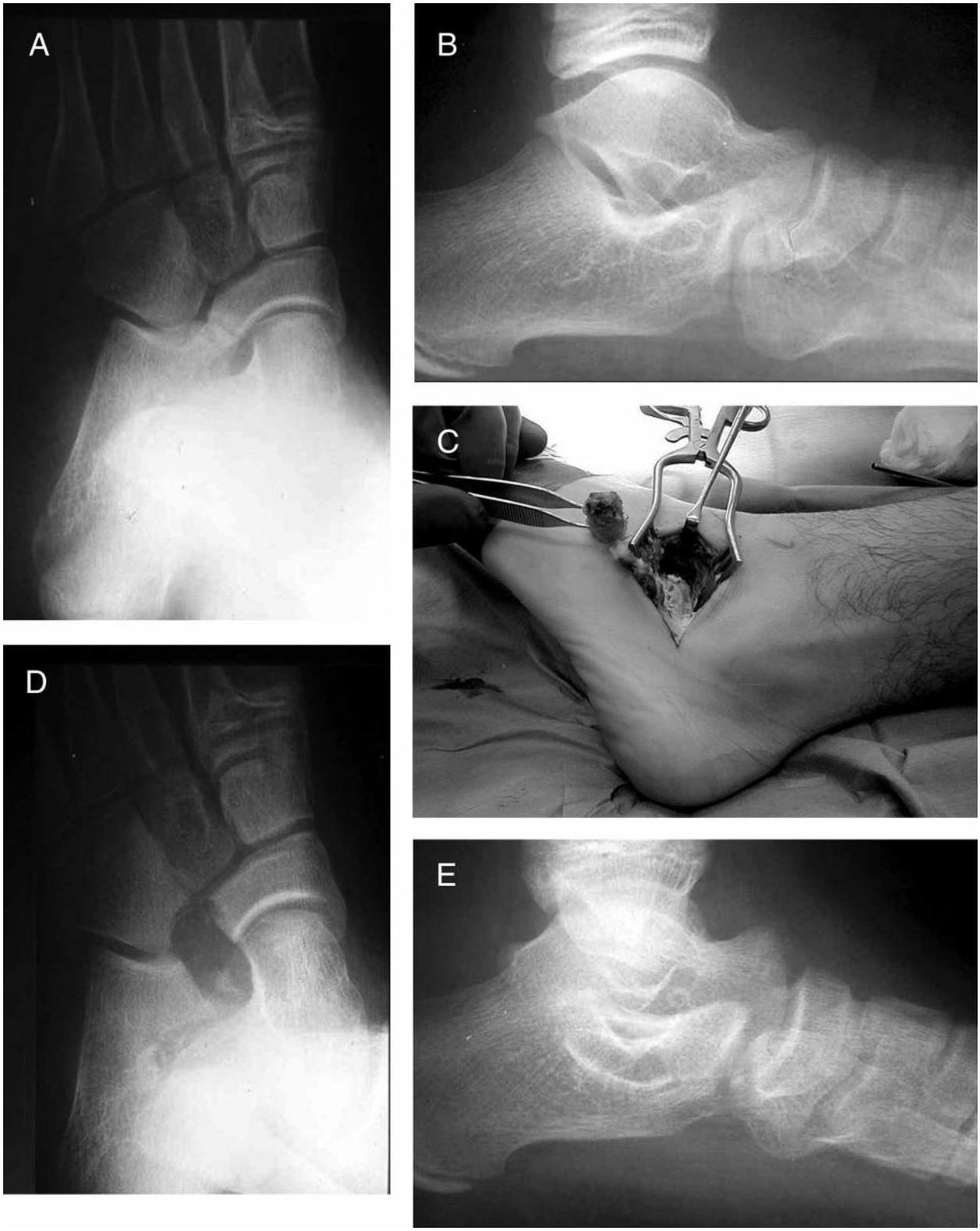


FIGURE 10 Calcaneonavicular coalitions may be fibrous, cartilaginous, or osseous. Younger patients may benefit by excision of the bar. (*A* and *B*) Oblique and lateral radiographs demonstrate the bar as well as the pronatory foot deformity. (*C*) Shown is an intraoperative view of the excised fragment. Excision should restore the mobility of the rearfoot complex. (*D* and *E*) The postoperative oblique and lateral radiographs show adequate resection of the extraarticular bar.

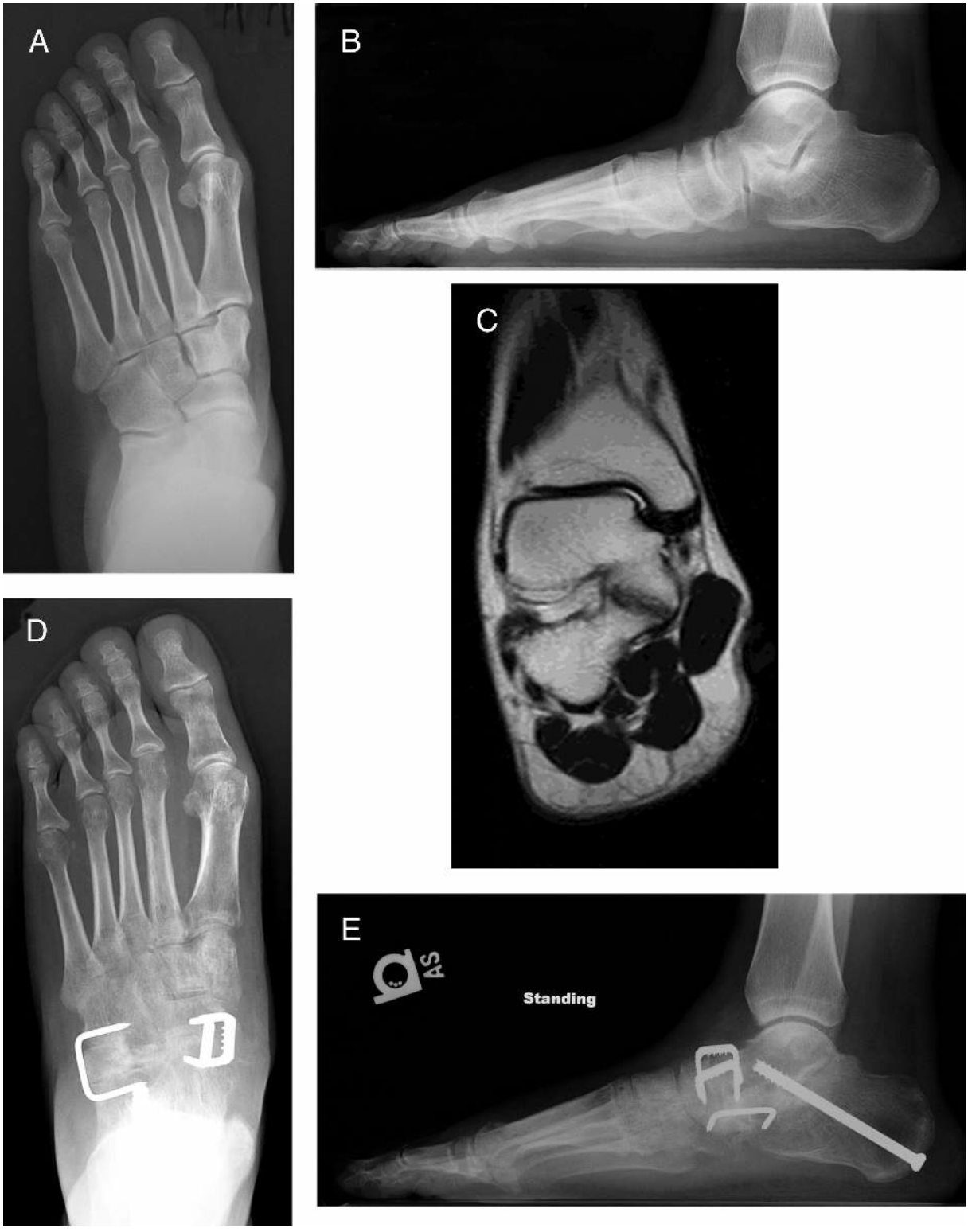


FIGURE 11 Talocalcaneal coalitions limit or prevent normal joint motion. Once they occur, degenerative joint changes are irreversible. Treatment in the older adolescent or young adult usually requires subtalar or triple arthrodesis. (*A* and *B*) AP and lateral radiographs show significant pronatory foot deformity with low calcaneal inclination, increased talar declination, and depression of the medial column. Clinically, no subtalar motion is present. (*C*) MRI evaluation shows a middle subtalar facet coalition. (*D* and *E*) Surgical treatment with triple arthrodesis restored rearfoot relationships and eliminated pain.

Peroneal Spastic Flatfoot Without Coalition (Pathway 5)

Peroneal spastic flatfoot without coalition is a painful foot deformity made rigid by spasm of the extrinsic muscles. Although tarsal coalition is the most common cause of peroneal spastic flatfoot (see Pathway 4) (123–132), its presence cannot be confirmed in a number of cases. Other possible causes (133) include juvenile chronic arthritis (134), osteochondral fractures in the rearfoot, osteoid osteoma, neoplasms (135), dysplasia epiphysealis hemimelica (Trevor disease) (136), and problems more proximal in the limb (slipped capital femoral epiphysis) (137). When no cause can be found, the condition has been labeled idiopathic peroneal spastic flatfoot.

Significant History (Pathway 5, Node 1)

The patient develops pain in the foot, followed by protective limitation of motion by the extrinsic muscles. Pain is experienced with activity, and symptoms may be precipitated by trauma. Many patients have been previously evaluated for tarsal coalition, but there have been no objective or imaging findings to support the diagnosis.

Significant Findings (Pathway 5, Node 2)

Peroneal muscle spasm, restricted subtalar and ankle motion, valgus appearance of the foot, and constant or intermittent pain in response to activity are the hallmarks of the condition. Clinical findings are not limited to the peroneal muscles alone. The extensors, tibialis anterior, and tibialis posterior are involved.

Gait pattern is antalgic with external rotation of the foot to the line of progression. There is little or no propulsion during late stance phase of gait.

Diagnostic Studies (Pathway 5, Node 3)

Diagnostic imaging that fails to show a tarsal coalition or typical secondary findings of a tarsal coalition (see Pathway 4) may show other pathologies that might explain the condition such as osteochondral defect, pathologic fracture through a bone cyst, or osteomyelitis (Fig 12).

A preliminary bone scan may help localize the pathology. A total body bone scan is useful to rule out otherwise silent multiple anatomical sites in systemic disease. In some cases, all imaging studies may be normal and further clinical investigation is indicated.

Laboratory studies (Node 4) should include a complete blood cell count with differential and acute phase reactants (erythrocyte sedimentation rate and C-reactive protein). Elevated inflammatory markers suggest a rheumatologic cause and merit further investigation or consultation (Node 5).

Diagnosis (Pathway 5, Node 6)

Peroneal spastic flatfoot without coalition is a diagnosis of exclusion and may be ultimately considered idiopathic.

Initial Treatment (Pathway 5, Node 7)

When a specific cause is detected, appropriate treatment is directed toward that cause. If no cause can be identified, symptoms dictate the type of treatment. When symptoms are intermittent, activity modifications may prove useful. This may include stopping sports, discouraging running and jumping activities, and taking the child out of physical education class. Activity modifications can be supplemented with nonsteroidal antiinflammatory medications. Footwear modifications, arch supports, and orthosis may also be beneficial.

In more difficult cases, immobilization in a walking boot may prove helpful. However, patient compliance is often a problem. This can be solved with a nonweightbearing below-knee cast and crutches. In extreme cases, an above-knee cast can be considered. Common peroneal nerve blocks can be both therapeutic and diagnostic.

Clinical Response (Pathway 5, Node 8)

If clinical response to treatment results in resolution of the symptoms and restoration of painless range of motion, follow-up orthotic treatment may be indicated and the patient should be observed periodically (Nodes 9 and 10).

Surgical Intervention (Pathway 5, Node 11)

If symptoms do not resolve with nonsurgical treatment, surgical options can be considered (Node 11). Surgical procedures include arthrodesis and realignment osteotomy. Observation and supportive orthoses should follow surgery (Node 10).

Iatrogenic and Posttraumatic Deformity (Pathway 6)

Iatrogenic and posttraumatic flatfoot are uncommon and encompass a broad spectrum of foot disorders. Management can be challenging and complex, necessitating case-by-case consideration. Surgical treatment of infant foot deformities often results in undercorrection or over-

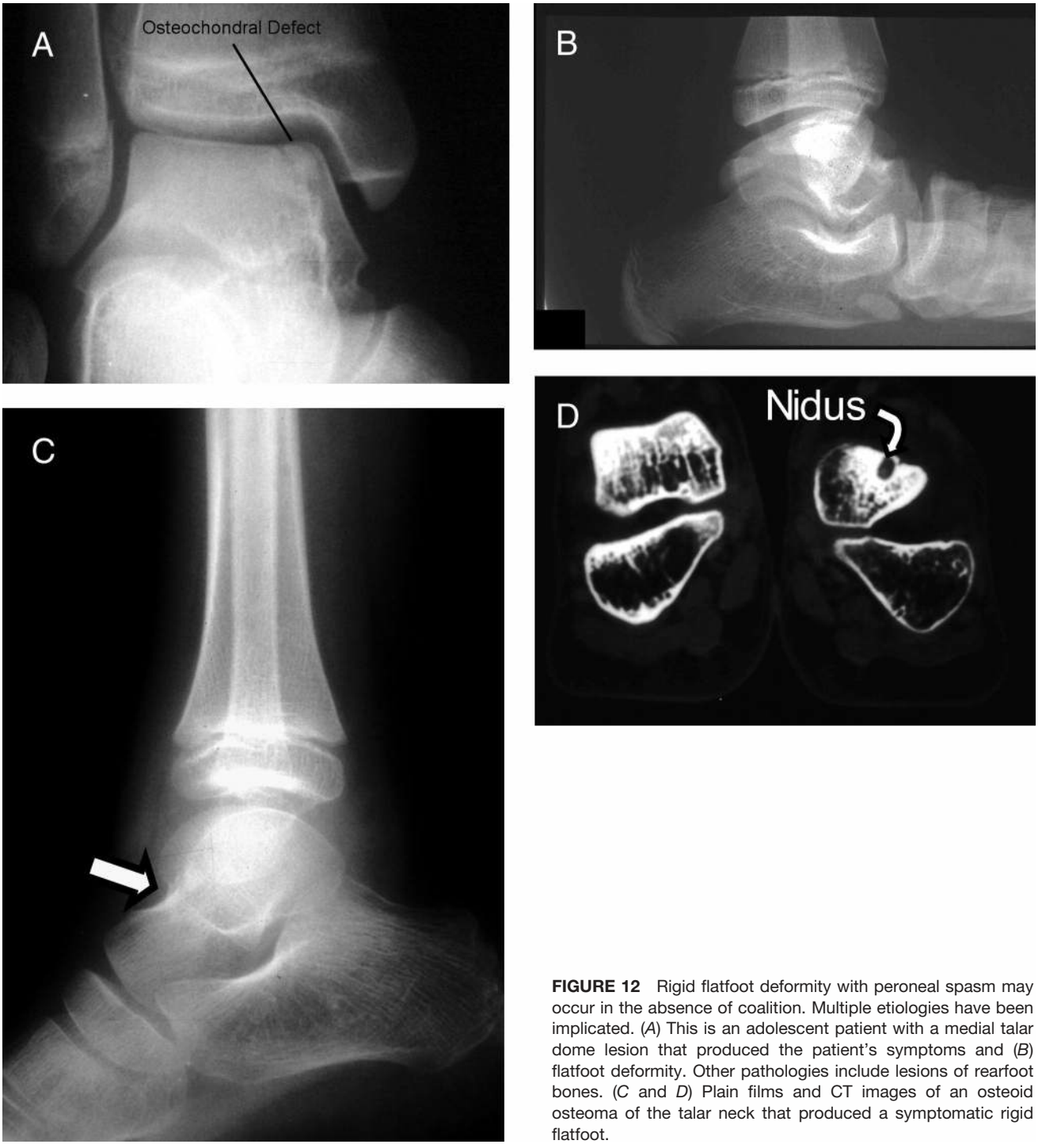


FIGURE 12 Rigid flatfoot deformity with peroneal spasm may occur in the absence of coalition. Multiple etiologies have been implicated. (*A*) This is an adolescent patient with a medial talar dome lesion that produced the patient's symptoms and (*B*) flatfoot deformity. Other pathologies include lesions of rearfoot bones. (*C* and *D*) Plain films and CT images of an osteoid osteoma of the talar neck that produced a symptomatic rigid flatfoot.

correction. This is particularly true for talipes equinovarus (138–144). The goal of treatment is a flexible, plantigrade, painless foot. In many cases, a perfect outcome is not possible. Often, the end result is a rigid and, hopefully, plantigrade foot.

Etiologic factors include overcorrected clubfoot (Fig 13), undercorrected vertical talus (145–148), failed flatfoot surgery, and end-stage trauma. Iatrogenic or posttraumatic flatfoot may also be caused by manipulation or casting of the pliable, easily damaged infant foot.

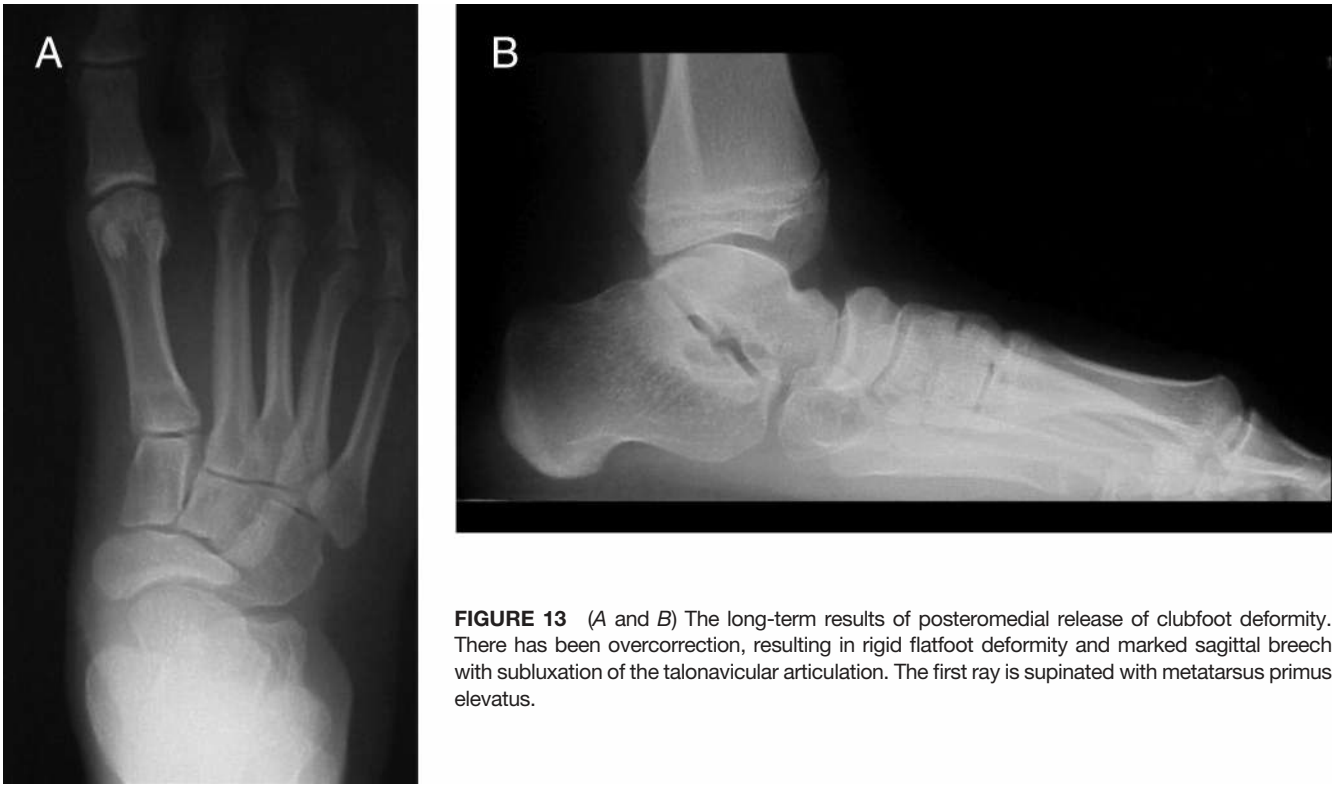


FIGURE 13 (*A* and *B*) The long-term results of posteromedial release of clubfoot deformity. There has been overcorrection, resulting in rigid flatfoot deformity and marked sagittal breech with subluxation of the talonavicular articulation. The first ray is supinated with metatarsus primus elevatus.

Significant History (Pathway 6, Node 1)

Patients with iatrogenic or posttraumatic flatfoot present with variable degrees of pain, loss of function, and progressive deformity. All feet in this category have a history of previous manipulation, surgery, or trauma. Onset of flatfoot deformity may be either immediate or delayed by months or years.

Significant Findings (Pathway 6, Node 2)

Examination may determine pain, stiffness, scarring, abnormal function, and gait disturbances.

Diagnostic Imaging (Pathway 6, Node 3)

Plain radiographs may show postsurgical changes, retained implants and hardware, malalignment, and arthritis. CT, MRI, and bone scans may be useful in further defining the deformity and in evaluating residual pathology.

Diagnosis (Pathway 6, Node 4)

The patient's history, coupled with diagnostic imaging, confirms the diagnosis of iatrogenic or posttraumatic flatfoot.

Initial Treatment (Pathway 6, Node 5)

Shoe modifications and bracing may be indicated in the initial management of these deformities. Activity modifications, weight reduction, physical therapy, and nonsteroidal antiinflammatory medication may be helpful.

Clinical Response (Pathway 6, Node 6)

If the clinical response is satisfactory, continued nonsurgical management and observation are in order (Nodes 7 and 8).

Surgical Intervention (Pathway 6, Node 9)

If there is no response to nonsurgical treatment, surgical intervention (Node 9) may be necessary to achieve the goal of a stable pain-free plantigrade foot. The specific procedures are directed to the deformity, the condition of the soft tissues, and the joints and osseous structures. Patient and parental education should be provided to encourage realistic expectations.

Soft tissue release, osteotomy, and arthrodesis (145–148) are the procedures most frequently used. In certain cases, severe deformities may be realigned with distraction osteogenesis (Ilizarov) (139). Rarely, in the case of intractable pain and unstable deformity or chronic osteomyelitis, an

amputation followed by a functional prosthesis is a reasonable choice to allow the patient to return to activities.

Patients should be followed up for observation (Node 8). Recurrence is possible and necessitates reevaluation.

Skewfoot (Pathway 7)

Skewfoot is characterized by forefoot adduction (metatarsus adductus) and heel valgus (149–151). The more severe cases have midfoot abduction. There are no universally accepted clinical or radiographic criteria for skewfoot (150) and the natural history of idiopathic skewfoot is poorly understood (150, 152, 153). There are 4 types of skewfoot: congenital idiopathic, congenital associated with syndromes, neurogenic, and iatrogenic (151).

Significant History (Pathway 7, Node 1)

Skewfoot may be asymptomatic or associated with activity-related pain and difficulty in fitting shoes (150, 154). It is often misdiagnosed as metatarsus adductus and flexible flatfoot. Skewfoot should be suspected if the infant does not respond favorably to treatment for metatarsus adductus.

Significant Findings (Pathway 7, Node 2)

The deformity is characterized as an S- or Z-shaped foot with forefoot adductovarus and rearfoot valgus (149) (Fig 14). In children younger than 1 year of age, the rearfoot valgus is not as apparent as the forefoot deformity (151). Contracture of the tendo-Achilles may be present (150, 151). Calluses and other skin problems may occur (150, 154).

Diagnostic Imaging (Pathway 7, Node 3)

Standard radiographs show metatarsus adductus and severe heel valgus (Fig 14).

Diagnosis (Pathway 7, Node 4)

Clinical findings and supportive radiographs confirm the diagnosis of skewfoot.

Initial Treatment (Pathway 7, Node 6)

Asymptomatic skewfoot in older children needs no treatment (Node 5). Management of skewfoot is based on age, degree of severity, and presence of symptoms (155). Manipulation and serial casting may be indicated for infants (155). Stretching exercises and activity modification may relieve mild symptoms but they will not change the deformity (150). Orthoses may be used for symptomatic relief but may exacerbate the symptoms in the presence of ankle equinus (150). Nonsteroidal antiinflammatory medications may also be beneficial. Management of comorbid conditions is important.

Clinical Response (Pathway 7, Node 7)

Clinical response to treatment is evaluated. Observation and continuation of initial treatment options are recommended for children whose symptoms resolve (Node 8).

Surgical Intervention (Pathway 7, Node 9)

Persistence of severe symptoms may require surgical intervention. Surgical treatment must address both the forefoot and the rearfoot components (Fig 15). Useful procedures include metatarsal osteotomies and midfoot osteotomy to correct the forefoot. Lateral column lengthening, calcaneal displacement osteotomy, and tendo-Achilles lengthening are used to correct the rearfoot (149–151, 155, 156).

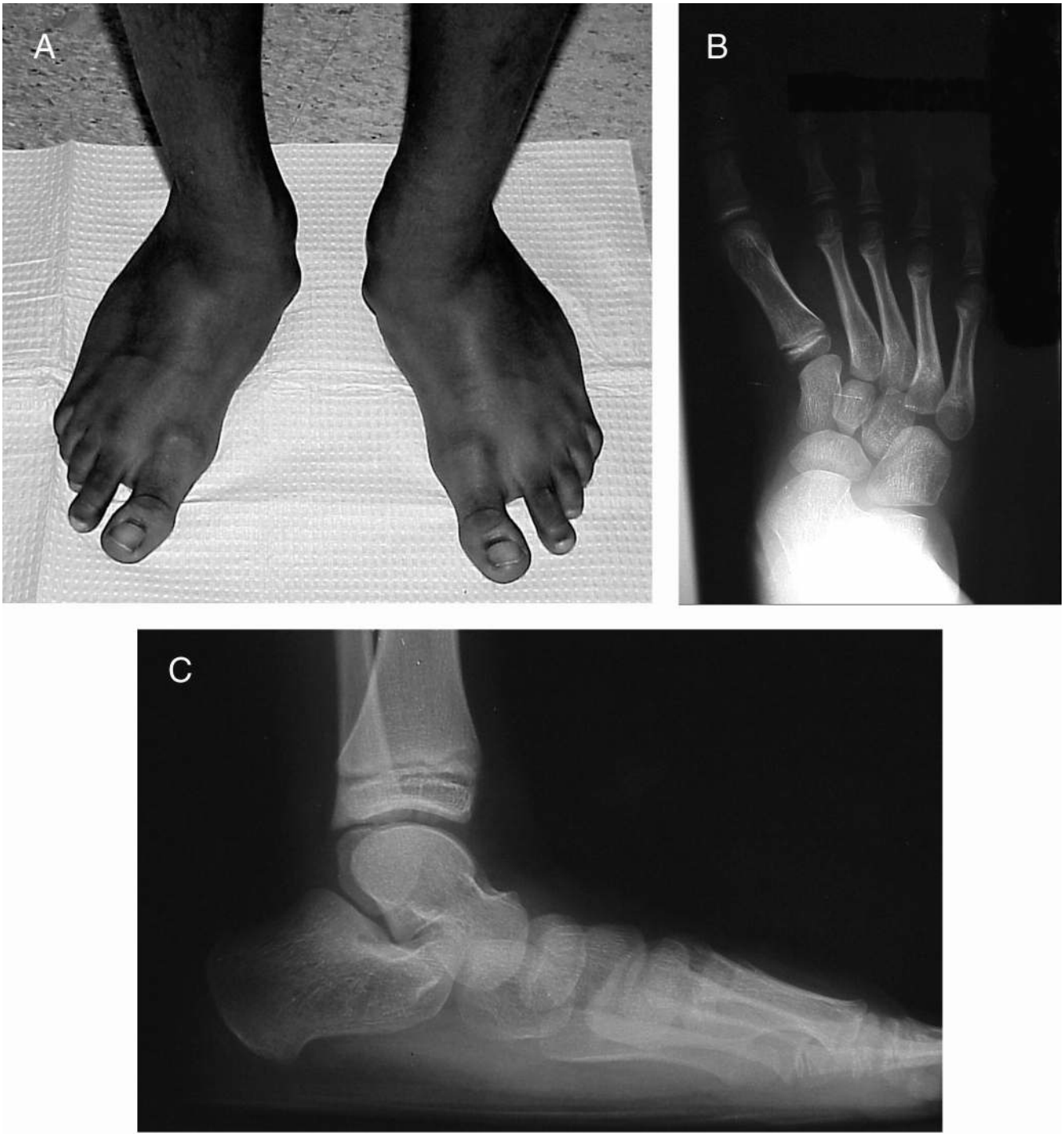


FIGURE 14 Skewfoot, an uncommon but very severe variant of the flatfoot deformity, is characterized by rearfoot pronation, midfoot abduction, and metatarsus adductus. (*A*) This clinical photograph of an adolescent patient with skewfoot shows forefoot adduction—unlike forefoot abduction seen with most other flatfoot deformities. (*B*) The AP radiograph shows very prominent metatarsus adductus deformity with a large talocalcaneal angle. (*C*) The lateral radiograph shows sagittal plane failure of the medial column with talar ptosis (pathologic declination).

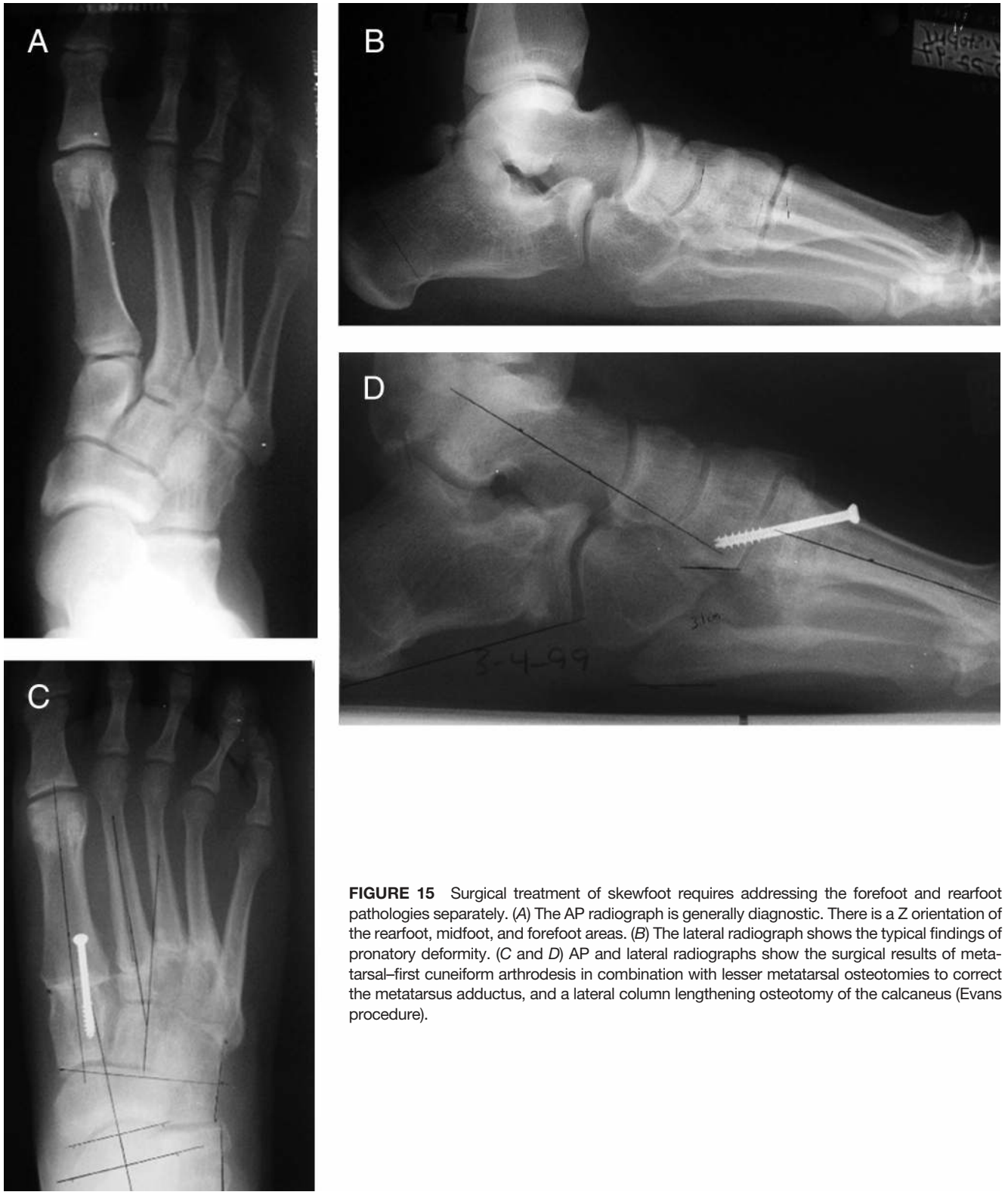


FIGURE 15 Surgical treatment of skewfoot requires addressing the forefoot and rearfoot pathologies separately. (*A*) The AP radiograph is generally diagnostic. There is a Z orientation of the rearfoot, midfoot, and forefoot areas. (*B*) The lateral radiograph shows the typical findings of pronatory deformity. (*C* and *D*) AP and lateral radiographs show the surgical results of metatarsal–first cuneiform arthrodesis in combination with lesser metatarsal osteotomies to correct the metatarsus adductus, and a lateral column lengthening osteotomy of the calcaneus (Evans procedure).

Other Causes of Pediatric Flatfoot (Pathway 8)

Some forms of pediatric flatfoot deformity do not fit into the previous schemes. They are unique because their clinical findings are dictated by the underlying pathology. Additionally, the clinical approach to diagnosis and treatment is dependent on the cause. Some have natural histories that are totally unpredictable, and early intervention is undesirable until the problem has fully expressed itself.

Significant History (Pathway 8, Node 1)

These forms of pediatric flatfoot are associated with generalized ligamentous laxity; Marfan disease; Ehlers-Danlos; and Down syndrome, cerebral palsy, myelomeningocele, developmental delay, genetic diseases, and other syndromes (Fig 16).

Significant Findings (Pathway 8, Node 2)

A variable pattern of foot deformities may be seen. The deformities range from hypermobile to rigid. Physical examination of these children must include observational gait analysis, assessment of generalized joint mobility for hyperlaxity and hypolaxity, and thorough neurologic examination. Examination of the foot for mobility, calluses, and skin irritation is necessary.

Diagnostic Imaging (Pathway 8, Node 3)

Diagnostic imaging should be performed as clinically indicated.

Diagnosis (Pathway 8, Node 4)

There is nothing unique about this group of pathologies that has not been previously discussed. Refer to previous pathways for detailed discussion.

Initial Treatment (Pathway 8, Node 6)

In planning the treatment of flatfoot in children with underlying diseases, it is important to consider the patient's baseline function, the demands placed on the feet, and the natural history of the underlying disease. Asymptomatic hypermobile flatfeet in syndromatic children are usually best left alone (Node 5).

Treatment is based on structural deformity and functional demands placed on the foot. Treatment is usually indicated if the child is ambulating or likely to become ambulatory. Children with an unstable base of support secondary to flatfoot may be treated with supportive orthoses (Node 7).

Surgical Intervention (Pathway 8, Node 8)

If bracing is not tolerated or does not provide a solid base of support, surgical intervention may be considered. Surgical options are aimed at the specific pathoanatomy and include osteotomies, arthrodesis, arthroereisis, and tendon transfers. Long-term orthosis management after surgical intervention is usually recommended to maximize function (Node 7).

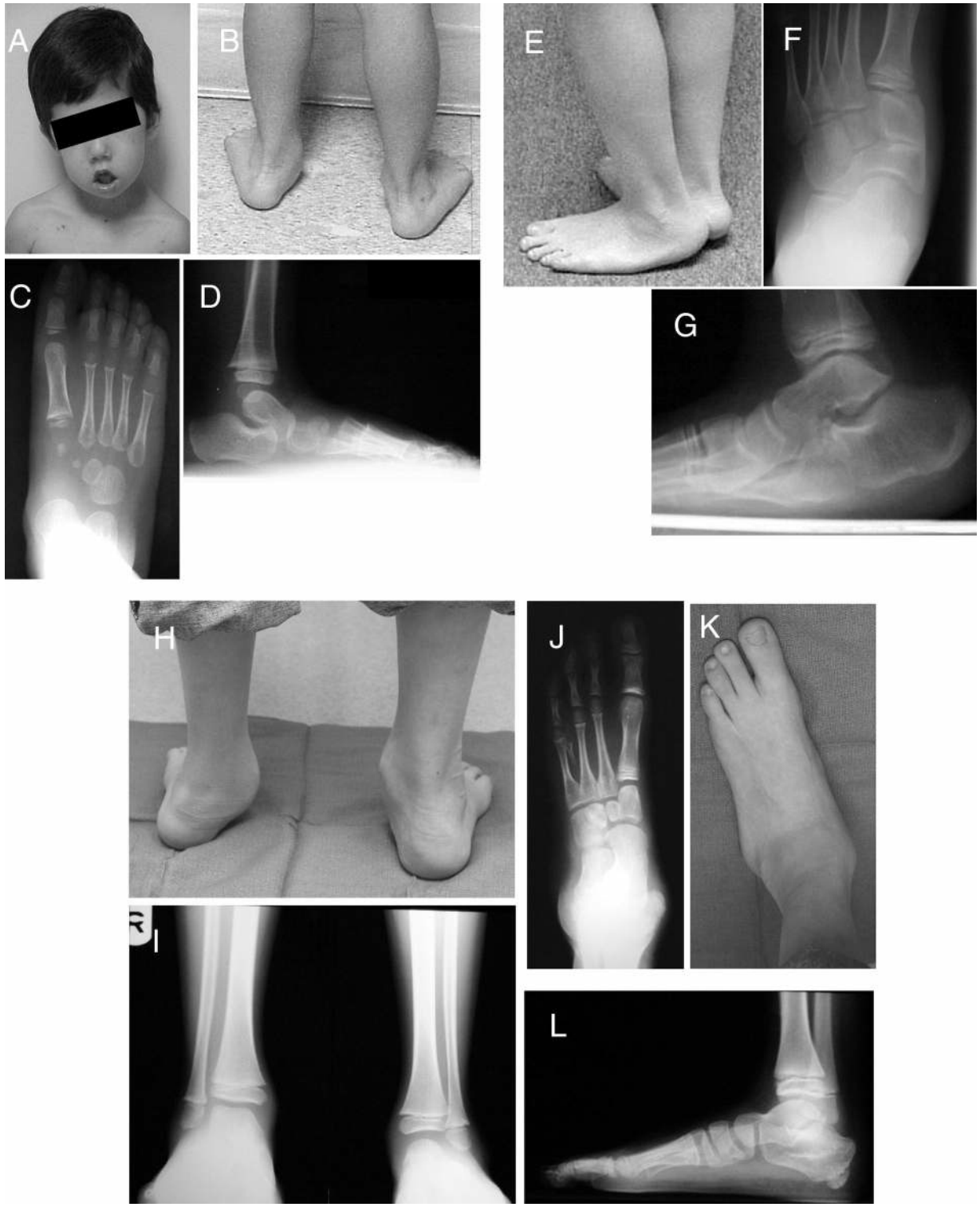


FIGURE 16 Flatfoot deformities in combination with systemic disease and syndromic patterns may be extremely difficult to treat. (*A*) Children with congenital myotonic dystrophy show characteristic facial weakness with a cupid bow mouth and inexpressive appearance. (*B*) Pronatory foot deformities are a regular feature shown clinically by excessive relaxed calcaneal stance position. (*C* and *D*) AP and lateral radiographs show typical features of severe flatfoot deformity. (*E*) This is the standing lateral photograph of an 8-year-old with chromosomal abnormality, showing pronation with equinus. (*F* and *G*) The AP and lateral radiographs show complex midfoot and rearfoot coalitions. (*H–L*) Shown is a boy with a congenital ball-and-socket ankle with a talonavicular coalition and absence of a lateral ray. Hindfoot instability with a valgus heel and forefoot abduction are shown clinically and radiographically.