Review Article

# Evaluation and Management of Adolescents With a Stiff Flatfoot

Samuel E. Ford, MD
Jacob R. Zide, MD
Anthony I. Riccio, MD

From the OrthoCarolina Foot and Ankle Institute, Charlotte, NC (Ford), Orthopedic Associates of Dallas, Baylor Scott & White, Dallas, TX (Zide), and the Texas Scottish Rite Hospital for Children, Dallas, TX (Zide and Riccio).

Zide or an immediate family member serves as a consultant for Orthofix and has received money from them for educational meetings; is a member of a committee for American Orthopaedic Foot and Ankle Society; and is member of the steering committee for the Pediatric Foot Research Group (PediFoRG). Riccio or an immediate family member has completed paid educational lecture for orthopediatrics at the European Pediatric Orthopaedic Society meeting; is a member of Pediatric Orthopaedic Society of North America committees; serves on the Board of Directors for Children's Orthopaedic Trauma and Infection Consortium for Evidence Based Studies (CORTICES); and has received investigator-initiated research support from Arthrex. Neither Ford nor any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article.

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## ABSTRACT

While flatfeet are normal in children, persistence into adolescence with associated pain or asymmetry warrants additional evaluation. Rigidity of a flatfoot deformity, whether a clinical report or evident on examination, should raise suspicion for pathology. The differential diagnosis includes tarsal coalition, neurogenic planovalgus, and peroneal spasticity. History must include pointed inquiry into birth and neurologic histories to probe for a source of central spasticity. Examination must include standing assessment of hindfoot and midfoot alignment. Hindfoot rigidity may be assessed by the double limb heel rise test and manual examination. Radiographs should include standing ankle (anterior-posterior and mortise) and whole foot (anterior-posterior, external rotation oblique, and lateral) images. Magnetic resonance imaging is more sensitive for identifying coalitions and better characterizes adjacent cartilage, subchondral edema, and tendon pathology, yet CT better characterizes the anatomy of a bony coalition. Conservative treatments are pathology-dependent and play a more prominent role in neurogenic or peroneal spastic flatfoot. Surgical management of coalitions is centered on coalition resection coupled with arthrodesis in the case of a talocalcaneal coalition with a dysplastic subtalar joint; concomitant planovalgus reconstruction is considered on a case-by-case basis.

Although most adolescent flexible flatfeet remain asymptomatic, rigid deformities have a less predictable clinical course and are associated with a variety of underlying causes. It is therefore critical to investigate the etiology of rigid flatfoot deformities when encountered such that proper management can be recommended.

Flexible flatfeet in childhood and adolescence are a variant of normal. Although 44% of children aged 3 to 6 years have hindfoot valgus and an associated flattened medial arch, alignment corrects to normal in nearly half of children by the age of six years.[1] In late childhood and early adolescence, medial longitudinal arch elevation continues, with the prevalence of planovalgus decreasing to 12% to 13% by the age of 12 to 14 years.[2,3] Increasing weight and body mass index correlate with a persistence of flatfoot deformity in adolescence.[1,3,4] Interestingly, a decreased prevalence with age occurs largely in children with bilateral flatfeet, while the prevalence among children with a unilateral flatfoot remains more constant possibly because unilateral deformities are often rigid.[3] Rigid deformities are distinguished by careful physical examination.

It is important that the differential diagnosis of an adolescent with a rigid flatfoot is viewed through a wide lens because the orthopaedic surgeon may be the first physician to evaluate the patient aside from their pediatrician. Management varies widely depending on etiology and is guided by patient complaints, location of associated pain, and severity of deformity. The most common cause of a rigid flatfoot is a tarsal coalition. Neurogenic causes of flatfoot include anoxic brain injury, cerebral palsy, Chiari malformation, syrinx, tethered spinal cord, trauma, and central nervous system tumors, among others. Neurology consultation may assist in working through this differential list. Finally, peroneal spastic flatfoot, which is a diagnosis of exclusion, may be considered.

## Patient Evaluation

### History

Flatfooted adolescents may present with or without pain, often in the context of parental concerns about the appearance of their feet. Adolescents with a unilateral, nonprogressive flatfoot, a history of multiple ankle sprains, or worsening of symptoms with a corrective arch support should raise suspicion for a rigid flatfoot.[5,6] They may describe a vague, aching or throbbing discomfort in the ankle or hindfoot that is worse with or after physical activity or at the end of the day.

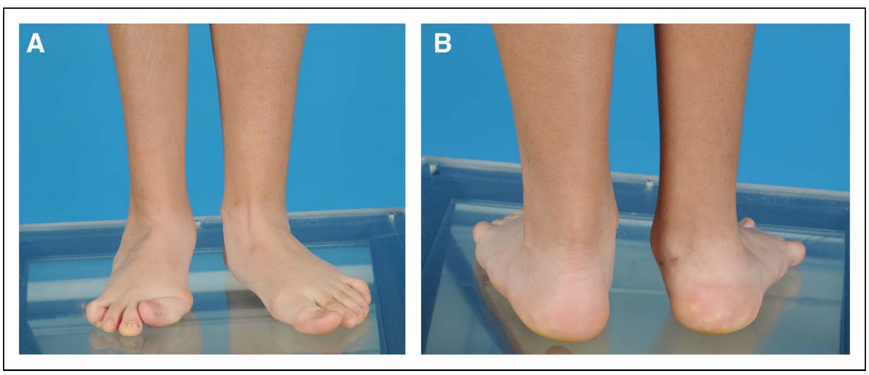
Obtaining a thorough medical history is important because patients with mild cerebral spasticity secondary to anoxic brain injuries during infancy can present initially to an orthopaedic surgeon for the evaluation of a rigid spastic flatfoot. Flatfoot deformity in these cases is often progressive, which should serve as a warning sign for the practitioner. A history of prematurity, prolonged neonatal intensive care unit stay, infantile seizures, or early infectious/traumatic brain injury requires a more careful and detailed neurologic assessment.

### Physical Examination

The patient should be inspected from both the front and the back (Figure 1). It is important to assess patient stature and lower extremity length and alignment because foot pathology can correlate with other lower extremity problems and global syndromes, such as fibular hemimelia, tarsal-carpal coalition syndrome, and other symphalangism spectrum disorders.[7-10] The clinician should observe for coronal plane pelvic tilt, asymmetry of muscle bulk, and a compensatory equinus foot position in the setting of a leg length discrepancy.

Adolescents with a flatfoot will have a variable degree of increased valgus hindfoot position, collapse of the medial arch, midfoot abduction, and forefoot supination. The "too many toes" sign is usually present but may be affected by the rotational position of the extremity and does not adequately describe the segmental characteristics of individual flatfoot deformities (Figure 2). The Silfverskiöld test should be used to assess for the contracture of the gastrocnemius or Achilles tendon because contractures are common in both rigid and flexible flatfeet.[11,12] If subtalar motion is present, assessing the gastrocnemius-soleus complex with the heel held in a corrected/neutral alignment is vital to avoid a false-negative test.

**Figure 1**




Clinical photographs of an 11-year-old girl with a right-sided rigid flatfoot due to a talocalcaneal coalition and a left-sided flexible flatfoot. Inspection from the front (**A**) demonstrates a more prominent medial malleolus on the right because of the more severe hindfoot valgus, clearly seen on examination from behind (**B**).

## Figure 2

Clinical photograph of a 10-year-old girl with a unilateral left-sided rigid flatfoot secondary to a talocalcaneal coalition. Inspection of the left foot from behind demonstrates severe hindfoot valgus and a "too many toes" sign. This "normally" aligned contralateral foot displays physiologic hindfoot valgus with only the fifth toe visible lateral to the heel.

The identification of a rigid deformity on examination is critical to establish the differential diagnosis and treatment options. A standing double limb heel rise will allow for a dynamic assessment of hindfoot motion. In a flexible flatfoot, heel rise will initiate inversion of the hindfoot by a pull of the posterior tibialis. Failure of the hindfoot to correct into a varus position with heel rise indicates that a rigid hindfoot is likely present (Figure 3). On seated examination, with the patients' feet hanging off the examination table with bent knees, visual inspection of a rigid hindfoot may reveal a resting foot posture of increased dorsiflexion and eversion (Figure 4). While seated, the hindfoot should also be manually assessed. With the patient relaxed, the tibiotalar joint is brought into a position of neutral dorsiflexion, drawing the wider anterior portion of the talar body into the ankle mortise and effectively dampening coronal plane motion through the tibiotalar articulation. Inversion and eversion can then be assessed through a passive motion arc by the examiner; a rigid hindfoot will exhibit little to no inversion-eversion motion.

Hindfoot rigidity should raise the examiner's index of suspicion for tarsal coalition and peroneal spasm. A palpable eminence may be noted (reported in up to 63% of cases) inferior to the medial malleolus and patients may be tender to palpation in the sinus tarsi in talocalcaneal (TC) coalitions.[13] A palpable subcutaneous bony projection off of the anterior process of the calcaneus in the calcaneonavicular interval may indicate a calcaneonavicular (CN) coalition. A palpable, tense "bowstring" peroneus brevis along the lateral hindfoot may indicate peroneal spasm.

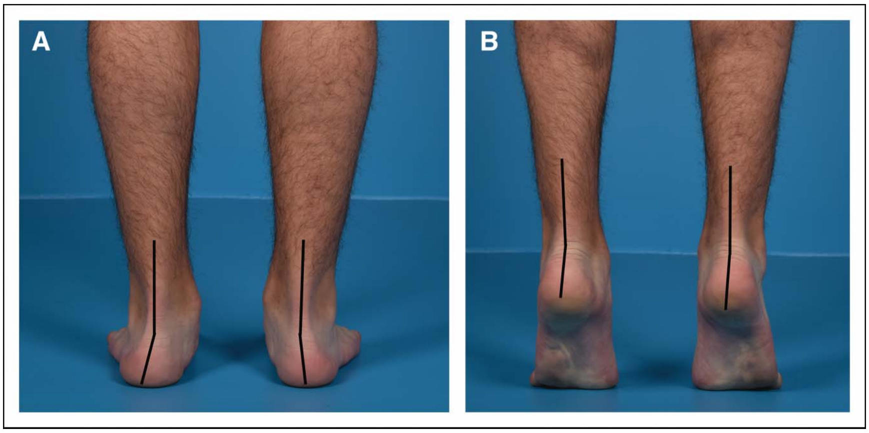
Finally, the plantar aspect of the foot, specifically under the talar head, should be examined for callosities indicative of abnormal pressure distribution during weight-bearing activities caused by malalignment.

## Plain Radiographs

Weight-bearing ankle (anterior-posterior [AP] and mortise) and foot (AP, 45° external rotation oblique, and lateral) radiographs should be obtained in children and adolescents who present with a painful and/or rigid flatfoot.[14] The AP and mortise ankle views define distal tibial alignment and hindfoot alignment relative to the tibia and may rule out ankle pathology.[15]

The AP foot view allows for the quantification of midfoot abduction (AP talus-first metatarsal angle) and talar head uncoverage. A 45° external rotation foot radiograph is perpendicular to the interval between the anterior calcaneal process and the lateral navicular pole; it is a useful

## Figure 3




Clinical photographs of a 14-year-old adolescent boy with a rigid left-sided flatfoot and a contralateral flexible flatfoot. While hindfoot valgus is present bilaterally in a standing position (**A**), the left hindfoot remains in valgus on heel rise due to restricted subtalar motion while the right corrects into a varus position (**B**).

## Figure 4

Clinical photograph of a 14-year-old adolescent boy with a right-sided rigid flatfoot secondary to a talocalcaneal coalition. Note the diminished resting plantar flexion and inversion of the right foot compared with the normal left foot.

radiographic view to assess for a CN coalition (Figure 5), although its utility requires mineralization of the coalition, limiting its sensitivity to just above 50%.[6,16]

The lateral view allows for the measurement of planus by the lateral talus-first metatarsal angle and calcaneal pitch, both of which are decreased in flatfeet. In addition, the lateral radiograph allows the surgeon to assess for increased naviculocuboid overlap, a “C-sign” (sometimes seen with a TC coalition), and talar beaking (often seen in both TC and CN coalitions) adjacent to the dorsal talonavicular articulation (Figure 6). Among patients with a CT-confirmed TC coalition, only 41% have a complete or near-complete C-sign.[17] Inversely, the presence of a complete or near-complete C-sign, defined by a narrow interruption and edge rarefaction, is 97% specific for TC coalition.[17] A C-sign is of limited utility in children younger than 12 years and is often present in children with flexible flatfeet who do not have a TC coalition.[17-19]

A Harris heel view may be obtained to delineate a bony medial facet TC coalition. Its diagnostic utility, however, is somewhat limited in children and adolescents because of poor sensitivity.[20] Nonetheless, it is a rapid, low-cost diagnostic that may function as a useful adjunct if MRI or CT is not readily available and serves as a baseline for intraoperative comparison during medial facet TC coalition resection.

### Advanced Imaging

Additional imaging with either an MRI scan or a CT scan is usually indicated to evaluate for the presence of a coalition; define the location, morphology, size, and type of coalition (if present); assess the health of nearby articulations; and screen for the presence of additional coalitions.[6,16,17,21,22] MRI is a better screening tool for pathology in a patient with a rigid flatfoot because it is more sensitive for cartilaginous and fibrous coalitions, characterizes the quality of adjacent cartilaginous structures, reveals subchondral edema, and effectively images potential nonbony pathology. Although CT scans are not as sensitive as MRI in detecting nonbony coalitions, they are useful for defining the bony anatomy of a known coalition, are less expensive, and are more rapidly attainable than an MRI.[16,21] Bilateral weight-bearing CT scans, which expose the subject to a small fraction of the radiation of a standard CT scan, allow for the additional assessment of standing alignment and comparative measurement of adjacent subtalar joint posterior facet narrowing relative to the contralateral side in TC coalitions and serve as an effective screening tool for contralateral coalitions (Figure 6).[16,21]

## Tarsal Coalitions

Tarsal coalitions, which are thought to persist because of a failure of mesenchymal tissue segmentation, are most commonly found spanning the middle subtalar facet (TC coalition) or the interval between the anterior process of the calcaneus and the lateral pole of the navicular (CN coalition).[13,24] Tarsal coalitions can be found spanning any hindfoot or midfoot joint. Specifically, talonavicular coalitions, an uncommon entity associated with ball-and-socket ankle joint dysplasia, are important to recognize.[25] Most patients with symptomatic coalitions present between the ages of 9 and 17 years.[6,26,27] There is a 2:1 ratio of symptomatic coalitions between male and female patients among published series that report patient sex and up to 20% of feet with coalitions have more than one coalition.[6,28,29]

TC coalitions are often bilateral (33% to 60%) and may be accompanied by tibial nerve-derived symptoms.[5,13] Takakura et al[13] reported that 34% had a “positive” Tinel sign over the tarsal tunnel, 25% reported sensory disturbance over the sole of the foot,

## Figure 5

An external oblique radiograph demonstrating an osseous calcaneonavicular coalition (arrow).

## Figure 6


Lateral foot radiographs showing a 15-year-old adolescent boy with a unilateral left-sided rigid flatfoot. A "C-sign" (black arrows) and talar beaking (white arrow) are present on the left foot radiographs (**A**) and absent on the normal right side (**B**). Coronal CT images (**C**) confirm the presence of a left-sided cartilaginous talocalcaneal coalition and normal morphology of the medial facet on the right side.

and 28% had peroneal muscle spasms accompanied by referral of pain to the lateral leg.

CN coalitions are bilateral in ~40% of cases and are typically cartilaginous or fibrous (~70%).[6,30] Similar to TC coalitions, adolescents with CN coalitions most frequently present with foot pain (88%) and activity limitations (75%) and often present for initial evaluation after an injury.[6] Accompanying coronal plane hindfoot deformity, whether varus (18%) or severe valgus (13%), is present in approximately 30% of cases.[6]

## Additional Workup in Patients Without a Structural Reason for Rigidity

In patients without an obvious intrinsic structural cause for their rigid flatfoot, potential neurologic sources of hindfoot rigidity and peroneal spasm should be investigated. Nervous system pathology, especially conditions affecting upper motor neuron function, should be considered. Examples of potential underlying disorders include cerebral palsy, hypoxic brain injury, Chiari malformation, syrinx, trauma, and central nervous system tumors. Electromyography is a mainstay of objective evaluation at this stage because it allows for the confirmation and quantification of spasticity around the hindfoot. This should be coupled with appropriate central neural axis imaging. Referral to a neurologist is often prudent unless the underlying cause of spasticity and deformity is already well defined and nonprogressive.

It is important to recognize that the presence of peroneal spasticity on examination, itself, does not indicate a neurologic diagnosis. Twenty-eight percent of patients with TC coalitions have been reported to have peroneal spasms when their hindfoot is forcibly passively inverted.[13] In fact, there is clear electromyographic evidence that patients with hindfoot coalitions exhibit abnormal peroneus longus activity.[23]

## Treatment

### Conservative

Initial treatment after an injury or acute symptom flare is usually 3 to 4 weeks of boot immobilization or casting.[14] Immobilization has been demonstrated to be moderately effective, facilitating durable pain relief in ~50% of patients at the 1.5-year follow-up.[31] Corrective orthotics do not alter the natural history of flexible flatfeet in adolescents and have not been studied in rigid flatfoot patients.[14,32,33] Corrective orthotics may exacerbate symptoms in patients with a rigid flatfoot while accommodative orthotics may offer some symptomatic relief. Activity modifications and nonsteroidal anti-inflammatories are useful short-term treatment options but are not viable long-term solutions.

An ultrasound or fluoroscopically guided subtalar joint injection may be useful in patients with symptomatic TC coalitions who have failed conservative measures. Combining steroids with a local anesthetic provides both diagnostic and therapeutic utilities when trying to differentiate pain from a coalition versus associated flatfoot deformity. If the patient's pain is due to the coalition, one would expect immediate pain relief from the anesthetic and at least short-term relief from the steroid. Pain driven solely by deformity would not be expected to respond to a subtalar injection.

### Neurogenic Flatfoot and Peroneal Spastic Flatfoot

If a neurogenic source of rigid flatfoot deformity is identified, treatment is specific to the neurogenic diagnosis. For example, decompression of a Chiari malformation may resolve the spasm responsible for generating the deformity. Managing flatfeet of irreversible neurogenic etiology (eg, cerebral palsy or hypoxic brain injury) is typically conservative with physical therapy, bracing treatment, and botulinum toxin type A injections of the involved muscle groups, which typically include the peroneals in cases of flatfoot deformity.[34]

If an underlying neurologic cause of hindfoot rigidity with associated peroneal spasm is not identified, additional psychiatric referral is recommended to further define underlying psychiatric or mental capacity disorders that may be associated with a diagnosis of peroneal spastic flatfoot, which should be considered a diagnosis of exclusion.[35] Adolescents with peroneal spastic flatfoot may have dramatically lower IQ scores, higher rates of intellectual disability, and lower junior high-school and high-school graduation rates than the general population.[35] In addition, they are commonly diagnosed with social phobia, attention deficit and hyperactivity disorder, major depressive disorder, and/or obsessive compulsive disorder.[35] Treatment is typically facilitated by physical therapy and psychiatric modalities if a comorbid psychiatric diagnosis is implicated.

## Surgical Management

### Talocalcaneal Coalitions

Historically, TC coalitions were managed with subtalar or triple arthrodesis, but the long-term repercussions of hindfoot arthrodesis on adjacent joints are undesirable. Beginning in the 1990s, reports of successful coalition excision shifted surgeons' approach to coalitions and helped define the risk factors for excision failure. When TC coalitions are effectively excised, ~90% of patients report improved pain, 77% to 92% have improved hindfoot range of motion (ROM), and the American Orthopaedic Foot and Ankle Society ankle-hindfoot functional outcome scores improve dramatically (mean 46 preoperatively to 90 postoperatively), despite differences in the technique among series.[5,13,26] Some authors recommend complete excision of the sustentaculum tali, others recommend coating resection surfaces with bone wax, and still others interpose fat graft or tendon into the defect.[5,26] A recent series published by Mahan et al[22] identified a subset of posteromedial TC coalitions that occur adjacent to instead of replacing the middle facet. After resection, the American Orthopaedic Foot and Ankle Society scores and activity-related pain levels improved to an even greater degree than classic middle facet coalitions. Long-term (13-year follow-up), functional outcome score improvements are durable after excision.[36]

Varying degrees of hindfoot valgus may accompany these coalitions and should be considered when formulating a surgical treatment plan. In one series, the CT-based measurement of hindfoot valgus associated with TC coalitions was on average 13°, with a reported range of 5° of varus to 32° of valgus.[26] The decision to include a calcaneal osteotomy is based on patient symptomatology, rather than the specific degree of deformity present.

It is important to identify patients who may fare poorly with motion-restoring coalition resection. Poor outcomes have been reported in patients with associated degenerative narrowing of the posterior subtalar facet.[37] This narrowing may correlate with large coalitions. In a widely referenced article by Wilde et al, middle facet coalitions with a cross-sectional area that measures at least 50% of the cross-sectional area of the adjacent posterior facet were associated with subtalar narrowing.[24] Although it was hoped that this 50% rule would provide a reproducible standard for deciding on appropriate surgical management, this has not been borne out in subsequent studies or in the authors' own experience.[28,36]

It is often unclear whether patients' symptoms derive from the coalition, itself, or result from the transfer of mechanical forces to adjacent joints and soft-tissue structures. Moreover, if an associated flatfoot deformity is the source of the symptoms rather than the coalition, then coalition excision may create a new source of pain by unmasking the poor functional potential of a dysplastic subtalar joint. Consideration should be given to leaving the coalition in place and reconstructing the flatfoot around the rigid subtalar joint when patients' pain is felt to be due to flatfoot deformity.

### Authors' Preferred Surgical Management

It is our preference to excise TC coalitions, rather than conduct subtalar arthrodesis, unless the coalition extends into the posterior facet or the posterior facet is narrowed on a CT scan compared with the contralateral side. When pain is thought to be a result of both deformity and coalition, excision of the coalition with concomitant flatfoot reconstruction is considered.[27]

The authors' technique for middle facet TC coalition resection uses a curvilinear medial hindfoot incision along the inferior border of the posterior tibialis tendon to access the interval between the posterior tibialis tendon and the flexor digitorum longus. Retracting the flexor digitorum longus protects the underlying neurovascular bundle. Dorsal and plantar periosteal flaps are developed directly over the coalition with the intention to use them to contain a fat graft after excision. Converging 0.062″ (1.6-mm) Kirschner wires are then used to define the planned resection, one dorsal and one plantar to the coalition, with a planned intersection at the apex of the

## Figure 7

Radiograph showing an intraoperative Harris heel view demonstrating the placement of Kirschner wires to facilitate resection of a subtalar coalition. The wires are placed dorsal and plantar to the coalition and converge just lateral to the lateral-most extent of the coalition. Osteotomes are then passed along the guide wires to remove the coalition en bloc.

coalition's lateral border. The wire position is checked with axial heel fluoroscopy before osteotomes are used to resect the coalition, using the wires as guides (Figure 7). Curettes and rongeurs are used for removing any residual coalition and smoothing the borders of resection edges. Examination of hindfoot motion is used to confirm complete coalition resection. Bone wax is interdigitated into exposed cancellous surfaces before a fat graft, obtained from the calf or gluteal crease, is packed into the defect and then secured by the closure of the periosteal window. Patients are immobilized in a splint for two weeks for soft-tissue rest and then allowed unrestricted ROM. Weight bearing is resumed six weeks postoperatively.

Subtalar arthrodesis is indicated if the posterior facet is narrowed, is dysplastic, or any amount of this facet is replaced by the coalition. Arthrodesis proceeds through the same exposure. After coalition resection, the posterior facet is prepared for arthrodesis by removing all cartilage with osteotomes and curettes. The subchondral surfaces are then drilled with a 2.5-mm drill bit and/or fish-scaled with a quarter-inch osteotome. The arthrodesis is fixed with crossing cannulated screws (Figure 8). The alignment of the arthrodesis can be manipulated to correct hindfoot alignment in the setting of an associated flatfoot. Patients are immobilized in a splint for two weeks before being transitioned into a cast for an additional four weeks.

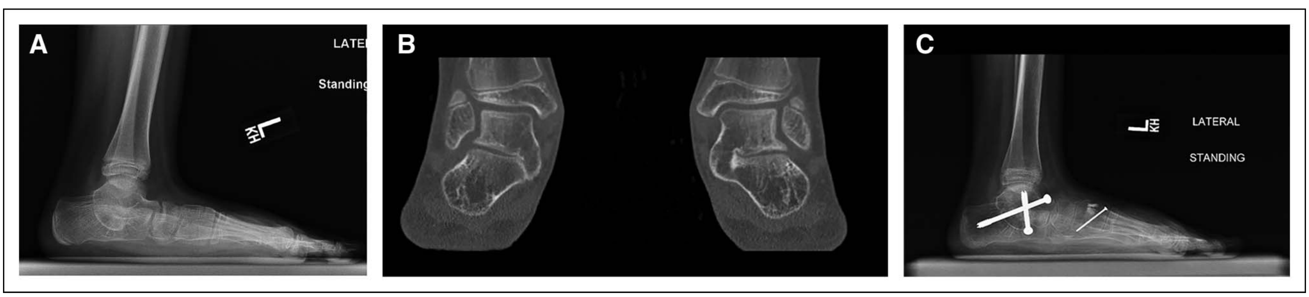
## Calcaneonavicular Coalitions

CN coalition excision in adolescents is effective and durable, producing pain relief and return to activity at both short-term and long-term follow-ups. At a minimum one-year follow-up, visual analog pain scores dramatically improve, yet 13% to 27% of patients report persistent activity-related pain.[6,28] At the 15-year follow-up, improvements in the American Academy of Orthopaedic Surgeons foot and ankle module and the Foot Function Index are durable after CN coalition excision, and gains in inversion/eversion ROM improve to a greater degree than that after TC coalition excision.[36]

There is a well-defined risk for coalition recurrence after CN coalition excision, so extensor digitorum brevis (EDB) muscle belly or fat graft is used to fill the defect left behind by the bony resection. EDB is vascularized and local, making it a prime candidate for interposition. However, some have raised concerns regarding postoperative shoe wear difficulties and calcaneocuboid bony prominence after EDB transfer.[6]

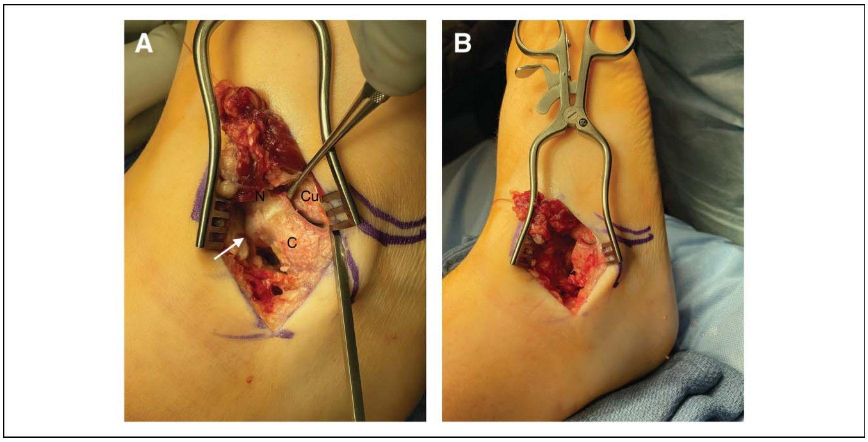
Historically, the use of local EDB graft for interposition was associated with a poorly defined "partial reformation" rate of 22% without any cases of complete reformation.[30] In addition, cadaver data confirm that transferred EDB muscle belly only fills the dorsal two-

## Figure 8




Lateral radiograph demonstrating a "C-sign" of the left foot in an 11-year-old boy with bilateral rigid flatfeet (**A**). CT demonstrates bilateral osseous talocalcaneal coalitions with marked narrowing of the posterior facet (**B**). After failure of the conservative treatment, deformity correction was obtained through a subtalar arthrodesis and medial cuneiform osteotomy (**C**).

## Figure 9




(**A**), Intraoperative photograph showing a cartilaginous calcaneonavicular coalition. The calcaneal portion of the coalition (**C**), the navicular component of the coalition (N), and the cuboid (Cu) are visualized along with a cartilaginous synchondrosis (white arrow). Although a wide resection is essential (**B**), care is taken to avoid violation of the calcaneocuboid and talonavicular articulations.

thirds of the coalition excision cavity, leaving approximately 1 cm of unfilled plantar gap.[6]

Using autogenous fat graft may allow for the maintenance of a more normal lateral hindfoot profile, but harvesting an adequate (1 × 3 cm) fat graft from the calf or gluteal crease requires a second surgical dissection and leaves a scarred soft-tissue dimple at the harvest site.[6] In a retrospective case series of fat graft interposition, 13% of CN coalitions reossified >50% of the postresection gap; symptomatic recurrences occur in 4 to 7% of patients.[6,28]

## Authors' Preferred Surgical Management

The authors' technique for CN coalition resection uses an extensile longitudinal incision centered over the coalition. Branches of the SPN are sought and protected. The EDB fascia is incised, and the muscle is elevated and reflected distally, exposing the coalition (Figure 9). The medial and lateral borders of the coalition are defined fluoroscopically with needle markers. Osteotomes are used to resect the coalition. It is important to avoid convergence of the tips of the osteotomes so that a rectangular excision is achieved. CN coalitions are deep, roughly 3 cm; the resection should allow the surgeon to place a finger through the resection cavity and palpate the plantarmedial soft tissues. Bone wax is then applied with a Freer elevator to the exposed cancellous surfaces.

If the EDB is judged to be large enough for interposition, a 2-0 vicryl tag stitch is applied to the proximal edge of the EDB muscle, taking care to include strands of tendons and fibrous tissues in the suture passes. A Keith needle is then used to pass individual suture limbs through the resection site and out of the plantar midfoot skin. A 2- to 4-mm soft-tissue bridge is intentionally left between the two suture limbs so that, after skin incision between these limbs, the transferred EDB muscle can be tensioned into the defect because the suture limbs are tied over the subcutaneous tissues. If the EDB is inadequate, fat graft from the calf or gluteal crease is used. Closure and recovery commence in the same fashion as that after TC coalition excision.

## The Role of Deformity Correction

Coalitions are frequently accompanied by associated valgus hindfoot deformity.[6,26] Among retrospective series reporting the outcomes of both TC and CN coalitions, corrective osteotomies have sometimes been done in conjunction with coalition resection, but the additional clinical effect of these adjuncts is poorly defined.[6,36]

Mosca and Bevan[27] published their short-term results using an evidence-based algorithm for planovalgus deformity correction associated with TC coalitions. Using data published by Wilde et al as a guide, the authors conducted calcaneal-lengthening osteotomies (CLO) in total 13 feet, without excising the coalition in nine symptomatic feet with a narrow posterior subtalar facet and a large coalition, defined as having a cross-sectional area of >50% that of the adjacent posterior facet.[27,37] All patients in their series, although small, reported resolution of preoperative pain and activity limitations. In addition, deformity correction was achieved with CLO whether the coalition was excised.[27] These results highlight that TC coalitions, especially large ones, associated with planovalgus deformities cannot be assumed to be the primary pain generator among symptomatic patients.

Similarly, the decision to correct a flatfoot deformity associated with a CN coalition is dependent on a patient's symptoms and physical examination findings. Radiographic measures of flatfooted alignment do not change after coalition excision, and the radiographic effectiveness of a CLO after CN coalition excision has been demonstrated.[38] Therefore, concomitant or staged deformity correction should be considered in adolescents with symptoms derived from places other than the coalition.

If a flatfoot deformity is present in conjunction with a coalition, soft-tissue considerations must be made if a corrective procedure is planned. The severity of associated gastrocnemius and Achilles tendon contractures correlates with the increasing severity of planovalgus deformity.[39] Thus, gastrocnemius recession or Achilles lengthening may be a useful adjunctive procedure. In patients with notable abduction, imbrication of the posterior tibial tendon and spring ligament may be necessary to reset the medial soft-tissue tension. In addition, abductor digiti minimi fascial lengthening and peroneus brevis lengthening may allow for better correction with a CLO, as recommended by Mosca et al.[27]

## Peroneal Spastic Flatfoot

If, on a rare occasion, a patient with a peroneal spastic flatfoot fails conservative treatment options, the authors recommend a peroneus brevis lengthening in addition to standard flatfoot reconstruction.

## Summary

A well-practiced orthopaedic surgeon must be able to distinguish a rigid flatfoot from a flexible flatfoot. Diagnoses other than tarsal coalition, including neurogenic causes and peroneal spasm, should be considered during the evaluation process of an adolescent with a rigid flatfoot. Talocalcaneal and calcaneonavicular coalitions that fail conservative treatment can both be managed successfully with resection considering other factors.

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